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THE PROSPECTS OF ANTHROPOCENTRIC PRODUCTION SYSTEMS

A WORLD COMPARISON OF PRODUCTION MODELS

Felix Rauner & Klaus Ruth

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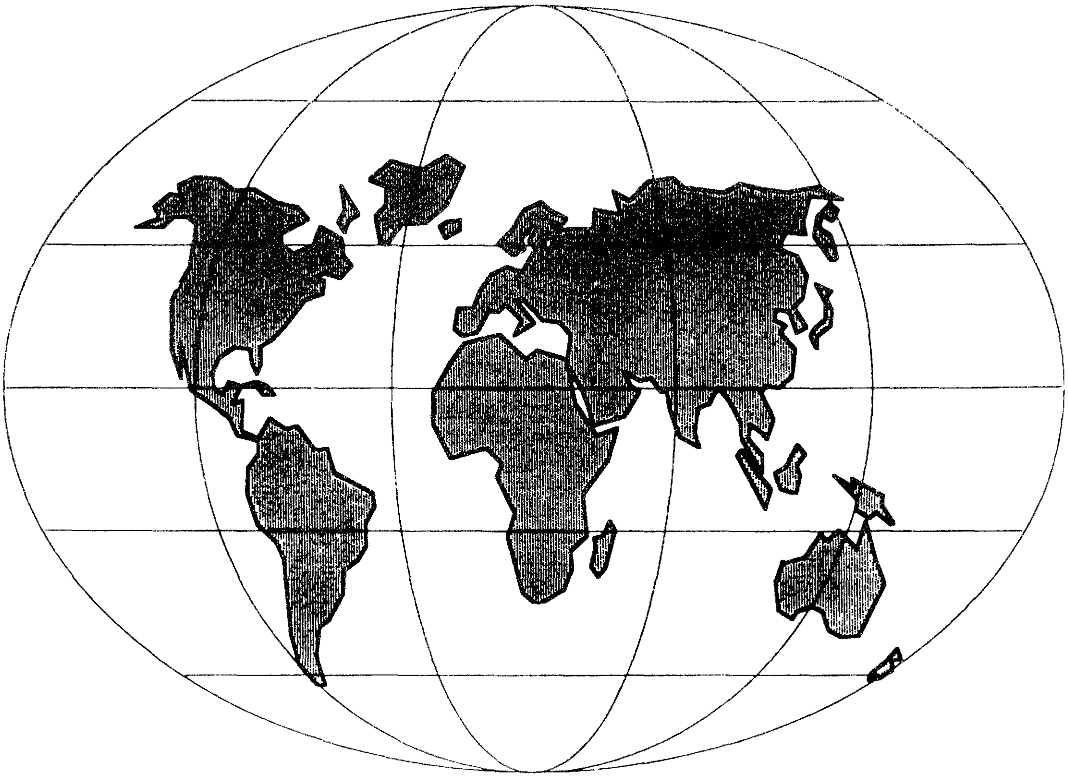

Authors
Felix Rauner
Klaus Ruth

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UNIVERSITÄT BREMEN
INSTITUT TECHNIK & BILDUNG
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CAPIRN
International Research Network
on Culture and Production

CEC - COMMISSION OF THE
EUROPEAN COMMUNITIES
Forecasting and Assessment
in Science and Technology

The Prospects of Anthropocentric Production Systems: A World Comparison of Production Models

A Synthesis Report

by

Felix Rauner

and Klaus Ruth

With Contributions from

Richard Badham

Richard Gordon

Joel Krieger

Michel Liu

Yuji Masuda

Felix Rauner

Klaus Ruth

Huguette Viala

FAST (Forecasting and Assessment in Science and Technology) is a research programme of the European Community.

In existence since December 1978, its main task is to analyse the social and economic long-term implications of scientific and technical change. Within the context of the 3rd Framework Programme for Science, research and technological development in which the main priorities have been : to improve the international competitiveness of European industry and foster European cohesion.

Since 1989, FAST is an integrated part of the MONITOR Programme which also includes :

SAST (Strategic Analysis in Science and Technology) and
SPEAR (Support Programme for Evaluation Activities in Research).

The FAST Programme includes : research projects, conferences, workshops, network activities, etc. A list of all FAST publications and other information about FAST is available from :

Mrs. Anne De Greef
CEE - FAST Programme
Rue de la Loi 200
ARTS-LUX 3/37
B - 1049 BRUXELLES

Tél. 02/ 235.97.55
Fax. 02/ 236.42.99

The reports comprise the research results of four networks:

The first - country studies co-ordinated by the Institut Arbeit Technik, Gelsenkirchen. It included social scientists from the member states who are to investigate the socioeconomic factors which affect the prospects and conditions for APS by the early 21st Century. This included, in addition, a synthesis report, comparing the research results from the various member states (Franz Lehner, Report no. 4) and special consideration of the less industrialized member states (coordinated by Sean O'Siochru, NEXUS, Ireland: Report no. 6).

Secondly, a Technical Recommendations Network, coordinated by P. Kidd (Cheshire - Henbury), comprising technical experts, who addressed the interface between the technical features of advanced manufacturing and human resources in order to identify future research priorities for the European Commission (Report no.3).

A third network, coordinated by D. Brandt (HDZ, Aachen), undertook a survey of case studies of the application of APS in the member states (Report no. 2).

Fourthly, the CAPIRN Network (Culture and Production International Research Network) coordinated by Felix Rauner (Bremen) and Richard Gordon (Santa Cruz), reports on the results of an international project on production cultures, comparing Europe with Japan, USA, and Australia and situating its analysis in the context of Anthropocentric Production Systems.

The series also includes a number of related studies of specific issues concerning the implications of APS for technology design.

Tony Charles & Werner Wobbe - FAST
June 1991

PREFACE

Since the mid 1970's industry in Europe has performed less well in comparison with the USA and especially compared to Japan. Europe has also lost ground in basic research where its spending on R & D (as a percentage of GDP) is below both the USA and Japan. However, the completion of the single market by the end of 1992 and the future prospect of an enlarged Community of EC16, or 18+ by the 21st century offers the potential for a resurgence in European manufacturing. Collectively, the papers in this series demonstrate how anthropocentric production systems can fulfill this potential. Based upon extensive research on the various sectors and regions of European manufacturing, the different reports converge towards a common conclusion: that reliance upon technology alone is an inadequate response to the challanges of world markets in the future; that successful modernisation of European industry depends upon its most valuable resource - human skills and creativity.

This report is part of a publication series presenting the results of FAST research on the "prospects and conditions for anthropocentric production systems in Europe by the 21st Century". The research was sponsored by the European Commission MONITOR - FAST Programme, 1989-1992 and generously co-funded by the government of Nordrhein Westfalen in the Federal Republic of Germany. Research teams from all countries of the European Community participated in the project, as well as researchers from the USA, Japan and Australia. More than twenty reports are available or in the process of publication providing a comprehensive and comparative assessment of the human aspects of advanced manufacturing in Europe.

All of the studies in the series address the general issue of defining anthropocentric production systems: national research traditions and manufacturing experience in the various member states have produced different interpretations of anthropocentric production systems; this is regarded as a strength not a weakness of European manufacturing in the sense that European diversity suggests a number of possible trajectories of change in manufacturing in response to world competition in the 1990's rather than a unilinear path of development, or an assumption that there is "one best way" of managing technological change. A central feature of the research was close collaboration between the research teams and workshop discussions: this helped to identify a common minimal definition of anthropocentric production systems and a common analytical framework for country comparisons without the straitjacket of a predetermined research schema which would have lacked sensitivity to cultural differences in Europe.

APS can be defined as advanced manufacturing based on the optimal utilisation of skilled human resoures, collaborative industrial organisation and adapted technologies. All the reports in the series explore the concept of APS in some detail, especially the general reports by Werner Wobbe - series no. 1, Paul Kidd - series no. 3 and Franz Lehner - series no. 4.

Main Subjects

- Industrial-cultural influences on industrial production
- Industrial-cultural assimilation of global flexibility requirements
- Convergency of rationalization and humanization interests
- Substantial elements of *humane work* (health and safety, qualified ambitious work)
- Anthropocentric shaping of work and technology
- Anthropocentric Production Systems (APS) in the machine tool building, the elctronics and car industries
- Educational (and vocational) systems and global competitiveness
- Vocational training systems, job definition, organization and the prospects of work-oriented production systems

Remark on the use of abbreviations in this study:

ACR denotes the American Country Report on *Anthropocentric Production Systems and U.S. Manufacturing Models in the Machine Tool, Semiconductor and Automobile Industries* (1990) by Richard Gordon and Joel Krieger

JCR denotes the Japanese Country Report on *The Concept of Production in the Japanese Manufacturing Industry* (1991) by Yuji Masuda

GCR denotes the German Country Report on *Prospects of Anthropocentric Production Systems and Industrial Cultural Variability* (1991) by Felix Rauner and Klaus Ruth

FCR denotes the French Country Report on *Anthropocentric Studies of Production Systems in French Industries* (1991) by Michel Liu and Huguette Viala

AusCR denotes the Australian Country Report on *Anthropocentric Systems and the Australian Production Culture: The Dilemma of a "Technology Adopting" Country* (1991) by Richard Badham

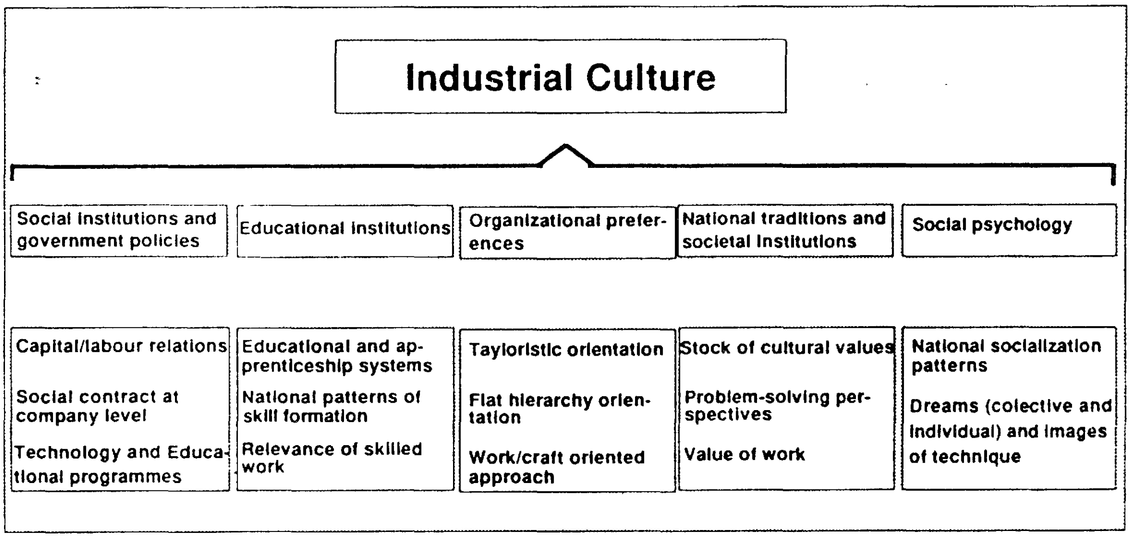
Contents

I. Executive Summary

This report focuses on the prospects of Anthropocentric Production Culture in Europe, Japan and the US with regard to its social and human quality as well as its competitiveness in relation to a technocentric production culture.

1. The concept of industrial culture developed by CAPIRN forms the basis for the inclusion of studies from Japan, the US and Germany as well as papers from France, Australia, the USSR, the UK and other industrialized countries. The following figure provides an outline of the key industrial-cultural dimensions.

Figure 1: Industrial-Cultural Key Dimensions and Variables



This concept allows one to explain the dramatic upheavals in the world market and in industrial production and to qualify modes of production as more or less anthropocentric.

2. In actual industrial production a general trend towards more flexible production technology and product organization (post-Fordism) is asserting itself on a global scale; in its social quality and competitiveness, however, it is characterized to a great extent by special industrial-cultural features and differences.

3. Industrial-cultural production in the US is extensively characterized by a pattern of process-related (full) automation. This is particularly supported by a traditionally low qualification level of the work force and inadequacies in civilian production-related R & D policy. These are the reasons for the technocentrically oriented industrial production in the US as well as for the competitive weakness and further declining competitiveness in the machine tool production and automobile industries.

4. Japanese production has, worldwide, the highest level of company and industry-wide flexibility in industrial production. The excellent in-plant flexibility is due, to an extremely high degree, to a work force having a general education as well as to a lack of a fixed occupational structure and rigid job classification (as in the US). In-house multiskilling as an integrating factor for flexible company organizational development with an extremely high degree of company loyalty is the basis for success in taking advantage of the available technological and economic options for highly efficient industrial production on a global scale.

5. Industrial production in European countries is, on the average, oriented to small markets and is thus subject to greater pressure on flexibility than industry in the US and to some extent in Japan. This fits in well with the European tradition of customer-specific small-lot and individual job production. In larger companies, however, the achievement of the necessary in-plant and industry-wide flexibility comes up against the limits of a more or less strict, occupationally shaped work organization, which in connection with traditional vocational education is characterized by a relatively low level of general education.

6. An analysis of production development in Europe, Japan, and the US shows that increasingly varied forms of concrete industrial production concepts compete with one another (nationally and globally). Four scenarios were developed with regard to the domain of work, technology and education; they are part of general scenarios concerning social conditions in Europe and are based on global technological and economic developments:
   Scenario 1: Tayloristic Automation (Computer-Based Neo-Taylorism)
   Scenario 2: Socially Compatible Automation (Accelerated Relieving Path)
   Scenario 3: Computer Aided Industry and Dichotomized Reprofessionalization
   Scenario 4: Work-Oriented Automation and Computer Aided Participation

7. There is an increasing worldwide trend towards anthropocentric elements in industrial production in all sectors.

8. The weakest development of this trend is found in the US. The anthropocentric production concept is only given a slight chance of asserting itself even in the future.

9. On the outside Japanese production has many features of anthropocentric production (cooperative forms of work, quality circles) and at the same time greatly limited employee rights. This contradictory development will continue in the Japanese producing industry.

10. In Germany there is a chance that the anthropocentric production concept will become the dominant one, especially in the machine production industry. The trend toward a greater degree of anthropocentric work and technology is expected to a substantially lesser extent for the automobile and electrical industries.

11. The Australian industrial culture is amidst a dynamic process of transforming and reorganizing its productive structure. There is some evidence that the evolving production culture will be more strongly oriented towards APS. An outstanding significance is assigned to Australia as a technology adopting country.

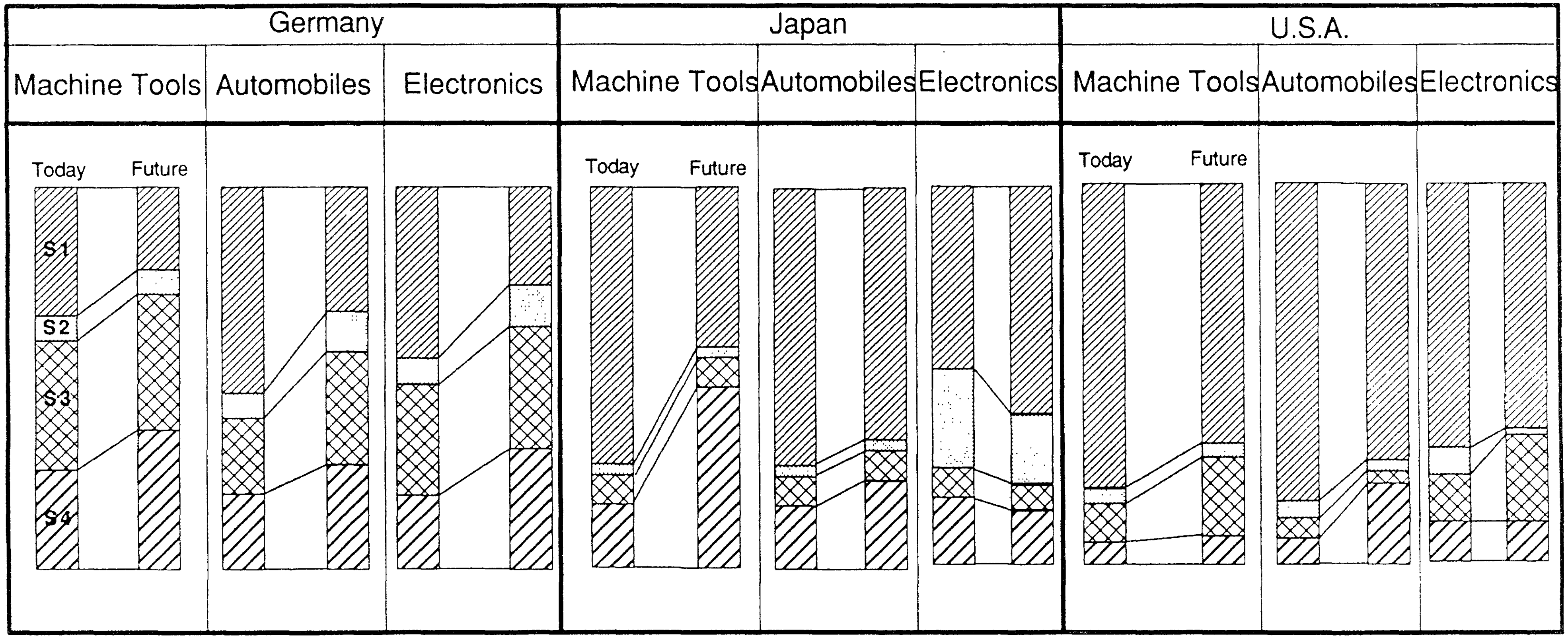
12. The concept of anthropocentric production refers to healthy and qualified work, various cooperation and communication options, a maximum of scope for action and shaping on the part of employees (minimization of restrictiveness), technology that is shaped so as to be complementary to human abilities and development potential as well as social and ecological utility of the produced goods (Goods and not Bads).

13. The global trend toward cooperative and work-oriented production concepts corresponds to an internationally widespread type of rationalization. It fits in well with the development of anthropocentric work and technology concepts. The convergence of rationalization and humanization interests thus created opens up economic prosperity and social stability to the European producing industry for the forthcoming development period if this convergence with its synergetic potential is supported and spreads by virtue of an R & D policy in science and technology tending towards the anthropocentric production scenario.

14. The anthropocentric quality of industrial production can be decisively promoted, though not yet achieved, by means of an anthropocentrically oriented development of technology and work organization in Europe in conjunction with a comprehensive education and qualification offensive using broadly defined and open job outlines (departing from a traditional narrow occupational orientation). Anthropocentric shaping of work technology can be expanded and transformed in a direction leading to anthropocentric production if, above all, this process is based on a system of industrial relations characterized by participation, co-determination and an interdepartmental, shaping-oriented statutory framework governing both employees' rights and the economy and committed to the guiding principles of humanization of working life.

The following table provides a synopsis of the results of the CAPIRN assessment study on the prospects of anthropocentric production systems.

Figure 2: Prospects of Anthropocentric Production Systems in Three Countries



The first of each pair of columns indicates the estimation for the present situation, the second column shows the assessment for the future (i. e. the next 10 to 15 years).

The columns indicate the structural composition of the branches according to the scenarios S1 to S4.

Scenario 1 (S1): "Tayloristic Automation (Computer-based Neo-Taylorism)";
Scenario 2 (S2): "Socially Compatible Automation (Accelerated Relieving Path)";
Scenario 3 (S3): "Computer Aided Industry and Dichotomized Reprofessionalization";
Scenario 4 (S4): "Work-oriented Automation and Computer-based Participation".

II. Introduction

This study attempts to evaluate the prospects for future shaping of production systems in accordance with anthropocentric aspects on the basis of reports from 4 industrial countries. The aim of the study is to analyze strengths and weaknesses in the industrial-cultural profile as well as in the industrial substructure of individual countries and to derive from them suggestions for the industrial policy of European countries or at least to provide the submitted analysis as a basis for political decisions.

In the following a brief outline of the FAST activities carried out up to now will first be presented, insofar as these activities are relevant for an understanding of the research and development policy foundation of this study, in order that this assessment study on the prospects of anthropocentric production systems (APS) can be fit into the focal points of the FAST Program.

In the first FAST Program (Forecasting and Assessment of Science and Technology) the focus of R&D activities, among others, was "to accompany the transformation of employment and to facilitate the establishment of new man-machine relationships" (FAST 1988, p. 8). The result was a contribution to stimulating European discussion on innovations in industrial production and their significance for technology and employment developments. The findings of this first FAST round found expression in the formulated tasks of the FAST II Program, particularly in the area of "Changes in the Relationship between Technology, Work and Employment (TWE Program)". The relations between technology, work and employment were sharpened into a greater technical and organizational understanding of innovation processes. Triggered by the ongoing change from mass production to new forms of industrial production in the 1980s, the interests in the FAST II TWE Program became increasingly oriented to new trends towards flexible specialization and reduction of production units. Both were viewed as important "European" lines of development which, along with other factors, constituted a specific production culture, by means of which European companies could effect rapid adjustment to market requirements.

In recommendations based on FAST II it is pointed out that the "European potential" can be developed particularly through efforts towards development of a flexible production organization and computer-aided integration of production while **utilizing** and promoting human resources. This reflects the insight that anthropocentric technologies are better adapted to future economic requirements, such as small-batch and high-quality production, greater flexibility and increasing safety and security standards in production.

Based on the term **anthropocentric** (or human-centered) **technology**, a study on applied technology assessment (ATA 1) was initiated as a result of the FAST II recommendations. It is concerned with the prospects of anthropocentric technology over the next 20 years and takes up and extends recommendations and questions formulated in the report on *European*

Competitiveness in the 21st Century: Integration of Work, Culture and Technology (by Prof. M. Cooley et al.). The report emphasizes the importance of specifically European competitive advantages, such as the existence of a highly skilled and flexible workforce, and of a large share of SMEs for future competitive production concepts oriented to *humane work* (based on distributed regional production networks, for example). Cooley et al. point, in particular, to Europe's cultural variety as a creativity pool supplying *human resource strategies* for the improvement of its competitive position in the global markets. The recommendations and questions formulated in the report provided new impulses in turning to new R&D areas and intensifying existing ones. Thus as a result, a number of, mostly, European research teams and institutions were commissioned to conduct studies on the conditions and prospects of anthropocentric productions systems within the scope of ATA 1.[1]

In addition to purely European work relations, the International Research Network on Culture and Production (CAPIRN) was asked to carry out a world comparison of production models so as to make an assessment of the prospects of anthropocentric production systems in Europe on the basis of evaluations of strengths and weaknesses of national paths of development. The CAPIRN research network developed an especially suitable instrument for performing these tasks at the beginning of its cooperation with FAST. Referred to as an **industrial-culture approach**, this instrument examines the social organization of production and innovation in various research projects using an international comparison. The study now presented summarizes the national reports drawn up by CAPIRN research groups in Germany, France, Japan, the U.S. and Australia. The aim of this final report is not so much to provide complete documentation on production models having different industrial cultures but rather to present an analysis of the strengths and weaknesses as well as, based on that, an assessment of the suitability of different industrial cultures for fostering or hindering the implementation of anthropocentric production systems. We place special emphasis on the specific features of the human resources as well as on specific industrial-culture preferences in shaping work systems (work content and organization).

By virtue of this study, CAPIRN can make a special contribution to conducting the FAST ATA 1 project by pointing to **divergent** patterns in the development process of the industrial society in general and with respect to the development prospects of anthropocentric production systems (with the target aspect of *humane work*) in particular and by making use of these diverging forces as structuring/structure-creating elements. Through this approach we expand prevalent "theories of convergency", which usually very strongly (and often exclusively) emphasize unifying tendencies in the development process of industrial societies (cf. the discussions about

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[1] In particular, a Europe-wide network was initiated under the direction of the Institute of Work and Technology (IAT) in Gelsenkirchen, which is involved in problem areas, such as assessing APS in Europe, investigating the specific conditions of peripheral countries and developing recommendations for the technical design of APS.

post-industrial societies or *information societies*).[2] This is certainly not wrong and also describes a strong impulse of current developments, but it does not adequately explain the lack of a simultaneous global creation of anthropocentric production systems. It is precisely at this point that the dialectic industrial culture approach unfolds its special explanatory value.

The central empirical instrument for assessing the future prospects of anthropocentric production systems within the scope of this study is the scenario method. Despite knowledge of the problems arising in the application of scenarios in various industrial cultures (for the most part due to the implicit "Eurocentric" orientation which finds expression, for example, in the welfare state premises included that do not exist to the same degree in the U.S. and Japan), we made use of this instrument since, first of all, it is an adequate one in the sense that forecasts or other more strongly deterministically oriented instruments do not do justice to the openness, in principle, of the development of work and technology, and secondly the instrument of scenarios was already developed and utilized in past FAST studies (cf. FAST Program II, Results and Recommendations, 1988, 147ff). In addition to the appropriateness regarding the subject matter itself, therefore, maintenance of continuity with previous FAST studies is also an argument in favor of developing and applying scenarios.

With regard to their original content, the FAST scenarios were work and employment scenarios - the ones developed by us relate work, technology and education (qualification) to one another as equal development elements and are aimed at making it possible to shape work and production systems according to more or less strongly anthropocentric orientations.

We base the scenarios on selected branches of industry which are only briefly described. Details on the analyses of the sectors can be found in the country reports mentioned at the beginning. This study synthesizes the results documented in the country reports and relates them to a uniform evaluation scheme in order, in the end, to be able to assess the prospects of APS on a global scale.

In the chapter which follows this introduction we give a rough sketch of the latest developments in industrial societies and world economy, i. e. the changing market conditions, new product requirements challenging new production and innovation processes, etc. After a short description of the methodology that underlies this report, in the following chapter (chapter IV) the basic concept of Anthropocentric Production Systems (APS) is circumscribed. This chapter is divided into three sections: in the first place we discuss some anthropological essentials of the term *humane work* and thus of anthropocentric production systems; secondly, we give reasons for the necessity of new participative design and implementation processes and suggest some new methods to fulfill the idea of anthropocentric systems design and implementation. In the third place we give a tentative specification of APS which is differentiated into three levels: at the micro level a pattern of work dimensions at the work places is specified, which allows to

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[2] See Bell 1973 and Heilbronner 1984.

assess the anthropocentricity or restrictivity of work. The intermediate level leaves single work places and focuses at the departments and inter-departmental sphere, the *anthropocentric* focus here is on de-hierarchisation, decentralized task and responsibility allocation, etc. We then draw the view to the macro level and paint social scenarios of possible anthropocentric work and technology developments.

In chapter V we present the results and conclusions of the country reports conducted within CAPIRN. The structure of this compilation follows, in the cases where it was possible, the branch differentiation (car, electronics and machine tool industries) and assesses the prospects of APS in the countries of the sample in the light of the industrial culture concept. Finally suggestions especially for European countries are made.

III. The Changing Complex of Problems

When the end of division of labor was proclaimed and a departure from mass production was discussed at the end of the 80s[3], developments in the processing industry were not nearly as well-defined as today. The theoretical debate did, however, reflect on the radical changes that were gradually emerging with regard to a restructuring of production regimes. Today attempts are being made at transforming which had begun as a debate on the development of a new production paradigm into new production concepts under the catchword: "End of Taylorism/Fordism".

Changing Market Conditions

The successful penetration of numerous markets (audio/video electronics, car and machine tool industries) on the part of Japanese competitors has caused a sensation in this process of reorientation. Japanese industry, which has become more and more successful in recent decades, drew the attention of the most important industrial nations to the "secret" of Japanese production concepts and subsequent to intensive "travel and pilgrimage activities" several elements of the Japanese productive structure were adopted by Western industrial nations (such as the QCs, with a relatively great deal of success). The growing world market performance of the Japanese is only one (and quite possibly a minor) development, the changes in the international markets in general are much more profound. The demand for high-quality products and increasing amounts of product variants is growing while at the same time the market volume for capital goods and industrial consumer goods is stagnating.

Changing Production and Innovation

A first glance at the *products landscape* displays that new challenges regarding the products (and product ranges) occured within the last decade. Not only an increasing demand for different variants of a basic product (e.g. in the car industry) but a generally increasing demand for high-quality, high-precision products (e.g. machine tools as well as semiconductors, and to a large extend metal parts in general) took place within the last years. Furthermore, the attempts to substitute unhealthy finished and semi-finished products increasingly influence the markets, the demand structure and the production processes. In addition, the necessity to develop and manufacture products which fulfill ecological requirements (an important challenge for the

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[3] See Kern and M. Schumann (1986), *Das Ende der Arbeitsteilung*; and Piore, Ch. and Sabel (1984), *The Second Industrial Divide*.

future car manufacturing)[4] will in the future determine the R&D efforts and the innovation processes to a large degree. Another dimension of the changing product requirements, which is discussed in Germany, the U.K. and Scandinavia since more than one decade and which mirrors the here sketched complex of problems in many of its facettes is the problem of *arms production* and the attempts to develop a conversion towards civil products (Einemann, Lübbing 1985; and Cooley 1982). These efforts do not represent a dominating social movement but with regard to APS they must be taken into consideration, because the problem of arms production can be regarded as the peak the product question in the APS discussions culminates in.[5]

If we take a closer, product-related view to innovation and production processes, an increase in so-called **research-intensive products** becomes evident.[6] This trend is especially pronounced in the semiconductor production sector of the electrical industry, where the consequences of this development for the innovation processes as such, for the integration of innovation and production as well as for the work assignment concepts can very clearly be shown. A frequently encountered pattern follows the sequence: new product - new process - new department - new work structures. The question of what scope is (may be) thereby created for APS will be briefly dealt with in the section entitled *Results.*[7]

Besides the changes in market and production structure, product and production cycles have altered. The assumption of a view of product life cycles as sequential, clearly defined and distinct phases of the product design, manufacturing and end-of-life stage, a view that was prevalent for decades, was based on the premise that high development costs are incurred for products and production processes having little (or no) demand in the initial phase (of design). In the following phase the development costs decline while demand remains at a stable, high level (manufacturing stage) and in the end-of-life stage the demand for *product A* decreases as the design cycle for *product B* simultaneously begins. This appears to be the model which worked until the eighties. Nowadays the production and product cycles are obviously not sequential but **parallel** and furthermore they are increasingly interlinked. There are no longer completed phases, the products are subject to constant redesign (product X faces competition from its own improved version X+); the phases appear to be compressed, in fact the path from initial design to the market, in general, has possibly become shorter or is at least covered at an accelerated speed. This development is accompanied by the effort to integrate the processes of innovation and production to a greater extent. The increasing intermeshing of innovation and

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[4] It makes some sense to expect that, particularly in Germany, this discussion will be embedded in the larger discussion of new public transportation systems - with the effect that in the future the car industry will follow new paths, e.g. production of solar mobiles, developping new engines and conversion of the production from private transports vehicles towards public transports vehicles, etc.

[5] See also chapter IV.

[6] In Germany the proportion of research-intensive industries in relation to total industrial employment in 1989 rose 46%; a particularly striking feature: 90% of newly created jobs since 1989 can be classified in the research-intensive category; see VDI-N 48, 1990.

[7] In this respect, see also the sections on the electronics industries in the country studies.

production - following Japanese practice - not only takes place on the company level (i.e. interdepartmentally) but also on an intercompany level (i.e. including the respective subcontractors).

These developments result in greater pressure on making manufacturing more flexible. This increasing need for flexibility, however, also makes it necessary to move away from the concept of economies of scale. The latter will disappear as a single concept and will be replaced by a combination of economies of scale and economies of scope. The trend will be towards a pursuance of economies of scope on the level of flexible overall systems and on the various system levels (production phases and functions) towards economies of scale.

One must also take into account the fact that in addition to globalization an increasing trend is under way towards Europeanization of technological innovation (Petrella, 1989), one result of which might be a joint European policy for research and technological development during the 90's. This would open up completely new product and market strategies whose backbone would be formed by Europeanized joint public and private R & D networks.

In short, the above mentioned developments are an expression of completely new product requirements which, in turn, cannot be met with the conventional means of production organization (of the 70's and 80's). Manufacturers have to adjust to this fact. They do so by pursuing just-in-time concepts, attempting to achieve total quality control and trying out the strategy of worldwide sourcing.

New Requirements for the Production Structure

The globalization of markets is not only increasingly connected with an internationalization of (product) competition but also with worldwide competition for production sites (e.g. Japanese transplants in the U.S. and Europe). It remains to be seen how this process will unfold within the EC and what its effects will be, particularly after 1992. On the other hand, regionalization developments are taking place at the same time as globalization trends. In some cases complete chains of production are being completely decentralized, i.e. subprocesses are distributed to many companies in a region. Today these distributed manufacturing networks are increasingly emerging in the particular form of subcontracting (in almost all branches of industrial production). The reduction of production costs and the simultaneous increase in flexibility are generally regarded as a major advantage of this form of production organization.

Since the mid-80's attempts have been made to meet the requirements by pursuing factory integration concepts on the basis of greater utilization of microcomputer technology. In view of the universal applicability of and relatively numerous options open to microcomputer technology, various paths can be taken today in moving towards "Factory 2000". In accordance with the idea of "increased flexibility in production", efforts are currently being made in the formerly classic mass production industries, such as the automobile sector, to adjust to the altering market conditions: a widespread tendency away from manufacturer markets and towards buyer markets is expressed, for example, in the demand for production of mass goods having more variants and in the substantially greater emphasis on customer desires with regard to capital goods. Both trends require flexible production which is to be achieved through the application of microcomputer technology and increased integration efforts (CIM). However, the question of whether flexibility can be developed on the basis of intensive utilization of human resources or whether a more technocentric path must be taken while excluding the "human factor" is still an open one. Answers to this question will determine the development of today's various production concepts for the next decade.

Thus the current situation in Europe is characterized by a broadly diversified production landscape with Europeanized (globalized) markets, widespread product circulation (end products and semi-finished goods), global access to and allocation of resources, on the one hand, and production organizations, on the other hand, which are resisting these standardization tendencies with relative success. The result is that differences regarding the production concepts pursued in various European countries are emerging to a greater degree. These differences are due to differing **industrial cultures**. We use the term industrial culture here to mean an industrial ambience or milieu, within which a network of standards, informal norms, conventions and traditions comes into force and attempts to explain the specific peculiarity of individual industrial societies and thus the *differentia specifica* beyond abstract *laws of motion* of modern industrial societies.[8] To enable empirical handling of the concept, a set of dimensions and structural variables was developed, by means of which various technology developments, courses of technology implementation and patterns of technology application can be explained as quantities shaped by industrial culture.

By drawing on the fact that production strategies are rooted in specific industrial cultures, one can assess the prospects of anthropocentric production systems in Europe via a description of the status quo of the European production landscape. The special advantage of the industrial-cultural approach is that political and cultural trends, with respect to their globalizing standardization (such as the approximation of consumption patterns, changes in values, etc.) as well as to the differentiating emphasis of *national* differences, can thus be analyzed and used to evaluate differing production systems and concepts.

This report represents an attempt to assess the future prospects of an anthropocentric production culture in Europe on the basis of an evaluation of current developments in Europe, Japan, the U.S. and Australia and in view of the above mentioned changes in the world economy and new product requirements. It is intended to point out the challenges and prospects as well as the possible industrial-cultural obstacles in the implementation of anthropocentric production systems while going beyond a mere stocktaking of the present situation. American, Australian, Japanese and German experience is to drawn on for this purpose.

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[8] For some details on the industrial culture approach refer to section V. The approach is further developed in Rauner/Ruth 1990.

Methodological Excursus

The basic methodological idea of this study was to develop an approach which could be agreed upon as the basis for the analyses and evaluations of the national studies. Initial discussions have already revealed the difficulties in this undertaking - there were very different theoretical and empirical preferences within the research network. Contrary to the originally intended procedure this synthesis report cannot simply *compare the uncomparable* by means of a contrastive compilation, because the research instruments applied within the country reports differ considerably. Therefore, in this synthesis report we relate the branch assessments to a minimalist common conceptual understanding (which is depicted in the following chapter) in order to enable a coherent cross-national assessment of the prospects of APS in the examined countries.

On the basis of our pre-understanding of APS, cornerstones for assessing the substance of work and technical systems are developed and applied at three analytical levels. The relations between work and technology, the communicative requirements of work and technology systems, the relationship between work and learning as well as the connection between work, qualification and education are applied on **the level of direct production** jobs as a framework of criteria to evaluate work and technology systems. This job-related assessment is drawn towards an **intermediate level** of departments and whole companies. The focus of interest in this layer were the questions of work design and the problem of inter-departmental co-ordination of operations.

Finally, the findings of the work place and company related levels are embedded into a frameconcept of social scenarios which comprise possible development of job content, work organization, technology and education. The scenarios explicitly include social developments and thus represent on the **sectoral/societal level** a correlate to the job-related anthropocentricity matrix as well as to the enterprise organization model.

In general, the scenarios do not indicate development paths in the sense of advancing along a decision-making tree where a probability calculation would have to be made at every branch (or embranchment point). Rather, they provide an assessment of development scope while deliberately omitting completely all hypothetical courses of development (Heidegger, et al. 1986). The thus resulting reduction of complexity increases the plausibility of our scenarios and, in the end, their suitability for discussion and evaluation. The scenarios are thus an appropriate tool for working up sector-specific anthropocentricity profiles, a tool which we placed at the disposal of experts in two countries - Japan and Germany - so that they could assess the actual situation in the respective sector of expertise as well as the prospects of APS within the sector on this basis.

IV. The Theoretical Concept of Anthropocentric Production Systems

The findings of this report are based on national studies conducted on the automobile, machine tool and electrical sectors in Germany and the U.S. as well as, in a somewhat different form, in Japan and Australia. The methodological access to the sectoral analyses favored in the respective substudies differ from each other and thus make a comparison difficult. This problem is reflected in, among other things, the detailed theoretical and methodological preliminary considerations preceding the national studies. Though this lack of compatibility does represent a disadvantage, there is, on the other hand, a gain in the culture-specific dimensions of the term *anthropocentric*, thus providing an opportunity to bring together elements for a subject-matter-related definition of terms and concepts that is not biased by cultural narrow-mindedness.

The recognition of the fact that the ideas developed in the country reports about what, for example, *anthropocentricity* means differed to a relatively great extent as well as the concurring interpretation of these disparities as, in the end, characterized by (industrial) culture led to an understanding of the industrial culture concept as a "repercussive" one, too - i.e. not only related to the research objects but also with repercussions for the research subjects.

At this point, in anticipation of later sections, we would like to go into a basic and probably not completely resolvable dilemma, the essence of which is that the assessment of a technology or production system as *anthropocentric* requires the real existence of the artefacts or systems. In any case, the final process of assessment by the users concerned is, therefore, preceded by a process of development and design, in the course of which operationalization of the anticipated anthropocentric qualities is to be carried out. In our view there are no easy solutions for the operationalization process as such or for the contents to be put into concrete terms so that a development process for anthropocentric systems lies outside the scope of the prevalent engineering methodology and working procedure. It is recommended, therefore, that new paths be taken for the design of anthropocentric *work and technology systems* characterized by:

1. the working up of new content-related cornerstones for APS and
2. the anticipated inclusion of users, i.e. instead of two discrete, sequential phases (development and implementation/assessment), one integrated phase in which users are also involved in the design process.

With this report we obviously find ourselves right in the center of this dilemma. We do not include the direct users of technical systems and there is no intercultural consensus (in two respects: neither between scientists of different industrial cultures/nations nor between the traditions of the humanities and engineering sciences - two cultures). Nevertheless, the value of the study is in providing cornerstones for APS and participative design processes and, generally, in stimulating the discussion of whether and under what conditions anthropocentric production systems are possible and feasible.

In the following we will comment on three problem areas having central importance for this study:

- the central **concept of anthropocentricity** (its theoretical and historical basis),
- **anthropocentric design and implementation processes** and
- **characteristics of APS**.

Anthropocentricity - Possible Meanings of a Central Category

Even though the heading of this section is the central concept of the study, the reader should not expect to be presented with a binding, consistent or even (universal) operational definition here. Rather, we will follow the example of Adorno (1973), who in other contexts, which are, however, also applicable here, criticized the widespread bad habit (especially of the positive sciences) of putting the definition of the relevant terms at the beginning of a scientific undertaking. This may be customary and appropriate for projects oriented to the engineering and natural sciences, but it has been shown to be unsuitable in the case of the project documented here for several reasons:

1. A research object such as anthropocentric production systems is, in its substance, so deeply **entwined** in categories of thinking of the humanities and social sciences that a consensus cannot be reached in putting anthropocentric contents into concrete terms, neither among the social scientists nor between social and engineering scientists.
2. The intercultural differences in the understanding of anthropocentricity are so enormous that a binding and clear definition cannot be achieved.
3. The special value of the anthropocentricity debate and of the APS concept developed in the course of this discussion consists of the relative openness of the draft.

Anthropocentricity can and should merely take on the role of a general orientation for participative system development in the current stage of discussion and conceptualization because the concept would loss part of its effect if rash detailed operationalization were carried out at an early stage.

Therefore, we do not attempt to provide *ex ante* a ready-made definition which might apply as a guideline for action, but rather to present a comprehensible (and plausible) description of the *definiendum*, as was discussed in the process of developing this report (and the national reports). We thus develop an extensively open concept which allows us to integrate the various interpretations.

An initial analytical approximation in terms identifies **anthropocentric** as placing the emphasis on man, "preserving for the worker the role as subject in the production process to the largest extent possible..." (ACR, 8). The logical counter-term, **technocentric**, can be considered as *machine thinking*, i.e. technology and not man is the focus of the production and work organization and thus of the rationalization efforts per se. The goal orientation of the technocentric approach is full automation with rationality (one might almost say subjectivity) placed on the system level and thus on technology; people are scattered among unconnected, nonautomated residual tasks and fill automation gaps. The technocentric development path is the continuation of the "old" Taylorism under the conditions of new technical possibilities.

This initial approximation confronts us with the dichotomous pair of terms, anthropocentric and technocentric, as has been discussed by, among others, Brödner (Brödner 1986) since the mid-80s. One can come to an understanding on such an abstract definition with any problem, even across cultural barriers - moreover, it has proven to be an excellent stimulus for numerous discussions. However, this view is not very operable; its disadvantage for shaping-oriented action is due to the relatively high level of abstraction and the pronounced dichotomization that rules out nuances. A more anthropologically/ontologically oriented description also brings about a consensus, to a great degree, but it still does not eliminate the difficulty of developing a manageable concept of *anthropocentricity* as a common working basis. Even the most timid attempts to find operational criteria for anthropocentric production systems reveal the dilemma. "Human-centeredness is ultimately a subjective concept which cannot easily be translated into operational criteria" (Corbett et al. 1990, 15). Subjectivity is expressed here in two respects. Firstly, research subjects are free to form their specific ideas about anthropocentricity; secondly, an assessment of technical systems with regard to its anthropocentric quality must be carried out by those directly concerned, the operators, and their implicit or explicit assessment criteria may differ very greatly from those of scientists and thus partially remain outside of the scope of scientific analysis. This insight will find expression at various places in the course of the study. First of all, we would like to briefly outline the intercultural common ground in the understanding of anthropocentricity which has taken shape in the course of the discussion and work processes.

On the philosophical/anthropological level we assume that human labor is a central activity of life via which people deal with nature and society for the purpose of production/reproduction. In addition to the purposefully rational component, the relinquishment of human abilities to the objects produced is addressed here (among other things, the *producers' pride*, which is very pronounced in certain sections of the German skilled labor force, feeds on this). Furthermore, however, this approach attaches decisive identity-constituting elements to human labor.

Thus a strong content-related impulse is, of course, connected with the development of anthropocentric production systems because if the production process is not only understood from an economic point of view, if the work process is not only understood with respect to purposefully rational efficiency criteria, if human labor is not only understood in the abstract, physical sense as an exhaustion of energy, then it, indeed, makes sense to devise and implement production systems oriented to "human standards" and based on comprehensive, emancipatory contents. The basis of such concepts is an emphatic concept of work, in which humane work apperas as a central element of humane practice and as an important constituent of humane subjectivity.[9] Thus, the ideas of APS developed in this report must be regarded as quintessence of such a more humanistic tradition. In the approach followed by this study, the driving force is the concept of **humane work** as a historically changing value in itself, and **not** the recently fashionable *human resource model* which is regarded as the more economical concept that additionally produces positive *spin offs* for humane work (Staehle, 1988).

Work is not regarded merely as bread-winning and working hours as necessary and lost (because determined by others) time[10], but positively as a medium for the shaping of subjectivity. This is a driving element, to a certain extent the subject-oriented one.

In this way we reach a more concrete level of the definition of anthropocentricity which is, at the same time, provides the basis for (industrial) culturally tinged differentiation. Particularly in Germany, but also comparably in Scandinavia and other European countries, the identity-creating character of work has special significance. Work is comprehended as one important medium in which identity is formed. Through work and in work - even in industrial-capitalistically deformed wage work - people experience confirmation and even the most mindless subtask is not completely devoid of meaning for working people. Often it is **the company as a place of communication** which, in spite of the jobs devoid of meaning, gives meaning to human labor via satisfaction of communicative and social needs (cf. Thomssen 1990, 305). How much more meaning and identity can be created via humane work based on an anthropocentric shaping of the system?

If we additionally include the specifically German (or European) type of well-defined vocational system of industrial work at the present stage of our considerations, then it becomes clear that the differential subjectivity elements linked with the vocational system (Vogel 1983, 74f) represent a major identity-creating element. The latter together with ideal social conceptions of work (organization and contents) and related demands and expectations as well as the assumed identity-forming potential is the background and driving element for shaping APS. The differences in industrial culture in the countries compared which have surfaced in this point will be dealt with in the following sections.

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[9] This - at a first glance - ahistoric confinement to "anthropological constant factors" in our contemplation of the relationship of *humane* and *labour* does not underestimate the historical shape of labour. In accordance with the formulation of the question underlying this report, it is evident that we concentrate on wage labour (in mature capitalist systems) and try to illuminate the shaping potentialities according to an emancipatory ideal of labour, which draws on anthropological as well as historical, philosophical sources.

For a good overview of the numerous metamorphoses of the real labour's shape in the course of history as well as of the understanding of labour since the classical antiquity, through the Middle Ages, the Reformation until modern times (Locke, Ricardo, Hegel, Marx, etc.) see Walther 1990.

[10] See Negt 1984.

In this approach, which is, admittedly, very greatly oriented to European traditions, it is obvious that work very decisively affects the formation of human identity and subjectivity.[11]

If we now want to proceed to explicate the meaning and conceptions of anthropocentricity (in the Kantian sense, to depict in detail the concept in terms of its possible meaning content), it entails incorporating the mutual and differing conceptions as they are found in the national studies and compiling them into a noncontradictory latticework of diverse meanings of anthropocentricity.

The strategic goal of anthropocentric shaping of system is to draw man out of his role as a plaything/object of the process and create the prerequisites enabling man to become the subject of production. This means the quality of production work:

- **must be qualified and qualifying;**
- **should raise the level of autonomy of the work/worker;**
- **and must raise the degree of self-determination of the subject in production.**

These relatively abstract *characteristics*, however, arose in **opposition** to Taylorist or technocentric approaches (i.e. mechanistic ones where the production process is seen within the metaphor of the machine with man as a potential disruptive factor and part of the machine). Mostly because of this origination context, it is difficult to find constructive operational criteria for humane work.

In the search for operational criteria one must first differentiate between two levels of meaning for *anthropocentricity*: a very **normative** orientation and a more analytic interest in the current developments of production systems. Both paths of identification are to be found in this study. The analytic orientation finds expression in the typological experiments of actual concepts of production and concrete work forms; the normative orientation directs itself to the discussion and effectuation of desirable developments and expressions of future work forms.

At the center of the analytic interest lies the "dissecting" examination of current "work and technology" systems and the tracking down of trace elements of humane work and the designation of beneficial peripheral conditions. A fundamental dilemma presents itself here: Is the humane quality expressed on the work system level or rather in the quality of specific job aspects (work station level) or at both levels? A theoretical academic demand naturally insists upon a work station as well as a work system level of humane work structures. An unwieldy reality, however, does not always allow for this. And one does not need a great deal of imagination to conceive of enterprises which, through open job profiles on the system level, intensive communication on all levels and even via hierarchical levels, enable a certain potential of *humane work* which is not redeemable on the job (i.e. work station) level (among other reasons, because the actual performance of work is still divided according to Taylorist/Fordist

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[11] Recent discussions are increasingly confirming a crisis of the *working society*. For a critique of the debate on the problem of *leisure time* vs. *working time* and its implications for the discussions on the social constitution of subjectivity, see König 1990.

principles). Conversely, it is conceivable - we must almost go so far as to assume it the rule for APS shaping - where work on the immediate work place level is shaped according to human-centered criteria even though this anthropocentric oasis is embedded in a hierarchical/Taylorist organization. The conclusion: the whole system must be considered in order that positive tendencies at the micro-level are not offset or cancelled by negating macro-structures and vice-versa.

A consideration and evaluation of anthropocentricity on both of these levels is, however, not sufficient. "Even more significantly, the focus of concerns about APS, whether considered as a question of technical design or of work organization, cannot be reduced to a single location (for example, the shop floor) within the firm" (ACR, 10). We thus view APS as a multi-layered interrelated structure that exists on several levels: work level, department level, company level, intercompany level (that is, supplier structures) and social level. On each of these levels anthropocentricity has a different form. On the work level, despite all objections (also those raised by us), ergonomic qualities of work equipment and of work systems as well as the increase of autonomy and self-determination of the production worker are important criteria for APS. On the intercompany level, on the other hand, criteria exist in the form of symmetrical, domination-free and power-free cooperation and on the social level in the form of extensive co-determination (relevant to products and processes, including education processes)

Anthropocentric Products - The Forgotten Dimension

Generally the discussions on APS focus on the production processes in a narrow sense - admittedly this report also biases the production processes, but we furthermore include systems design and implementation (see the paragraph below) and we are at least aware of another dimension of the anthropocentricity complex: the question of anthropocentric products. Both, the processes and the products must be considered adequately in an APS concept.[12] In a sense that both elements are *sine qua non* conditions for anthropocentric systems design. For all (real or theoretical) attempts to devise APS, this means that establishing anthropocentric production processes - assumed the feasability of the attempt and the clearness of *anthropocentricity* - provided that they are realized in a production sector which manufactures social and ecological detrimental products (e.g. automobiles without catalyst, products containing asbestos or PVC or the field of arms production) cannot be seriously classified as anthropocentric.[13] The quality of products and processes are both constituents for APS, this is why they ought to be integrated. A possible means to develop the integration of both spheres is provided by the below sketched participative design approaches.

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[12] For the products this means to extend the common notion of product quality (as a matter of precision) which we shortly sketched in section III in a common economic sense.

[13] For a deeper discussion on the complex of *human-centred* products (especially the problem of arms production and the social movement that stands behind), see Cooley 1982; Einemann/Lübbing 1985 and Löw-Beer 1981.

Further reading of this report obviously discloses that we do not explicitly discuss the complex of anthropocentric products. We presume the question of healthy products and non-arms production as an implied condition without which the possible anthropocentric character of work and production systems would be nullified. For future discussions, we would suggest, that the complex of anthropocentric products should be more explicitly tied into the complex of anthropocentric systems.

Anthropocentric Systems Design and Implementation - Participative Processes

Besides a special systemic quality, the concept of anthropocentric systems of production provides for a qualitatively different development and implementation of technology. This is because the distinctive feature of technocentric systems of production is that they are based on a shaping of technology in accordance with scientific, rational (structurally oriented) calculations of engineers[14] - excluding those affected by the technology. This deficit is not only compensated for by anthropocentric systems design but is actually elevated to the status of a central characteristic of anthropocentric systems.

Contrary to the traditional development processes for technocentric systems of production, which are essentially designed as a succession of clearly distinguished process phases based on a design logic that is a consequence of how the engineer sees himself, we will formulate in the following approaches and guidelines for new design processes. The new participative design and development processes differ from the technocentric design and development processes, whose distinctive feature, in our view, lies in expropriating skill and knowledge transfer processes, in that they are oriented towards the central idea of supportive knowledge and skill transfer and thus make the skills and knowledge of the workers concerned the foundation of the shaping of production and work systems (Rauner, Ruth 1989).

The utmost which the traditional, technocentric *engineer's approach* committed to Taylorism is capable of achieving is an ergonomic adjustment to the external, usually superficial human conditions (improvements on the man/machine interface) - often, however, belated and then only with the purpose of securing the original goal (increase of efficiency or productivity) determined with the technical artifact in mind. Technical specification and design as well as the design of work systems lies to a great extent within the autonomy of engineers. In comparison, considerations regarding (work) psychology, work organization and work content are only included in a post-process phase (in the worst case, after initial implementation has failed).

A holistic approach to the design of technology and work must involve the consideration of human-centred technical and social criteria from the beginning of the design process. Amongst most contemporary engineering designers, the design of technology and work is still viewed

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[14] If we are allowed to oversimplify we would say that constructivist engineering logics imply that anything which can be analyzed and defined is designable.

almost solely as a technical concern and it is therefore important that some method whereby human-centred considerations can re-shape this process is made available to designers in order to direct this trend towards anthropocentric principles.

Apart from methods of socio-technical systems design and designing by doing we believe a combination of design by use of scenarios, designing along guidelines/criteria and designing with user participation to be most appropriate in designing APS.

The first element of the combined design methodology is the **Design by Guidelines or criteria** and involves the combined expertise of engineering, economics and the social sciences in order to optimize the human and social shape of the system.

The second element of the parallel design matrix is **Designing by Doing**, which was developed in Scandinavia (Ehn, 1988). It's main idea is the involvment of the users from the very beginning of the process. In collaboration with designers (engineers) specifications are elaborated by experiments (prototypes, simulations, etc) and then draw up a specification for use by design engineers. This approach is obviously very advantageous but covers the problem of a real collaborative communication between users and designers (engineers).

The use of **Scenarios** - a third parallel design method - is a recent development and it is difficult to evaluate its effectiveness in shaping design. A scenario is basically a picture or vision to illustrate what a system would look like if certain social considerations were included in the design. By itself, a scenario is only a starting point for parallel design, and may leave the design process largely unaltered, and therefore technically driven. So it is very important emphasize the social and cultural premises of design processes and on the other hand to anticipate the impacts of technology design processes.

Last but not least the method of **User Participation** is based on the assumption that the involvement of the users will cause better systems, because on the one hand it better meets the needs and skills of the working people, on the other hand only the users at shop floor level have the knowledge of the "real" production processes which of course must be included in the technical design process. Evidently users must be involved from the beginning and during the whole participative process. Appropriate means to reach that goal can be the creation of multidisciplinary design teams including product designers, manufacturing process designers, workers who are manufacturing the machines/technical artifacts as well as the potential end-users. Recently there have been developed three examples of participative designing processes which shall be scetched roughly:

* design for manufacture,
* simultaneous engineering and
* reverse engineering.

The **design-for-manufacture** initiative, which, especially in the U.S., has been discussed in connection with *Crisis in Manufacturing* analyses (cf. Office of Technology Assessment 1990: Dertouzos et al. 1989) and which has proven reliable in initial experiments, assumes that important course settings, which are difficult to correct later and affect product quality, shaping of manufacturing processes, etc., result in the very early phases of engineering design processes without an extensive and broad integration of all departments concerned. Design for manufacturing stands for the configuration of interdisciplinary and interdepartmental design groups that also include the user in accordance with the goal of participative design and shaping processes Possible first steps in this direction can be seen in the "proprinter project" at IBM and in several initiatives at Xerox, NCR, Ford, etc. (Dixon, Duffey 1990, 12f.).

The principles of **simultaneous engineering** are evidently only a first step towards participative processes. In the case of the Italian automobile manufacturer, FIAT, for example, where simultaneous engineering was essentially introduced as a strategic measure (along with decentralization of decision-making, training programs, reinforcement of quality circles, etc.) to improve product quality, simultaneous engineering stands for the cooperation of multidisciplinary work teams, consisting of experts from various areas such as planning, technology, buying, cost analysis, marketing and customer service for the purpose of common product development throughout the whole product life cycle (VDI-N. 9/1991). Within this experiment the participation of direct production work was obviously still lacking. This is probably due to the (still) very strong product orientation of the experiment. In a holistic development strategy of innovation and production processes, i.e. not product-oriented but rather process-oriented, the production worker must also be included in simultaneous engineering processes.

The principles of **reverse engineering** harmonize well with participative processes. The example of the NC/CAD linkage may elucidate this: supplementing data flow along the, previously, exclusively one-way street from CAD to the workshop (NC), reverse engineering provides for inverse data transfer. In the workshop, for example, prototypes are constructed on the basis of rough sketches, the resulting geometric data transcribed and then passed on to the CAD system. In this way practical knowledge and skills can be included in product development and in manufacturing planning.

Characteristics of APS - a Tentative Specification

The specific anthropocentric quality of APS, especially computer-based systems, must prove in a new functional division between computern/machin-systems and the human worker. Essential characteristics for an anthropocentric allocation of functions are "(i) *system architectures* to support decentralised design and production competencies; (ii) *hybrid automation* that ensures the appropriate allocation of functions between systems and operators at every level to enable and encourage the exercise of human judgement; and (iii) *user/system interfaces* that support rather than undermine production skills and tacit knowledge and enhance the 'tool' like character of new systems" (AusCR, 16). These rough guidelines can be regarded as cornerstones for APS.

To what extent these cornerstones are realised in existing production systems remains to be examined on the above sketched levels of assessment.

Micro Level

At the **direct workplace level** the characteristics of APS reflect themselves in varying degrees of freedom of central assessment indicators. The focus of our shaping and evaluation grid lies upon the following six work dimensions:

- time structure,
- space of movement,
- social relations,
- control flexibility,
- qualification and
- stress control.

These dimensions must not be misunderstood as separate and separable assessment variables, rather individual dimensions always exist in close connection with (at least one other) further dimension. In this regard stress control must be understood and evaluated from the perspective of time structure. Both dimensions are, in turn, connected with control flexibility and social relations.

The work dimensions shown above can be summarized on a matrix and assessed along a scale extending from *maximum restriction* to *maximum performance flexibility*. By classifying each work dimension in this manner according to the degree of restriction, an anthropocentric profile is produced which allows evaluation of the anthropocentric quality of the actual workplace on a relatively abstract level. The matrix of work dimensions can be seen in the diagram on the next page. Only the objective, work/shaping perspective of the problem, however, is captured in this matrix, not the subjective, discovering/experiencing dimension. The matrix can, therefore, only be utilized as a partial evaluation grid for anthropocentricity on the shop floor level - it is unsuitable for comprehensive evaluations since it does not cover the "subjective factor". As suggested earlier, the experience with and the experiencing of production systems by the workers affected is the decisive test for anthropocentric quality.

Intermediate Level

Leaving the area of the immediate work stations, we will now proceed to the department and company levels. There is no doubt that the work dimensions shown above are embedded in the organization of the whole enterprise. The degree of freedom of the work dimensions with regard to restrictiveness and performance flexibility depend to a large extent on the overall company organization structure. This is depicted essentially in two dimensions: **work design** and **co-ordination of operations**.

Figure 3: Differentiation of the Dimensions of Discovering/Experiencing, Shaping and Evaluation the Work Situation for Computer Assisted Production Work

	Grade of restriction/ performance flexibility	Dimensions of discovering/experiencing, and shaping of the work situation					
		Time Structure (Z)	Space of movement (R)	Social Relations (S)	Responsibility and control flexibility (K)	Qualification level (Q)	Stress-control (B)
5	**Centralised hierarchical manufacturing concept CAD centred, precision planning objectification of factory work**	Time-rhythm bound programme Time schedule	Strictly bound to one place without possibility of place change, or change in movements	No minimum work related social connexions maximum control (technically facilitated)	Total control via higher factory department technologically transmitted	Senso motoric abilities	Stress completely steered externally (technologically transmitted)
4 maximum restriction (technocentric)	**Operator orientated manufacturing with a large degree of AV in CAD and work preparation, separate skilled work (machine operators, qualification control, secondary skilled workers)**	Not time-rhythm bound but definite handling times for definite processes	Largely bound to one spot with markedly reduced freedom of movement e g machine oriented	Formal hierarchical work related minimum cooperation, no informal contacts possible during work, extensive control (technically transmitted)	Broad control, technologically and socially (personnel) transmitted	Routine fulfilment of job requirements according to a given work programme/rhythm, narrow variation span	Stress largely externally steered (technologically transmitted) little variation in the work speed
3	**Classical skilled worker orientated manufacturing with advanced AV and the separation between machines and secondary skilled workers**	Variable time organisation within the AV blueprints (e g optimising of CNC programme and varying of technology input data)	Largely bound to one spot (machine group) and occasional shift in space, dependent on cooperation	Cooperation via work based communication technology, minimal informal cooperation possible, social and technological control	Broad control due to planning structures, and personal control	Controlled, understood and self-optimised work (e g skilled machine work)	Stress largely externally controlled (technologically and socially transmitted) variation of the work speed possible within defined borders
2	**Classical skilled worker based manufacturing with limited workshop orientated work planning and centralised material-tool economy, also AV orientation in programming of tool machines**	Variable time organisation (e g in relation to the variation of lots to be handled)	Workshop orientated possibilities for movement (subject to cooperation and work diversity, e g by means of secondary skilled work)	Technologically and socially transmitted cooperation on the workshop level necessary, informal social cooperation possible to a limited extent (social + technological control)	Limited control (reduced to more complex work situations)	Self programmed, planned manufacturing on diverse manufacturing installations experimental abilities (above all in secondary skilled work)	Work speed externally and self controlled by work breaks and a combination of work activities (primary and secondary skilled work)
1 maximum performance flexibility (anthropocentric)	**Integration of primary and secondary skilled workers. Broad decentralisation of manufacturing, with partly autonomous manufacturing islands, largely autonomous workplan, and geometrically based construction (CAD)**	Open time organisation on workshop level in the framework of definite time sectors (e g 14 days) for the lots to be handled, including maintenance, servicing, repair	Good possibilities for movement (necessary because of broad responsibility on the shop floor level)	Social and technologically induced cooperation and communication with relevant informal components, social control	Largely (cooperative) collective social control	Planning in the frame of part goals within a broader given goal, carrying out of diverse duties/tasks in the workshop	Participation in decisions about stress/burden largely possible decentralised work planning
0	**Completely decentralised workshop orientated production, with autonomous production islands, (partly) integrated construction and work planning**	Open time organisation of the workshop, and participation in production planning, autonomous workplace orientated work planning	Good possibilities for movement on the shop floor level and beyond	Social and technologically induced cooperation and communication (horizontal structure), with well developed informal components, great degree of self-control	Largely self-responsibility and self-control in a work collective	Planning of complex work relationships, carrying out of complex tasks (in manufacturing and production)	Maximum involvement in the decision making process concerning stress possible via decentralised work shaping

Source: Rauner, et al. 1988

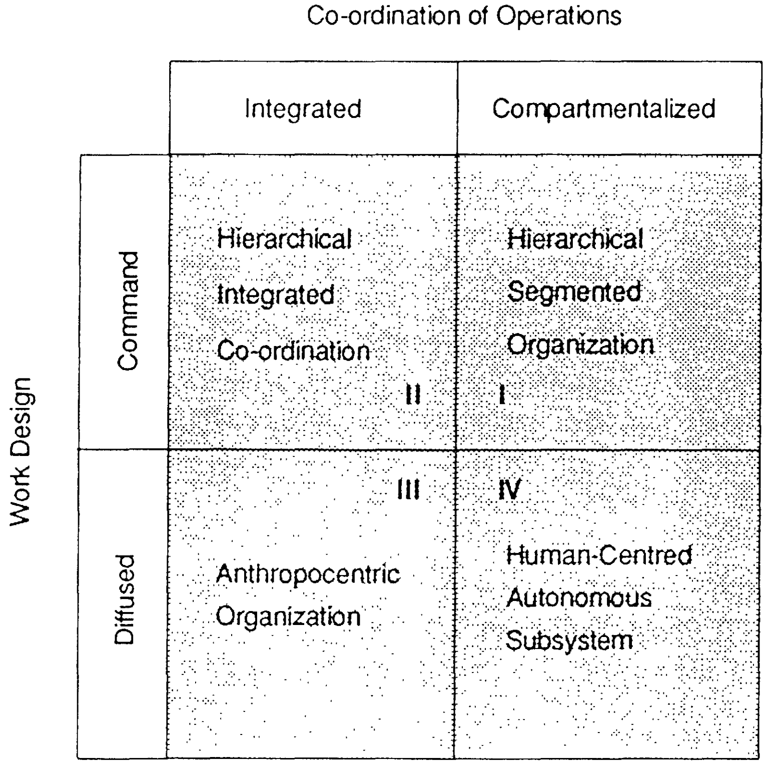
The specific shaping of **work designs** in either more anthropocentric or more restrictive paths can be seen in task and function allocation within the enterprise organization (as well as in the intra-departmental sphere). In this connection two fundamental goals are distinguishable. One direction, involving a large degree of self-determination of work groups (or departments), is distinguished by a function allocation aimed at autonomy. One might designate this as the *diffusion model.* "[T]he diffusion model involves multi-skill systems-oriented training, task allocations and work responsibilities, the adaptability of machines to user experience and preference, and the broad integration of responsibilities and dissemination of knowledge and expertise within the production department" (ACR, p. 23).

A second goal, in contrast to the more anthropocentric direction described, is distinguished by a rigid curtailment of autonomy, a close monofunctional gearing of tasks, "limited individual responsibility within hierarchical chain of command, and machine-driven operations" (ACR, p. 23). The guiding principle for this work design corresponds to a *command model.*

The **co-ordination of operations** is essentially based on a symmetry of communication, an intraorganizational command structure and integration or separation (disintegration) of functions and departments. According to the shaping of, for instance, communication in a hierarchical/dehierarchical, centralized/decentralized manner and the forming of the command structure in a top down manner or as a balanced and distributed decision-making network, one can speak of an *integrated or compartmentalized model* (cf. ACR p. 23f).

The roughly sketched two dimensions with their respectively dichotomized shaping may be portrayed on a four-field matrix defining the four types of enterprise organization (see the following figure):

Figure 4: Organization of the Enterprise



Co-ordination of Operations

		Integrated	Compartmentalized
Work Design	Command	Hierarchical Integrated Co-ordination II	Hierarchical Segmented Organization I
	Diffused	III Anthropocentric Organization	IV Human-Centred Autonomous Subsystem

Source: ACR 1990, p. 24

"*Hierarchical-Segmented Organization* (Cell 1) represents the maintenance of traditional hierarchical command structures over work organizationand machine utilization combined with a disarticulated pattern of relations between the various formal departments and functions of the enterprise as well as atendency towardsfragmented technology applications. In this instance, hierarchical command structures are reinforced by the Fordist assumptions guiding technology design and application, while the integrative potential of PA is undermined by the traditional compartmentalization of the production process and segmentation of work practices. By contrast, with *Hierarchical-Integrated Organization* (Cell 2) the enterprise takes advantage of the integrative possibilities of PA to restructure the relationship between functional activities (R&D, manufacturing, marketing, etc.) in the context of implementing a thoroughgoing technological integration of the firm. In this model, the increased intra-departmental coordinating capabilities of new technologies are purposefully exploited, while the technocentric assumptions built into hierarchical command structures are rigorously maintained. In other words, creativity is pushed as far as possible up the organizational structure, while technology is deployed to insinuate integrated centralized control as far down the structure as possible.

Anthropocentric Organization (Cell 3) combines the diffusion of control, responsibility and learning to the location of actual work tasks, flattened hierarchies, and decentralized applications of technology (group technology, production islands) with the functional integration of techno-organizational linkages. Production islands spatially and organizationally aggregat the components and techniques necessary to produce a particular parts family, sub-component or product as well as evolving indirect functions (production control, work planning, programming, supply and management of tools, maintenance, material supply, personnel requirements) to the direct work group. Conventional batch production layouts group machines by the type of operation performed (machine function), rather than by the type of product to be made (operational requirements). This traditional mode of organization confronts certain inherent blockages: extensive set-up times, parts queuing, coordination of throughput, integration of process changes. Regrouping equipment in production islands reduces set-up time, simplifies work flow and facilitates production planning and control. Integration of production islands with common data bases and information flows provides critical centralized knowledge and information without diminishing localized planning and decision-making autonomy. In the most thoroughgoing form of anthropocentric organization, the source of integration would lie not in revamped managerial hierarchies alone but on the shopfloor. It is critical to distinguish this stronger case of anthropocentric organization, in which there is a more holistic application of human-centred technology and more participatory principles of organization throughout the plant from weaker cases of *Human-Centred Autonomous Subsystems* (Cell 4) in which more anthropocentric applications appear as isolated and localized instances within relatively traditional disarticulated and compartmentalized organizational forms. Far from leading to more horizontal forms of coordination, such localized and ultimately incoherent instances of anthropocentrism, whether they emerge informally or as part of more deliberate organizational experimentation, may actually encourage the elaboration of more centralized control systems as the only viable means of integrating diverse sets of work practices and incompatible technical interconnections between groups and departments" (ACR p. 25-26).

In addition to the already mentioned *sites* affected by anthropocentric shaping, inter-company relationships have increasingly stepped into the spotlight and become a more and more relevant aspect of interconnected production systems, especially in the last few years. Two distinctive development poles have appeared. The more technocentric extreme is based upon traditional supplier relations which are, however, quite hierarchically structured, leaving the suppliers in a helpless, dependent situation. Technologically/systemically induced communication and data flow undermine the autonomy of the supplier ("remote-control") and can even have a (negative) effect within the work and organization structure. Between this extreme and the more anthropocentric one there is a broad continuum in which, for example, Japanese single-sourcing is situated closer to the positive pole.[15] With its integration strategy providing the supplier with possibilities for cooperation and involvement in early phases of product development, autonomy of the supplier is strengthened. The regional, decentralized distributed manufacturing networks embody the anthropocentric pole in the intercompany manufacturing relationships. These networks combine regional small and very small firms into dynamic and innovative production system alliances whose characteristic feature is a well-balanced, rather control-free, cooperative structure (for example, Emilia Romagna in Italy). Cost reduction and increases in systems flexibility are generally regarded as the major advantages. Above and beyond that, the specific company structures, the integrative production structures and the innovation structures allow for such networks of organization developments and work forms that meet the above mentioned standards for anthropocentricity (Office of Technology Assessment 1990).

Macro Level

A discussion of requirements and prospects of APS remains incomplete without including the social dimension. In contrast to the exposition of the micro and intermediate levels, a typology or a grid of variables will not take priority. Rather open and plausible pictures of the future will be outlined in the form of scenarios. This procedure makes sense among other reasons, because the micro and intermediate considerations are embedded in the social structure as a whole, and this provides pathways for future development (of the micro and intermediate levels), particularly in its political dimension.

In this way the macro level systematically supplements the other levels and provides for an extensive overall assessment.[16]

The following scenarios have been arranged and numbered along the continuum technocentric - anthropocentric. Different types of technology determine the respective trends of employment,

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[15] There are, indeed, examples within the Japanese manufacturing regime which are not so positive. We would like to disregard them, however, since we are basically interested in the two extremes and not in outlining possible case examples lying somewhere in the middle.

[16] In our view, it is not a question of which of the levels mentioned is the decisive one, but rather the other way round: How much technocentricity does a production system tolerate on the intermediate level, for example, in order that it may be regarded as anthropocentric on the level of the entire system?

which, on the other, have helped pave the way for the former - in the sense of an interdependence of factual and social factors. Accordingly, scenarios S1 and S2 involve a fast, scenarios S3 and S4 a slow development path of technology; both refer to the production technology that actually predominates in a given company. Each scenario includes both a shaped and an unshaped variant.

> "**S1 Tayloristic Automation (Computer-based Neo-Taylorism).**
> Traditionally Fordist Mass Production has been based upon the application of specialized machinery to manufacture standardized goods with unskilled and semi-skilled workers in a fragmented and strictly hierarchically organized division of labour. Thus, new technologies are mainly applied to provide a narrow and restricted range of product variation, to rationalize centralized coordination of standardized production processes with the result of labour substitution. Strategic reorientation at the level of the firm is focused upon the acquisition and diffusion of embodied technology within essentially unchanged organizational parameters. Thus, the implementation of new technologies is widely not accompanied by structural innovations in work organization. Instead of complementary consideration technological innovations seem to exclude organizational innovations.
> This concept encompasses residual activities that are either not automatable yet, or whose objectification would be unprofitable. The latter category comprises simple jobs whose objectification would require expensive robots (e.g. stacking differently shaped parts on a transport trolley) as well as demanding maintenance jobs the substitution of which by expert systems is not likely to become profitable in the foreseeable future.
> Computer-integrated manufacture is largely independent of skilled work in primary process areas due to a powerful technology efficiently linking reaction to sensors. Data processing systems necessary for real-time operation are available.
> Knowledge-based systems are capable of reactions that involve adapting to not directly pre-programmed system states. Example: adapting machine tools cutting speed and depth by "assessing" the cut being carried out.
> Skilled work (preventive maintenance) is clearly restricted, partly simplified, and hence partly deskilled. Important aspects of current preventive maintenance are partly computerized. This is mainly true for the recognition of dangerous weak points (such as the wearing down of a ball bearing) reported by sensors by means of oscillations. This applies also to diagnosing disturbances. In both cases, there may be applied expert systems whose diagnosing accuracy is profitable (e.g. 80 - 95 % of cases) and which can thus be substituted for large areas of human decision making. They also give detailed instructions as to maintenance and repairs.
> Current un- or semi-skilled jobs are reduced. Repetitive residual jobs are largely carried out by robots which can be programmed freely and are adaptable by means of sensor-actor linkages. Methods of graphics processing permit robots' variable use. Non-repetitive, simple jobs have also to a certain extent been taken over by robots by means of generalized sensor- actor-linkages. Knowledge-based systems sometimes permit 'quasi-intelligent' action, e.g. in order to route transport trolleys in factories.
> Production planning is centralized by means of a computerized network for information exchange between all departments. Forced software design has made available sufficiently powerful operation models. Here, too, knowledge-based systems partly substitute decision-making, while complete replacement is unnecessary for profitable operation. At the same time, the effects of `elitist` design and planning departments as

well as the actual power of management have increased as compared to today.

Increasing fragmentation and centralization of production occur alongside growing fragmentation of human work and the trend for automating residual jobs.

As a result, a considerable number of existing industrial jobs are cut. The remaining simple, residual jobs require low-skilled marginal staff, whose composition fluctuates markedly. Complex manufacturing jobs are carried out by highly skilled core staff who, due to their relevance to keeping production disturbance low, are well paid and enjoy high social status.

In development and design work, simple jobs will disappear due to CAD, CAE and the increased application of knowledge based systems, while the remaining design and planning jobs will be carried out by a technical elite.

S2 Socially Compatible Automation (accelerated relieving path)

The concept of socially compatible automation is based on the forced rationalization of industrial production by means of computer-based and integrated production technology, and by robotics in particular.

Robotics has been introduced with much greater speed. Robots are even used where it is unprofitable provided that they substitute simple jobs. Both production processes and products are largely designed so as largely to do away with low-skilled and laborious jobs or to substitute them by robots to a large degree.

While internal planning and coordination of production occur largely by efficient software 'company models' on the computer, supra-company networking is less advanced. With regard to supra-regional networking, software models are only used to support decision-making. It is at these interfaces that important decisions are made concerning the planning of the overall economy, of branches, and regional development including labour markets.

Here, regional interest groups should be given more scope for participating in decision-making and in shaping some of the conditions of employment and guidelines of technological development. Such pulbic influence can only be effective if decision-making is sufficiently decentralized.

Due to social shaping, however, automation is in the first place geared towards first substituting the least meaningful jobs, even though this may put up costs. Similar effects are had by the restriction of maintenance, repair and planning jobs (carried out by humans) through the use of `intelligent` robots and expert systems. Such increase of costs leads, via price rises, to a relative reduction of consumption, which is explicitly approved - in the former case in order to improve working conditions. The key-feature of the scenario, however, is a marked reduction of working hours for as many people as possible. A planning procedure operating at society level distributes the cuts evenly among all people, including even, where possible, members of the technical elite. One possible solution would be regular sabbaticals devoted to further education and training.

Gorz (1989) has designed the scenario of 20,000 working hours distributed over an entire working life. By radical reduction and the flexibility of employment, which is up to the individual, all adults, including parents - and mothers in particular - would be able and obliged, without major difficulties, to work 20,000 hours in the course of their lives. By integrating all women into this employment system, total working hours at society level decrease realistically.

With the jobs of professional elites not being amenable to reduction at will and to lengthy breaks, the relevance - and hence, viewed over longer periods of life, the duration - of employment will preserve the hierarchical structure of working life. For the majority of those working for short periods of time and - voluntarily - flexibly changing jobs, employment will deprofessionalize. Both the necessity at any time to guarantee employment following a break, and people's desire for varied jobs require wide-ranging qualifications for rather different jobs which can only be the result of many years of training and experience. Due to a generally much higher level of qualification among all those in employment, hardly any jobs will require lowering qualification requirements below the level of today's skilled worker or employee. Rather, outside those 20,000 hours, people will take a large variety of further education courses, during employment, will have extensive opportunity for training on the job and further training as well as permanent opportunity for learning at the workplace for the entire duration of their working lives.

Given the only sporadic stay of `marginal staff' in companies, there will be no more scope at the workplace for the immediate shaping of work and technology than today. Highly educated people, who will then form the majority of the population, will be better able to make an impact on works and community councils, through citizens` committes or trade-union groups linked to companies.

S3 Computer Aided Industry and Dichotomized Reprofessionalisation

In this scenario a technological development is assumed as a nonstructured process with a relatively low application rate of CIM XPS's and robots for the optimal realization of technically and economically sound possibilities.

In the CIM area this means the realization of "short" CIM process chains, an increased reliability of the CAD/CAM combination, etc.

In relatively uncomplicated cases, XPS's serve well as decision-supporting systems, robots with limited recognition patterns eliminate repetitive work processes.

Accordingly, this concept is accompanied by a relatively slow rate of development and introduction of new techniques, which complies with valid experience made up until now. Under these circumstances, the importance of the human being in production and administration will be retained at all levels for the foreseeable future, even without explicit restructuring with a view to de-hierarchisation, albeit with a decrease in working time volume. In this scenario it is even assumed that the significance of human intervention in production and administration will increase. The relocation of intelligence to the core where the actual production work is carried out is not only made possible but also required by the computerisation of the production process, as only in this way can its potential for increasing production be fully exploited.

Unlike concept S1, this concept does not involve an extensive relocation of intelligent activities and responsible decision-making to the planning, development and management level. Instead of skilled workers, this scenario requires assistants with technical college and semi-academic training.

There are two factors which explain this. Firstly, the theoretical demands on formal functional knowledge are increasing. The necessary basic theoretical insight cannot, however, be conveyed in further education, especially to people no longer used to theoretically orientated learning, unless a fundamental change is made in the curriculum. Theoretically-orientated work is more suitable for skilled employees with semi-academic qualifications: Production assistants, graduates of applied courses with a good theoretical background, as well as engineers with technical college qualifications, are increasingly taking over the jobs in production and administration. Although engineers are at first given management tasks, people with these qualifications tend later to slip further and further down the hierarchical scale. Particularly in organisational units such as semi-autonomous production islands or supervisory and maintenance teams, it has therefore proved to be rational to relax the hierarchical system and to distribute work in accordance with the "new concepts of production". The "semi-academics" then take over the traditional functions of the skilled workers, which are integrated into their both cognitively und functionally demanding areas of responsibility in intelligent production, supervision and installation maintenance.

The second factor is the steady increase in tertiary qualifications, especially at college and university level. Employees with a good secondary and tertiary education are offered, in a number of ways, the possibility of obtaining qualifications to which employers are increasingly adapting their employment policy.

A complementary field of more simple skilled work for untrained and trained workers is also taking shape. Traditional skilled work is going through a process of separation into assistant jobs and trained/untrained jobs.

In the areas directly related to production, i.e. planning, steering, supervision and control - below management level -, software tools are available to semi-academic assistants which are suited to a production concept with a more decentralised structure of organisation and, particularly, which leave the main duties of production steering and work planning to those on the factory floor.

S4 Work-orientated Automation and Computer-based Participation

The technical core of this concept is similar to the previous one, with the crucial difference that its feasibility and chances of realization are guided by socially desirable principles, i.e. its humanisation potential.

As before, this scenario assumes that employment takes up a substantial part of a person's life. It is linked with the ideological traditions of the union movement, but varies from it considerably in its concept of the future. It involves not a dichotomised, but a general reprofessionalisation. Wherever possible, competence and intelligence are relocated to the actual point of production. This development is supported by a revaluation of tacit skills and knowledge (Polany 1966), i.e. implicit skills gained by experience and practice, which have a far greater significance in the smooth running of production, especially in the primary process areas, than has been assumed up until now (Cooley 1988).

This general reprofessionalisation is, on a broad scale, based on compromise and the convergence of interests between employers and employees (manufacturing consent) (Hildebrandt, Seltz 1989).

On the one hand, employers now see that creative people in production are a decisive factor in production effectivity; but also the employee, as a consumer, has an interest in more effective production and administration. On the other hand, the form of organisation envisaged here meets with the demand for self-determination and autonomy at work, which is historically, the aim of the working movement; this must be in the interest of the employer in modern, especially compromised forms of production in as much as it provides for flexibility and responsibility among the work force. This is just the point where greater compromises must be made in the interest of the employees.

Flexible work groups are not just encountered at the production core on the factory floor (e.g. on the production islands), i.e. in the production of single products and small batches, or in the servicing and maintenance of production installations, but also in the

> corresponding administration islands. The "marginal" employees are integrated more and more "from below", so to speak, into qualified group work.
> Technically, this scenario is supported by the "Human Centred Computer Aided Integrated Manufacturing Concept" (Rauner, Rasmussen, Corbett 1988), developed in the ESPRIT Project 1217. The components of this system have a distinctly instrumental character. The human-machine interfaces, adapted to the capabilities of the users, are especially designed to allow employees to acquire and maintain the skills necessary for each particular process. Various CAM-CAD combinations enable the generation and documentation of construction plans during the production process on the factory floor.
> "System-based learning" is extensively realised by means of self-explaining routines and easily operable information systems. In this way, chances and possibilities to learn during the work process are greatly increased, so that the chance of becoming a hybrid technician is available to all employees. This model is supported by a structure-orientated further education model (Heidegger 1988).
> The networks are structured in such a way that extensive intervention is possible at all levels of the firm, retaining and supporting direct communication, as well as making information extensively available, so as to inform about the elements of production relevant to work processes" (GCR, 23f).[17]

Contrary to the original plan to project the scenarios onto various sectors and thus make them assessment models for the prospects of anthropocentric courses of development, it had become increasingly evident that the social scenarios cannot be completely portrayed on the sector level. The first signs of this, however, were recognized and consciously accepted right from the beginning. In course of drafting the country reports, it became increasingly obvious that the scenarios possessed a serious weakness inhibiting the carrying out of a world comparison: the scenarios are essentially eurocentric.[18] This is, for the most part, based on the political concept (including the national and political perception of the welfare state in Central Europe and Scandinavia) and the philosophy of production but also on the relationship between leisure time and work time. In general, the European traditions of thought and politics are reflected particularly in scenario S2 which presents a very unique solution for the automation (unemployment) dilemma as well as the work-leisure-time problem.

If, then, final assessments are to be made on the basis of the scenarios in the following sections, the limited transferability must always be considered within .

The Synthesis of all Levels

Our assessment of work and production systems is grounded on the integration of the above sketched three evaluation levels, the micro or workplace level, the intermediate or company

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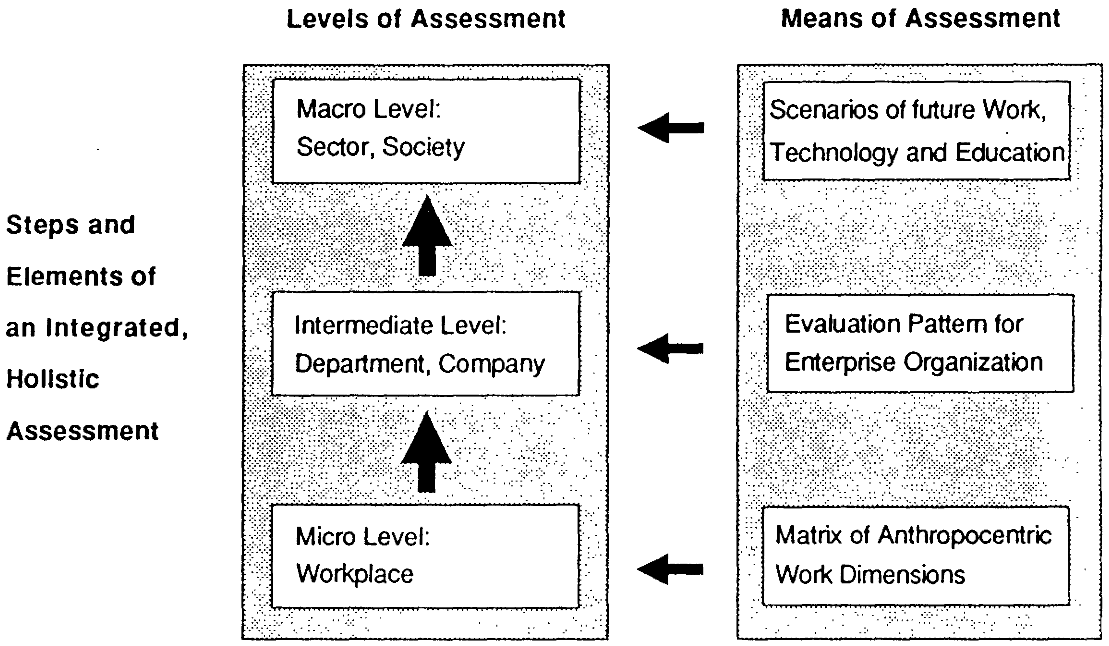
[17] The above paragraphs have been quoted from the German Country Report, they originate from Heidegger et al. 1986 (in German language).

[18] This may not be disadvantageous for a study commissioned by a European agency to draw up recommendations for technological and industrial policy, but it does represent an obstacle to maintaining comparability of the country reports on the level of an internationally comparative analysis.

level and the macro or societal level. In contrast to widespread approaches[19] which focus almost exclusively on the micro level, we employ - in a first step - the intermediate level with the aim to avoid narrow considerations of the anthropocentric qualities of humane/machine interfaces (which might in some cases proof to be more human-centred than other interfaces, but which are still embedded in a strictly Taylorist hierarchical company organization structure). Both layers still are not sufficient for a comprehensive assessment, because such items like educational institutions, technology policy etc. are social elements which influence the shape of APS without being able to examined micro and intermediate level.

Figure 5: Synthesis of Assessment Levels



Source: ITB/KR 1991

The above figure shall render the necessity to integrate all three levels for an appropriate assessment of the prospects of anthropocentric work and production systems. Each level is assigned with a corresponding means of assessment which have been developed above: scenarios for the macro level, the organizations evaluation pattern for the intermediate level and the anthropocentricity matrix for the micro level. **It is only the synthesis of all levels which approximates towards an appropriate, holistic assessment of APS.**

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[19] A considerable number of software and hardware ergonomic efforts fall in the category of a too narrow *human centred shaping* approach. See Pateau 1991 and Frese et al. 1991.

V. Conclusions and Recommendations

The analyses and assessments at branch and national level we make in the following paragraphs are embedded into an evaluation pattern of the social and cultural circumstances of shaping anthropocentric production systems. On that behalf we refer to our concept of **industrial culture.**[20] The industrial culture approach presupposes that there exists a set of influential factors which exercise a more or less strong impact on the industrial sphere, i. e. the processes of design, transfer and use of technology. It is likely that specific, in different societies varying, industrial cultures can either foster or hinder anthropocentric production systems design. For the purpose of assessing the prospects of APS in the countries of our sample the task consists of working out the specific shape of each industrial culture. In the result we will have two assessment levels, one at society level aiming at the common features and one at branch level figuring out the branch specific industrial cultural shape.

The concept of industrial culture is based on a set of interconnected dimensions which form the interpretative frame. The abstract categorial frame consists of the following selected key dimensions:

- National traditions and societal institutions,
- Organizational preferences,
- Social institutions and government policies,
- Educational institutions.

Along this pattern we want to sketch the peculiarities of the German, the U.S., the Japanese and the Australian industrial cultures. We differentiate the above key dimensions into a network of interconnected variables which are embroidered with the differing contents which take shape within different industrial cultures.

1. Conclusion: In Germany there is a chance that the anthropocentric production concept will become the dominant one, especially in the machine tool industry. The trend towards a greater degree of anthropocentric work and technology is expected to a substantially lesser extent for the automobile and electrical industries.

Among the **national traditions** the attitude towards work combined with the dominating social assessment of work give us a first important hint on the shape of the industrial culture. It is not only the unions but also the works councils and more generally (and informal) a social consent (even under certain groups of workers such as skilled workers) about the demands towards work. Positive developments of the work contents (job enrichment,etc), working security and

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[20] The concept of industrial culture is developed in Rauner and Ruth, 1990, for further details refer to this source..

preservation of health are evidently demands that are raised in all industrial cultures, but besides this a strong claim for self-determination in the work, qualification protection and securing are important issues rooted in the union movement as well as in the group of skilled workers (Cf. IG Metall 1984). The fact of the existence of a large skilled work force with a certain qualification level which exists in all above sketched branches (dominating in the machine tool building and less widespread in the electronics industry) effects a permanent societal "bargaining fight" within which the postulations are claimed. And in so far as in management circles the "human centredness" ideas get more influential there are good chances to realize the above mentioned claims within APS - especially because the qualificational prerequisites for such developments truly exist. These attitudes to and dominating assessments of work are of course a necessary but no sufficient precondition for anthropocentric systems design.

Organizational preferences contribute to the specific shape of the German industrial culture. The German social-organizational corporativism with its roots in the medieval guilds and taken over into the craftman's shops has obviously strongly influenced the organizational structure especially in the German machine tool building (with a certain regional variance). The "Meister/Facharbeiter" system on the shop floor level is concordant to work/craft oriented, highly flat organization patterns which are broadely found in the machine tool sector but also in several fields of the other branches (e.g. in the electronics: the production of ASICs and to some degree the production of capital goods as a whole; in the car industry: the manufacture of mechanical parts and to a large extent the special motor vehicle building). Despite of the widespread orientation to Taylorism/Fordism in the car and electronics industry there always existed attempts (and tendencies) to flatten the hierarchies and to establish group-oriented organization principles (often supported by government policy; see following issue). This obviously stands in close connection to the relatively strong bargaining power of the unions and is to some extent covered by the co-determination efforts of the works councils. Although there is a dispute on the question whether or not issues of work contents and organization are legal rights of the works councils (Müller-Jentsch 1986) there is some probability that the special shape of the organizational preferences within the German industrial culture will enable more decentralized, (semi-) autonomous organization concepts: There is evidently a higher probability in the machine tool branch, but the existence of certain pilot-projects in the other branches (especially in the car industry) give some plausible indications for a general re-orientation towards Post-Taylorist/Post-Fordist organizational developments.

The **social institutions and government policies** will be exemplified by explaining the industrial relations, the shape of the social contract at company level and by some selected examples of the government policy in the work and technology area. The social contract at company level emphasizes the politics **in** production, i. e. to emphasize the existence and relative independence of an (informal) social structure at company level which is complementing the formalized industrial relations. The latter can be divided into two areas. The unions as one conterpart in the collective bargaining process are acting at branch level, they are structured as industrial unions which organize all employees of a sector. Similar the associations of employers. The second area of action is the company level where there are works councils which are formally independent of the unions. Their rights cover participation and the right of information regarding questions of work and technology, whereas the industrial unions used to emphasize the questions of wages and working time. Of significance here bis the tradition that the strongest industrial unions (usually the metal workers union "IG Metall"), i. e. the unions of the economically strongest sector, are playing the role of trendsetters who fight for their postulations (reduction of the weekly working time, etc). For the other industrial unions remains the task to adopt this result (often without tough bargaining and strikes).

The social contract at company level is an **informal** company-internal system of norms, rules and routines. It is based upon the consensual and mutual integration of all groups within the companies. It comprises a common understanding of a system of informal rights and obligations concerning policy of employment securing, continual training at company level, wage fixing and performance control, etc (Hildebrandt, Seltz 1989). Evidently this institution takes different shapes in different branches and regions (Hildebrandt has worked it out for the German machine building branch) but there are of course some common expressions which constitute the German industrial culture: A very fundamental but significant issue is the dominating communication model which is fundamentally based on social partnership and appeasement. There is a mutual awareness of the legitimacy of the postulations and obligations of the partners. This allows to develop company-internally new work and organization structures which sometimes lie far beyond the formal/institutionalized agreements. Especially if progressive managers (or small company owners) meet a cooperative, highly qualified and motivated work force the prospects of APS are positive. But all in all the probability is the higher the smaller the company size.

To exemplify the significance of government policy we refer at first place to the German government-sponsored WOP-programme on "shopfloor-oriented programming of CNC-machine tools" (Nuber, et al., 1989 and Projektträger Fertigungstechnik, 1987). During the last years this programme was carried out by a consortium of machine tool producers, machine tool user companies and research institutes with the goal to develop user-oriented programming techniques which are highly adapted to the specific productive processes and to the skills of the "Facharbeiter". As a result the developed programming system is used far beyond the involved user companies. Many machine tool producers that have not participated in the WOP-programme are now producing CNC-machine tools with shopfloor-oriented programming facilities which can be seen as important preconditions for new organization models informed by semi-autonomous, de-centralized groups. The development of shopfloor-oriented programming tools is going to be a relatively strong movement in the German machine tool building. This sensible government policy gave highly efficient inputs and caused strong spin offs. The whole WOP programme of course was enabled by an industrial culturally determined consensus of all relevant social groups and by the insight into the necessity of governmental support in the fields outside of basic technologies.

This consensus is also taking effect in the R&D Programme on "Work and Technology" by the Federal Ministries for Research and Technology, Work and Science and Education with the invovement of the unions. One of the working priorities for example was layed on the "Human-centred application of New Technologies in Manufacturing". Within this field they will attempt to develop decentralized, autonomy supporting organizational models on the basis of the "existing broad qualification" of the shop floor personell structures (Bundesminister für Forschung und Technologie 1989). These projects will probably create a positive encouraging climate for shaping and implementing of APS in several industrial fields.

Another relevant field of governmental policy is the educational policy where there are continually conducted pilote projects regarding the contents of the vocational education curricula, the methods of learning, etc. This issue is overlapping to the next industrial cultural key dimension: Educational institutions.

In the industrial culture concept **educational institutions** are of extraordinary relevance for the design and use of thechology. In particular we see the educational systems, the contents of educational processes, the relevance of skilled work and the patterns of skill formation processes as the powerful key variables in this field. The historical genesis of the educational system in Germany is distinguished by government-sponsored education and vocational training. This policy formed the base of the dual vocational training system - qualification **at** work and **for** work - with its institutionalized combination of theory and practice (theory in school, practice in the companies). The system is formally based on the compulsory education consisting of 10 years plus 3 years apprenticeship. The vocational education covers both, specific process and material knowledges and complementary general education. Exemplarily in the metal working (and electronic) sector there recently was a reform of the curricula contents (1987). The major result is a stronger orientation towards "organizational contents and skills" such as: planning, controlling and steering capabilities (Heidegger 1989). With some caution we can say that this resulted/will result in a relatively highly qualified skilled labour force which has the operative and intellectual capability to work within more autonomous, self-determined and thus anthropocentric work and organization structures.

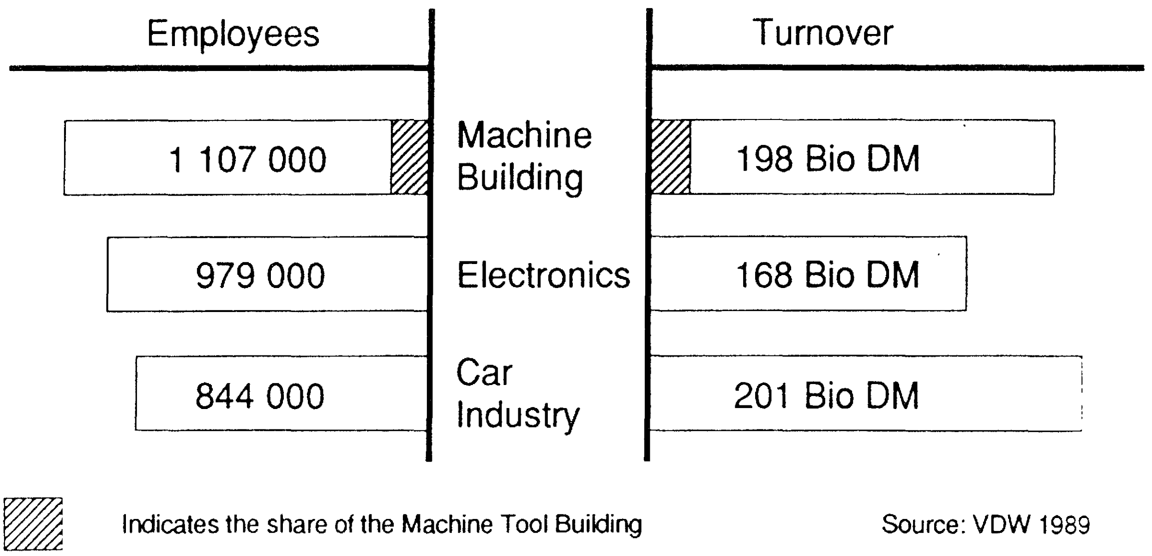
The underlying in Germany predominantly cultural orientation is the so-called skilled-labour-demand approach in which the educational system provides skills, qualifications and knowledges in sufficient quantity and quality. Education and the vocational system is forced upon the individuals whereas other cultural contexts shape a human capital approach in which individuals decide on their personal investment in qualification and education (Lenhardt 1987).

In the course of history the institutionalized skilled-labour-demand system caused a large amount of skilled labour (Facharbeiter) which is one of todays caracteristics of the German economy and probably the most valuable starting point for any developments towards APS - **but** even if we consider the apprenticeship system as dominant we must not forget the remaining 30 % of the workers who do not have a formal qualification. They depend on the internal qualification offers of the companies which enable them to get the status of semi-skilled workers (thus they rely heavily on the quality of the qualification offers which vary between simple o-j-t programmes lasting some weeks/months and continuation courses during several months). As a result of our branch reports, the electronics industry - and there especially the female work force - is characterized by a dominance of semi- and unskilled workers. No doubt, a small group of women will be raised in its qualification level and will probably reach the level of skilled worker qualification but in the short and middle terms the majority will stay at a semi- or unskilled level. This is one reason why we estimate the prospects of APS in the electronics branch not so positive as in the machine tool building.

In the light of our industrial culture approach we estimate the prospects of anthropocentric production systems in Germany as follows: According to our assumption that the most important factor for shaping and developing APS is the education and qualification dimension, the branch with the highest rate of skilled workers also has the highest probability of developing and implementing APS but the international comparison indicates that beside these branch-specific differentiations the German shape of the industrial culture displays favourable preconditions for an anthropocentric production systems development (similar to Sweden and Denmark which unfortunately are not included in the assessment).

The branches analysed in the following paragraphs distinguish by the fact that they as a whole accumulate about 38% of the turnover and 43% of the employees in the German process industries. In absolute figures it is about 2.9 Mio employees producing a turnover of 560 Bio DM. Thus, these industries are of certain significance for the productive structure of the German economy on the one hand and on the other hand they indicate the particular skill formation and qualification structure.

Figure 6: Basic Figures of Selected Industries



▨ Indicates the share of the Machine Tool Building

Source: VDW 1989

The Machine Tool Industry

In overall debates the German Machine tool industry is usually discussed in terms of "world export championship" - this discussions evidently scratch only the façade. The real situation, the technological role of and the shape of work within the sector and even the prospects of the machine tool industry as such can not sufficiently been discussed in terms of championship. In the following we want to give a well-founded estimation which goes beyond the statistical surface: we want to concentrate on what goes on inside the sector, its structural peculiarities, its capabilities and prospects - Nevertheless we first present some statistical data which circumscribe the general situation.

The German Machine tool branch is a quantitatively small sector of the machine building branch. It covers approximately 8.5% of the total employees of the machine building branch and a relating 8.5% of the total production of the whole branch. The machine tool sector's significance is debted to its role as a creator and server of innovation and rationalization technology for almost all fields of the metal processing industries.

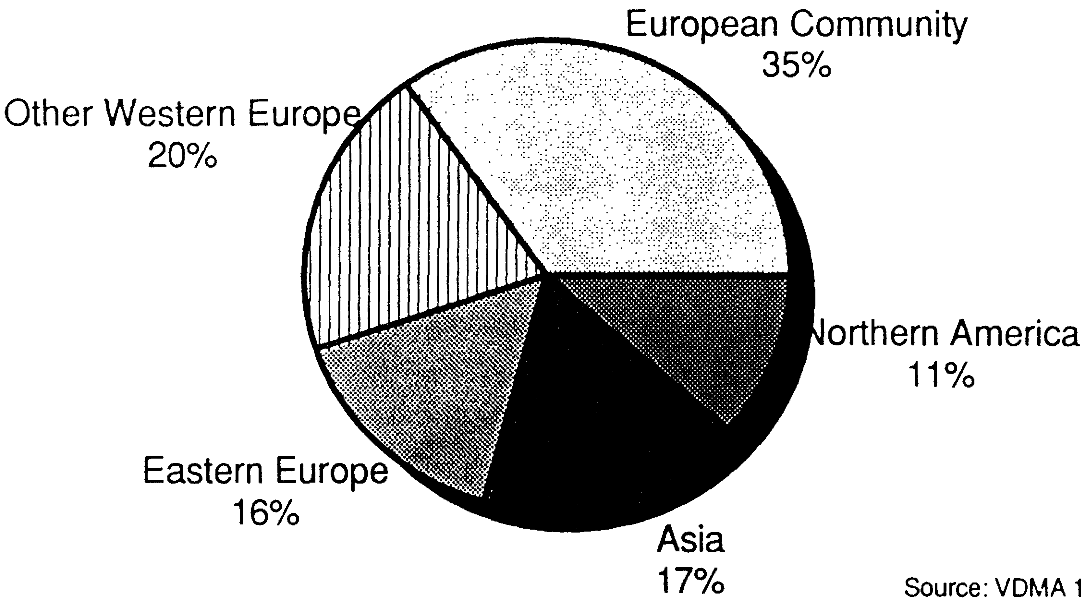
The German Machine Tool Industry is traditionally a net exporter of machines and parts. This has not changed since the stage of producing conventional machine tools and it is the reason for a strong dependency on the foreign demand and the world market changes. The comparatively slowly growing world market is characterized by a tough competetition on the market shares. The world demand (and the production volume) display some cyclical expansions and contractions which shows the high sensibility for economic stagnation (or recession) - the machine tool sector serves so to speak as an hyper-sensible early-warning system for changes (and here especially for declines) in economic activity. This explains the severe decrease of the world production in machine tools during the stagnation in the beginning 80s (between 1980 and 1984 the world production decreased from 26.5 Bio $ to 19.5 Bio $; cf American Machinist various volumes). The cyclical ups and downs of the world demand and production in machine tools are reflected in the production figures of the German Machine Tool Industry: Between 1973 and 1980 the production volume increased continually. In 1980 it accounted for app. 5.5 Bio $, and the world production share of German machine tools mount up to 18% (the U.S. share was equally 18% and Japan about 14.5%).

In 1981 a severe descent began and lasted until 1984. It was not until 1986 when the production level of 1980 was reached again. This four-year phase indicates, beyond a general economic stagnation, the transformation of the German machine tool industry from the production of conventional/NC machine tools to producing computer numerically controlled machine tools. Too long during the beginning 80s the German machine tool industry had missed the opportunity to develop and produce CNC machine tools. This failure resulted in a reduction of the world market share from 18% in 1988 to 14% in 1984 (to the favor of the Japaneses competitors) and in a loss of 15.000 jobs which is equal to a reduction of 15% of the employees in the sector (cf VDMA 1989 and VDI-N 40, 1990). Strong efforts in technology development have been made during this period and since 1986 the production index on the basis of 1985=100 displays an increase to 113 in 1986, and 109 in 1987, 107 in 1988 to 117 in 1989 (cf. VDMA 1990): The development of the production volume since 1985 must be circumscribed as continually slowly increasing with some slight interruptions in the shape of stagnations.

A quintessential resumen of the statistical review concludes the situation of the sector in the end of the eighties as follows: The production volume of the German machine tool industry has stabilized at a high level of about 14 Bio DM, an order backlog of 20% above the production in 1989/90 which caused significant delivery times, and an extremely high capacity load of 95% (VDI-N 40, 1990). Approximately 60% of the total production is exported, the world exports share is relatively stable and amounts for approximately 22% (similar the Japanese, the U.S. share decreased continuously since the 70s to a level of 4% in 1989).

A short glance at the export structure displays a strong orientation towards the countries of the EC, followed by other non-EC western European and Eastern European countries (see the following figure).

Figure 7: Export Structure of theGerman Machine Tool Building in 1989



Source: VDMA 1990

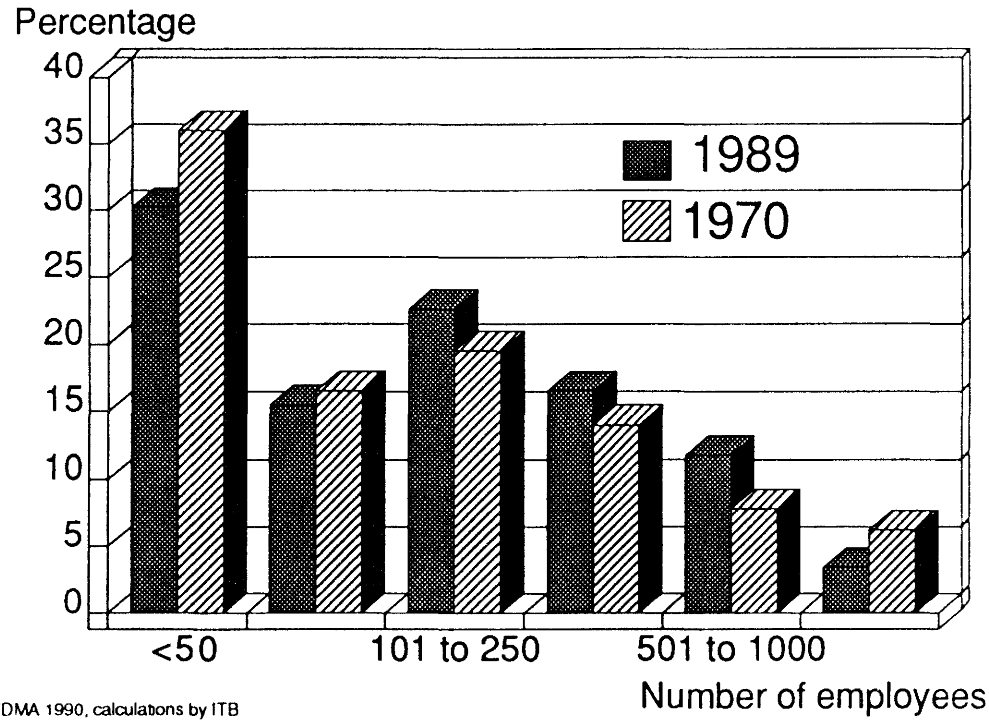
The share of the exports into the U. S. is about 9.6% in 1989 (the difference to the above quoted 11% is exported to Canada). The most remarkable fact here is that with Japan and Switzerland as the only exceptions there exists a trade balance deficite in machine tools. The negative trade balance with Switzerland is rooted in the trade with grinding and milling machines whereas with Japan the turning lathes and FMSs caused the negative saldo.

The branch structure

The regional distribution of the machine tool industry in Germany (FRG) displays the following picture: Baden-Württemberg, North-Rhine Westphalia and Bavaria are (in descending order) the leading regions/federal countries in the contemporary machine tool manufacturing. The northern parts show a very weak performance

The machine tool sector employs approximately 97 500 persons (in 1989; increasing since 1984 when 83 000 were employed). The machine tool builders association VDW estimates the number of enterprises at about 390. The branch is dominated a by firm scale which must be characterized as typically small and medium sized. One third of all machine tool manufacturing companies have less than 50 employess and a cumulated percentage of about 68% covers all companies with less than 250 employees. The average firm size is so small that you don't find a German company within the ten world leading machine tool producers (measured in annual turnover). The following figure gives an overview of the current structure and contrasts it with the situation in 1970.

Figure 8: The Dominating Firm Size of the Machine Tool Sector



Source VDMA 1990, calculations by ITB

The number of companies with less than 50 employees has decreased during the time but it still is the dominating category. Most remarkable is the increase in the middle categories 101 and 1000 employees: To some degree this is debted to a shrinking of former large companies, to some extent a growth of the smaller companies contributed to this tendency. Especially the former small companies build up and developed their in-house innovation capacities by growing and reaching more favourable company sizes, and of course a medium company size between 250 and 500 enables the enterprises to offer service and maintenance in an international or at least European scale.

In all following estimations the general dichotomization in small companies with less than 100 employees and companies with more than 100 employed has to be seen as a crucial consideration. It is true that the large companies (500 and more) employ about sixty percent of all the employees of the whole sector, thus all the structural pecularities concern approximately two thirds of all the employees of the branch, on the other hand looking at the small companies gives us an insight in the organizational and structural peculiarities of two thirds of all the branchs' companies. In the following we differentiate accordingly into small and larger companies.

A common feature of all machine tool enterprises is the generally very high proportion of skilled workers. Experts estimate that the latter make up approx. 70-80% of all workers in the branch. Statistics show the skilled worker share in the entire machine production industry to be 60-65%.[21] Experts agree that the corresponding percentage for the machine tool industry is higher than that for the machine production sector. Based on this figure, therefore, one can designate production in the machine tool sector as skilled worker production (production in other branches of machine construction, on the other hand, would have to be termed as semi-skilled worker production).

To be able to draw conclusions from the characterization of production regarding the structuring of work and technology systems, it is necessary to take into account additional indicators. The average size of the production orders is especially significant in this connection. According to an intercompany study of the VDMA (1987a), the average batch size in the machine tool industry was 30.7 (ranging from 4 to 40)[22] with a moderate to high degree of complexity of the finished parts. Furthermore, the majority of companies involved in machine tool production (more than 75%) state that their best-selling products are manufactured according to customer specification.

Taken together, the qualification structure on the shop floor level and small batch sizes of the customer-specific, moderately to highly complex products are significant factors for the production process and thus for the shaping of work and technology: production (manufacture and assembly) in the German machine tool industry is, in large as well as in small companies, predominantly organized according to the workshop principle, i.e. separated according to technological method the workpieces are run through the individual workshops. The greatest disadvantages are long flow times, relatively long transport distances and an enormously high

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[21] The VDMA (1990) comes up with a figure of 59% while the company study conducted by ISF shows 65.3% for machine production (see Hirsch-Kreinsen et al., 1990).

[22] The average batch size for the entire machine production industry was approx. 76 (VDMA 1987a).

control expenditure; on the other hand, the high degree of flexibility of this type of production is a great advantage.

As a result of what has been stated above, the shop floor or skilled worker as the dominating protagonist of this production site has a relatively high degree of autonomy for taking action because of the relative lack of clarity concerning the production process and due to the necessity to additionally achieve flexibility potential. At the same time, however, this shows in turn the need for and necessity of production control systems. This is where a differentiation between small and large companies comes in:

In larger companies attempts are made to solve the problems of planning, controlling and monitoring the time and substantive element of the production process by introducing PPS and BDE systems. These strategies are based on two kinds of orientation: rationalization **and** monitoring. On the one hand, this approach is intended to find a solution for the rationalization dilemma which is typical for the entire machine production industry and which is reflected by the successful resistance of skilled workers against reduction of qualification requirements and the increasing breaking up of work operations, i.e. by a relatively low degree of rationalization.[23] The results noted up to now with regard to the introduction of new PPS and BDE systems are expressed in concrete rationalization steps in production: by means of statistically/mathematically calculated specified times, it becomes possible to increase the monitoring element and to achieve more efficient utilization of skilled machine work while reducing autonomy[24] **and** at the same time retaining the qualification requirements. The reduction of autonomy is not necessarily, though frequently de facto, coupled with a more restrictive time structure, a more limited scope of movement and a diminishing of responsibility and control flexibility on the work station level (while assuming no change in qualification levels and social relations).

Thus this rationalization concept does not work according to Taylorist patterns, though the objectives are identical. The development described is more of an indication of technocentric orientation and thus tends to point towards scenario 1, although one has to consider that it will predominantly appear in the category of "larger enterprises" as merely a subordinate tendency.

Though the above mentioned rationalization dilemma does also apply to small enterprises, there is a tendency to pursue other strategies. Because job planning and programming offices are often lacking due to the small size of the firms, planning, monitoring and execution of the production process predominantly take place on the shop floor. There is a high degree of autonomy (concerning job scheduling and operations) and, as the *other side of the coin*, the

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[23] At the same time the machine tool industry is a supplier of automation techniques that are applied successfully (in accordance with Taylorist/Fordist rationalization) in mass production companies.

[24] For example, by virtue of the fact that completion of orders in the workshop is carried out via individual control instead of through "bundle control", i.e. each individual order is checked in and out, the order sequence is fixed, etc.

production process as well as the shop floor seem as a whole like a black box to the management.

The relatively successful application of so-called shop floor-oriented CNC programming systems is exemplary for a strategy of support and expansion of autonomy for skilled machine workers on the shop floor (Brödner 1989). By enabling skilled workers to prepare NC programs efficiently on site (or supporting this endeavor), these systems basically reduce the division of labor (insofar as the programming task was previously the responsibility of a special department) and make a qualification-oriented reorganization possible on the shop floor level. It would be particularly appropriate at this point to refer the reader to some very successful attempts at reshaping the organization of production according to the principle of production islands.[25] This organization concept departs from the typical workshop performance production arrangement and arranges machines according to families of parts. Qualified group work forms the basis of this concept while the "production island work force" is given a quite far-reaching enlargement of tasks that may include the following: order management and planning (not centrally controlled deterministic total planning but autonomous basic planning); autonomous preparation and management of operations scheduling; NC program management; quality control; diagnosis and system monitoring. The shop-floor-oriented CNC programming tools are an important cornerstone since they facilitate complete processing in a production island via a **standardized** user interface. In addition, decentrally applied workshop control systems (PPS) are an excellent means of providing for partially autonomous job scheduling on the part of machine workers, i.e. externally fixed final deadlines can be planned in detail by the group flexibly and autonomously.

Since this form of organization is based on the requirement that every member of the group can execute all tasks that arise in the production island (including new ones), such organizational developments are usually linked with continuous, parallel qualification measures. They start with the existing qualification level of the shop floor work force and develop it further - this path could thus be designated as a qualification-oriented strategy for solving production problems. Measured against our job assessment matrix, it is characterized by greater time flexibility, a raising of the qualification level, enlargement of the scope for movement, improvement of social relations as well as avoidance of externally directed stress situations. If one projects these job-related considerations to sectors and level of society, one sees that they correspond to a great extent to the anthropocentric scenario 4.

In connection with what has been said above, one notes a dichotomization in scenarios 1 and 4 (analogous to company size) which is also reflected, though with some peculiarities, in the survey of experts conducted. The relatively advantageous structural requirements of the sector (company size, qualification structure as well as a customer-oriented small-lot production) make scenario 4 quite probable, at least for the smaller enterprises. The experts' opinions on the

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[25] Cf. Klingenberg, Kränzle 1988.

prospects (in the near future, 10 to 15 years) indicate less relevance for scenario 1 and greater significance for scenario 4. However, the experts questioned also presume a certain degree of probability for scenario 3.

Thus, within the German industries the **machine tool branch** has the most favourable structural preconditions to realize APS on a broader scale: Not only the highest rate of skilled work but also the production volume and scope (customized small batch production), the average company sizes all are favourable for technological/organizational innovation strategies along the anthropocentric path. The prevailing dominating shop floor organization allowes an enlargement of job contents and relatively high degrees of autonomy for the machine operators. The path ultimately dominating in the branch depends to a large extent on external conditions. Therefore, the question of basic social developments is of decisive importance in this context: Will there be an adequate number of skilled workers in the future? In this case skilled work might become the basis for a qualification-oriented path (scenario 4). Or is a structural erosion imminent which will have a dichotomizing reprofessionalization effect (scenario 3)? Therefore, whether scenario 3 or the anthropocentric scenario 4 asserts itself in addition to scenario 1 as a minority path will depend on basic industrial-cultural conditions.

The Car Industry

The car industry is the largest of our selected branches measured by turnover which accounts for approximately 200 Bio of DM which is equivalent to 13.7 % of the turnover of the whole processing industries. The German car/road vehicle industries employ approximately 800.000 people which accounts for 12 % of the total employees in the processing industries. Of course, these statistical figures only give a first very rough impression of the branch. Deeper analyses should focus on the general situation of the branch as well as on the micro (work place) and intermediate level as it presents itself in the beginning 1990s.

The West German automobile industry is involved in an increasingly intense competition for shares on international markets; and with the opening of the European Market beginning in 1992 enormous pressure will be applied particularly by European and Japanese competitors. "Forecasts indicate that vehicle production in 1990 will reach an annual figure of 51 million units worldwide in contrast to an estimated total demand of 42 million vehicles. This would mean an overcapacity of approx. 20%. Nearly 30% of the latter is accounted for by production in Western Europe (2.4 million units)." (Roth 1989, 185) A competitive process in which Japanese conglomerates in particular will drive other companies out of the market is imminent since they intend to sell a portion of the 2 million units manufactured at U.S. plants and 1 million units produced in Europe on the West European market. (Muster 1989, 7ff)

Thus mass production is only marketable in a strategically favorable and finely tuned market situation and, therefore, a continuously updated, high-quality product is required. "It will become a question of survival for the automobile manufacturers to produce as many different types and variants of products as possible with a high degree of quality in shorter and shorter cycles. For the companies this means that series and lot sizes will get smaller and smaller while product complexity and variety increase" (Roth 1989, 185).[26] In addition, this development encouraged a drastic reduction in direct material stocks - also to effect a concentrated application of capital - so that today *just-in-time* production is the rule or the set target.

Furthermore, ecological requirements, such as "low energy consumption, exhaust emissions, raw material consumption and pollution", will have to be complied with in the competition of products. Because in view of "overcrowded roads and apparently a 60% share of the climate-altering air pollution coming from cars", the automobile is increasingly called in question (Muster 1989, 89); to combat this imminent, extensive drop in demand, it would seem advisable to implement a strategy of product extension from "automobile" to "means of transportation". However, the struggle not only involves the product but also the price. Here it is necessary to distinguish between five approaches:

"1. Drawing up of new boundaries between in-house and external production, i.e. restructuring of vertical range of production.
2. Better internal and external networking; i.e. smoother, more compact execution of operations and new logistic concepts.
3. Alteration of working and operating hours; i.e. more flexible working hours, Saturday work, 3rd shift.
4. Completion of technical rationalization; i.e. flexible automation.
5. Further decentralized rationalization of operational organization; i.e. expansion of tasks and functional integration." (Schumann et al. 1989, 122)

In short, to attain a high level of production capacity, a standardized (modular principle) form of mass production must be maintained, at least with respect to parts and components; in order to ensure a high degree of product quality as well, a highly differentiated, short-cycle, flexible form of production is required. Thus in the classical branch of Taylorism/Fordism adequately organized human qualifications are also regarded as a decisive productive and innovative potential: whether the aim is to ensure that the capital-intensive, highly complex, extensively automated, mechanized production system processes are flexible or to shape personnel-intensive, direct-production subprocesses in a more productive manner.

Work and Qualification Structure at Workplace and Company Level

According to Schumann et al. (1989, 1990), the work and qualification structure of automobile production can be divided into 4 types each and differentiated according to processes:

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[26] "Further development of the already tried and tested market strategy of high quality and reliability, technical perfection and variety of models and types" (Schumann, et al 1990, 49).

The **processes** can be described according to technical level as follows: the *pressing section* (5%) and *mechanical production* (10%) are automated, except for portions of the peripheral areas, and can be characterized as high-tech fields; *carcass work* (20%) and *paint work* (11%) are only partially automated in the core area and are dualistically structured as high-tech and low-tech fields; the *assembly of units* (9%) and *vehicle assembly* (30%) are still only automated to a very low degree and thus low-tech areas though the increasing use of carrier systems here makes disconnection from the line possible.

> "Along the axis of 'technical level of production' and selected 'solution for operational organization' one must distinguish between the following **types of work**: 'manual work on the product' (in premechanical production approx. 77%); 'manual work on machines' (in mechanized or partially automated production approx. 17%); 'machine/equipment operator' (in mechanized production without automated process control 1%); 'system regulator' (in (partially) automated production with program-aided/controlled process execution 5%).
> We grade the **qualification** according to type and duration of the industrial learning process: 'simple semi-skilled qualification' (short training period, occupational learning process for up to 1 year) (54%); 'higher semi-skilled qualification' (systematic training phase over several months, occupational learning process for up to 3 years) (34%); 'skilled worker qualification' (relevant apprenticeship or systematic training over many years) (10%); 'higher skilled worker qualification' (skilled worker apprenticeship and additional special training) (2%)" (Schumann et al. 1990, 50f.).

This characterization according to level of *flexible automation* corresponds to the following *reshaping of operational organization*: In the high-tech area an integration concept of job enrichment has asserted itself in accordance with the "assessment that the qualified production worker, who also performs maintenance functions, is particularly well-suited to ensuring a high degree of equipment utilization" (Schumann, 1989, 124). This concept not only provides for the production but also for its control, programming, maintenance and quality control. *System regulators* (so designated according to Schumann et al. 1990) become the determining new type of worker who ensures smooth operation of the process.[27] However, plant teams, who, as it were, collectively make up the hybrid skilled worker, are employed due to the thus given industrial level of qualification and training.

In the assembly sections production is, in some cases, carried out by work groups in so-called "boxes" with little extension of work through rotation, quality control and touch-up work. However, more far-reaching integration on the skilled worker level in partially autonomous positions has only been tried out to a small extent in pilot projects (Ulich, 1983; Roth, 1989). There are corresponding mixed forms in the transitional areas. In addition, there are another 15% who are allocated to `miscellaneous' without further specification. Participation or at least work-station-related co-determination does not seem to be very widespread yet in the

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[27] "His main characteristics no longer involve the function of controlling a process, but that of putting the process sequence controlled via programs back on the specified, programmed track in the case of deviations or faults by means of regulative intervention.." (Schumann et al. 1990, 124).

automobile sector, with the exception of pilot projects (Kaßebaum, Thelen, 1989). Finally, the level of training is divided into *no apprenticeship* (48%); *apprenticeship not connected to occupation* (12%); *relevant apprenticeship* (40%) (Roth, 1989).

In summary, it can be said that automobile work is still predominantly (94%) carried out as manual work on the semi-skilled level (88%) though there is a considerable degree of overqualification (52%). The system regulation share (5%), however, accounts for approx. 30% of the jobs in the most advanced area (mechanical production); over 50% with skilled worker qualifications. And this development is reflected in the structure of the pilot projects, in which 50% and more of the workers carried out system regulation functions in nearly all processes - with the exception of vehicle assembly and paint work, however - and were qualified accordingly at the skilled worker level.

The expectations for the future work and production in the automobile industry must be differentiated according to high-tech and low-tech areas: In the **high-tech area** the remaining independent functions will also be almost completely automated or allocated as unqualified portions to system regulation in the near future. A system regulator's work requires especially high qualifications and competence since "in his manipulations he has to take into account and coordinate: 1) the immediate reality of mechanical and process technology and 2) the indirect, symbolic, computer-based world of communication and information technology. This requires both abstract, theoretical understanding and knowledge... as well as concrete, empirical... sensorially obtained knowledge based on experience... His pivotal function between theory and experience also gives him considerable social competence." Especially since this complexity and diversity of tasks only permits limited information control" (Schumann et al., 1989, 136). Thus scope for co-determination of work content will be opened up for workers accordingly, and an elitist consciousness will probably develop among the majority of them due to the fact that other areas will continue to be characterized by lower qualifications and a more dependent position.

In accordance with *pilot experiences* (Schumann 1989, p. 134), automation comparable to the high-tech area or an enriching form of group work can be expected in the assembly of units **in the low-tech area**. The situation is different in the remaining areas[28] of vehicle assembly: at least carrier-aided *box assembly* and extensive job enrichment through maintenance and quality control work will assert themselves here; in some cases, there will also be group skilled work with specific information control and partially autonomous organization.

In the near future the processes of the *high-tech/low-tech areas* will not be able to be as extensively automated or work-integrated as the present high-tech area; extension of the work structure will hardly take place due to a lack of task requirements. The still dually determined structure of these processes will thus split into one area or the other in the future. However, the

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[28] A portion of this work is transferred to the partially standardizable preliminary assembly. (Jürgens, Malsch, Dohse, 1989)

scope for exerting a determining influence in all processes is restricted by virtue of the planning and control specifications that can be controlled via information systems. In all companies a specific co-determination based on participation groups or quality circles is practiced for all processes.

In short, the central importance of the *working personality* as a productive force is recognized in all processes and production levels, though only hesitantly at first. Whether on a high-tech level to ensure systemic productivity or on a low-tech level to implement production that is as wear-free as possible, the most favorable degree of flexibility can only be achieved on a permanent basis if the human productive force is integrated. In view of the situation of massive competition in the automobile market and the still strong tradition of deterministic management, however, all human-centered innovations regarding job enrichment and co-determination are hindered by intensive time specifications and systemic external control.

The Prospects of APS at Workplace Level

Before, in conclusion, an assessment is given with respect to the scenarios, the anthropocentric shaping prospects should be systematized at work place level on the basis of the dimensions of the restrictivity/flexibility matrix we presented above.

The *time structure* is predominantly specified on a binding basis, whether on the level of the company-determined shift work structure, on the level of processes that can only be interrupted without conflict in the form of stipulated breaks or on the level of work operations that are predetermined via system-controlled specifications. A certain leeway can be attained particularly in the only partially implemented, functioning group work structure or on the basis of, in some cases, insufficiently calculable specifications in highly complex system control. *Space of movement* is primarily restricted to the workplace. The work is predominantly carried out at one certain work station, which can vary, however (rotation). It is only possible to leave the work station during breaks or special meetings (e. g. in quality circles). *Social relations* are predominantly tied to the workplace and are subject to interference, particularly through noise. According to the extent of group work structure, direct mutual - though usually work-related - contacts can be exchanged with respect to a problem or issue under discussion. Times for breaks and quality circles make more detailed discussion possible during the limited time available.

With regard to *responsibility and control flexibility*_it is only possible to determine the working conditions within the scope of systemic planning and control specifications; they depend on the technical level and the thus given complexity of the tasks related to processing and ensuring smooth operation of the process and on the degree of job enrichment and of group work structure.

The current requirements according to *qualification level* and *stress control* looks in the following manner: Routine processing of action programs is predominant. Social planning requirements and responsibilities as well as diversified knowledge have to be coped with or furnished, respectively, particularly in group-type high-tech areas, in some cases in group work in the low-tech area and in quality circles. In the case of a predominantly high intensity of the performance specifications, relative coping potential exists according to the complexity of the areas or the type of group structure in interaction with specific responsibilities. In addition, stress - primarily through noise - arises from the working environment and can be coped with to a limited extent via quality circles.

The result after differentiation on the basis of the shaping dimensions is thus: relatively moderate prospects for shaping automobile work according to technical level areas and type and extent of group structure. The rating according to the anthropocentricity matrix ranges between 2 (moderate performance flexibility and thus moderate anthropocentric) and 5 (max. restriction and thus technocentric).

The above sketched evaluation at a work-place level will in the following paragraphs be transformed into an evaluation of the prospects of APS on the basis of the worked out scenarios: In the majority of processes an increased automation can be expected, which, however, does not lead to removal but to new kinds of more intensive utilization of the working person. Productive coping with the complexity of processes requires the - cooperative - application of specific human competence. And even in areas that are not to be automated, the new target variables (low run time, low share of indirectly productive work, flexible production) can only be achieved through extensive - group-type - job enrichment and integration of human competence. On the other hand, the "old hierarchy" of central planning and control will not be eliminated but exists in a new technological information system form. Relative potential for increased external determination as well as for limited co-determination exists side by side. Computer-based reorganization attempts will be determined predominantly according to company efficiency criteria, the skilled workers who ensure smooth operation of the process in the high-tech area - and to a correspondingly relative extent those working in groups - are in a secure position. Work tasks matching their qualifications become available to them via job enrichment and group work basis. Co-decision-making competence, however, remains essentially limited to the work station level. The situation is different for those working on a low-tech level with little group work structure. They are threatened with relative stagnation if not the loss of their job.

Within the scope of the company's capital utilization as well as planning and control interests, the social organization of automation can to some extent be expected to be qualification-oriented. Prospects of a occupationally oriented shaping of work, however, only exist to a limited functional areas. Corresponding intra-company qualification efforts for semi-skilled workers will only be carried out for those working in a direct group context and for the few highly flexible workers. Participation is, in some cases, possible up to the level of partially autonomous work groups, for most workers, however, only within the framework of work-station-related quality circles or participation groups.

To sum it up: The experts' estimation for the **German car industry** shows more than half of the companies following scenario 1 and only weak tendencies towards scenario 3 and 4 - this is debted to the historically dominating Fordist/Taylorist traditions and reflects to some degree the structural disadvantages of the branch (compared with the machine tool building): large companies, strong demand for centralized logistics, etc. But for the future the experts expect an increase of anthropocentric concepts (or at least anthropocentric pilot projects) to app. a fourth each, scenario 3 and 4 and a decreasing (but still dominating) share of scenario 1.[29] The reasons for the expected growth of group/team oriented, stationary modular assembly concepts - or generally of the "anthropocentric" scenarios must be seen in the pressure that is exercised by the intensification of world-wide competition, rising cost efficiency, variants flexibility, high quality and J-I-T demands, etc.

The Electronics Industries

According to the dominating classifications within the electronics industries we emphasize consumer electronics, covering household equipment as well as audio, video, tv and high fidelity equipment, and as the second field we concentrate on industrial electronics which consists of electronics capital goods as well as elctronic components (e.g. semiconductors, ASICs, etc). In the case of consumer electronics and particular the audio/video/tv branch it is very doubtful, whether it is legitimate to entitle this case study "German consumer electronics" or if considering the internationalization within this field it would be more appropriate to call it "production of consumer electronics in Germany". The dramatic changes in the ownership of companies during the last decade makes the consumer electronics sector a Europeanized production.[30] Nevertheless it makes of course sense to characterize the production organization in that field as a typical German one, in so far as there is no total elimination of the pre-existing industrial culture when companies are internationalized (Europeanized). Historically dominating elements of the local industrial culture are continuing.

An important figure which highlights the structural specifity of the electronics industry as a whole is the company size. Contrary to the employment structure of the machine tool industry but very similar to the automotive industry the dominating company size measured by the number of employees lies in the category '5000 and more' (56% of all employees of the branch are within this column). If we cumulate the categories '1000 to 5000' with the category '5000 and more' we get 76 % of all the branch employees within this aggregation (ZVEI 1990).

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[29] See Figure 2.

[30] This process is accompanied by an increasing share of Japanese production plants in Germany (and Europe) which is the second stage of the "import offensive" (Cf. Tetzner 1989).

To begin with the production structure of the electronics branch we have to consider the share of the different fields within the branch. With regard to the use of the goods the distribution in the year 1989 is the following:

- Capital goods	65 %
- Consumer electronics	15 %[31]
- Components	20 %

(Source: ZVEI-Statistik 1990, calculations by ITB)

Corresponding to the intra-sectoral differentiation we find a differing shape in the production volumes. The consumer electronics production is largely characterized by industrial mass production similarly with the production of components such as semiconductors. A little different is the production of capital goods, the batch sizes here are differing according to their potential use and the character of the product.

Very important for our purpose to assess the prospects of APS in the electronics branch is the employment structure. Generally the employment volume displays some ups and downs since the 1980s which are accompanied by a steady shift between the different segments of the electronics industries (e.g. the number of employees in the audio/video/tv sector was decreasing from 125 000 in 1978 to 80 000 in 1987) all in all these losses have been compensated by other fields, thus the volume of employees is remaining more or less constantly at approximately 1 Mio from which the share of female workers was **decreasing**. The number of female workers nowadays lies at about 35 % in 1989 (ANBA 1990) which is still above the average of the processing industries as a whole (about 27 %). Furthermore the branch distinguishes by an outstanding work productivity per working hour which was in the 70s at the average level of the processing industries and increased until 1983 to approximately 10 % above the average of the processing industries (ZVEI 1990).

With regard to the qualification structure the most striking observation is the share of skilled workers. Compared to the car industry which displays approximately 50 % skilled workers and the machine tool building with about 60 to 70% the electronic industry has a portion of about 40 % skilled work (estimated on the basis of the ANBA figures on 1st, 2nd and 3rd performance rate, ANBA 1990). The peculiarity of the branch must be seen in the fact that the 60 % of the employed male workers are holding a qualification level of **skilled work** with according work contents, whereas of the 360 000 female workers of the branch only 3 % are holding the qualification of a skilled worker and 35 % are semi-skilled workers (with an o-j-t of at least some months). The majority of the employed women are working at an unskilled level. The developments of the internal labour markets is of greatest importance especially for the semi-skilled, because the value of their skills can be realized only in-house, thus their carreers depend upon the possibilities offered by the companies within the companies. This group is of certain interest for future product and process developments which usually are accompanied by

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[31] During the last decade the share of consumer goods was decreasing steadily from 20 % to 15 % and the share of components was incresing respectively.

changed organizational/qualificational requirements. There the problem of closing the "qualification gap" occurs. A possible but probably not dominant strategy could be the expansion of the apprenticeship system in order to widen the group of skilled workers (the past developments show that this is more frequently the solution for male workers). The second possibility is the development of company-internal attempts to re-qualify workers (especially females) and to offer structured continuous qualification programmes.

If we now draw our attention to the fields of work carried out by occupational groups in the electrical industry we find that these will provide us a better understanding of possible solutions for anthropocentric production systems.

Skilled workers

Skilled workers, i.e. those who have completed the initial stage of vocational training, master craftsmen and technicians carry out a variety of tasks, beginning with work (together with others) on development tasks up to the performance of services. Their share of the total number of employees varies greatly. It decreases relatively where the focus is on development functions and increases relatively in areas where series products are increasingly produced in variant forms.

Semi-skilled workers

Here it is even more difficult to draw an exact picture of the tasks assigned to semi-skilled workers. The increasing future application of microelectronics leads to a new division of simple production work with regard to

- technical and organizational requirements,
- work structure in combination with and depending on qualification,
- personnel policy in the in-house labor market and regarding the labor supply in the industry.

> "Whether and how the qualification deficiency of unskilled and semi-skilled workers will be compensated for in the future in the electro-mechanical production areas undergoing change towards electronic production is an open question. It is probable that two parallel strategies will gain acceptance in the medium term:
> - A slow, numerically insignificant expansion of the initial stage of vocational training in the areas of communication technology and energy electronics;
> - a gradual turning to the group of unskilled and semi-skilled women with the aim of being able to distinguish better between simple, qualified and highly qualified areas of work and to provide further qualification in this connection" (Gensior 1989, 116).

To some extent the situation of **engineers** is of significance for our shop floor-oriented examinations. There is a growing need for engineers in very different areas, such as electrical development, in customer consulting services and sales as well as electronics-based production functions, which may cover production support, quality control, etc. The response to this need within the company consists of:

- hiring (new) employees;
- qualification measures and
- measures related to (operations) organization.

As there exists a shortage situation hiring new employees is not very successfull and at the same time it often has a negative effect on in-house qualification measures; the existing work volume rarely permits systematic qualification. The decision regarding the quality and quantity of qualification is frequently left to individual initiative.

New Production Concepts

As in all other production sectors, a trend towards a comprehensive CIM solution is also taking place here: the solution, which necessarily has to be a company-specific one, gives rise to unsolved detail problems. These solutions are most advanced wherever large series of, in principle, equivalent products are manufactured with a great number of variants. Here again development has not gone beyond a technical production networking in certain segments.

Company strategies are very different and not specific to the sector. They range from (operations) organization solutions to new qualification concepts. Thus the vertical range of production, for example, can be reduced by purchasing product elements; the company's development and production expenditures are more likely to increase rather than be reduced. The companies want to close two gaps with qualification concepts. On the one hand, an attempt is made to cover the personnel needs in the development department internally; skilled workers rarely receive the opportunity of advancement. On the other hand, the need for semi-skilled workers must be met. The extent to which this further qualification is carried out depends, among other things, on:

- the company's initial situation. The numerical composition of the company's employees (engineers, skilled workers, semi-skilled and unskilled workers) is reflected in a distribution of the qualification potential; it differs from company to company and is basically determined by the past personnel policy as well as by technical production requirements;
- the possibility of falling back on different production variants that allow the companies to bridge the gap between the existing qualification level and the desired short-term level by means of operations organization measures;
- the labor market situation, i.e. the possibility of hiring additional workers.

Anthropocentric Production Concepts

The discussion concerning anthropocentric production systems (APS) is still, as in other branches of industry, in the beginning phase. APS become relevant wherever, in the first place, the number of variants is growing within the scope of series production and requires interdepartmental information technology networking and, secondly, these objectives can no longer be implemented within the framework of Taylorist production concepts.

On the whole, there is no reason to assume that APS will play a role as a forerunner in the electrical industry, as compared to other sectors.

In the mechanical engineering field production automation processes as well as centralized forms of operations organization have not utilized the existing skilled workers level - the available potential here was wasted. The same processes have had far fewer negative consequences for the skilled workers in the electrical industry, though the consequences for the semi-skilled and unskilled workers there have been severe. For this reason there is much less justification here for anthropocentric production systems. On the other hand, this does not mean that, for example, a withdrawal of the centralized forms of operations organization as well as modified forms of automation processes are not economically advisable (compulsory cost reduction due to increasing production of variants) and cannot lead to more work satisfaction.

If one applies the degree of the work satisfaction to the matrix presented above, then a second, more important difference with respect to mechanical engineering becomes evident. Regarding the technical production process, the skilled workers in the mechanical engineering sector are the ones that, in the end, execute the operations. Those workers performing auxiliary functions for them play a subordinate role and are often assigned to the logistics section. In the electrical industry, however, it can be observed that semi-skilled and unskilled women carry out manual work, primarily the assembly of pc boards and simple, easy-to-handle units as well as functional checks. The magnitude of the women's work grows to the extent that these tasks increase proportionally relative to the production expenditure. Women's work also increases wherever mass production predominates. It is obvious that women are subject to a great employment risk here if their work can be replaced by automatic assembly and handling systems (robots).

For the employed men, on the other hand, 60% of whom are skilled workers, the utilization of women's work results in a work profile which is fundamentally different from that in the mechanical engineering sector. First of all, they are assigned as specialists for complicated pc board assembly and inspection tasks to the extent that these tasks require skilled worker qualifications (wherever such work constantly arises to a certain degree, it is also performed by semi-skilled women); and secondly they are responsible for the organization and monitoring of the production process. This includes technical conversion for the production of new products; in this connection there is also cooperation with engineers in the production (here: superiors) and in the development department (coordination with respect to technical production implementation options).

The operations organization structures, which differ greatly in the electrical industry, have little influence on the skilled workers as far as the range of their tasks is concerned. They perform work that corresponds to their level of training: in smaller companies and in the production of unique items their tasks are more product-related; in larger enterprises and/or in mass production they are more process-related.

An anthropocentrically oriented decentralization of operations organization and of process control has a positive effect for skilled workers: on the basis of the scheme presented, improvements of 1-2 levels to the levels 1 and 2 would result with one qualification: on the basis of the collective skilled workers of the company, the quality level would not have to rise; on the other hand, the individual skilled worker would have the opportunity of applying the range of his theoretical knowledge and practical abilities - while in the mechanical engineering sector the depth of knowledge would additionally come in useful (see above).

There are only limited opportunities for women employed in the electrical industry to improve their work situation. Their primary areas of work (assembly, inspection) are increasingly becoming mechanizable. The utilization of automatic assembly and handling systems threatens them with the loss of their job since other, compensatory work exists only to a negligible extent. An anthropocentrically oriented decentralization develops far fewer positive aspects than for male (skilled worker) colleagues even in areas where these rationalization techniques are not applied. On the basis of the proposed scheme, an improvement of one level to the levels 3 or 4 might result.

Since the assumption of skilled worker tasks founders due to the lack of the theoretical range of the selectively oriented further training, only the prospect of changing areas of work, which can only slightly improve the work situation based on the criteria of the proposed scheme, remains. Previous experience has shown that positive developments towards theoretically sound further training are scarcely evident. The lack of willingness on the part of companies to provide training is often justified by the argument that women perform this work for only a few years before taking on the role of housewife and mother so that the training would not pay for itself. However, a major reason can be found in the physical and psychological stress at the work place (piece rate and shift work as well as great demands on eyesight). Another obstacle is that the in-house, even though secondary, qualification and advancement paths for women are destroyed by the application of automation techniques: "On the one hand, the reduction of jobs related to qualified semi-skilled tasks diminishes corresponding advancement and qualification opportunities while, on the other hand, technological barriers are set up by the application of new, complex technologies, thus increasingly reducing the chances for workers to acquire capabilities and knowledge for tasks requiring special qualifications via in-house on-the-job training" (Bednarz-Braun 1987, 359f).

As long as no changes take place here, and they are hardly to be expected, there remains only the modest prospect of making full, creative and optimum use of the narrow framework within the scope of new, anthropocentric production concepts - this will only be possible if the women concerned are actively incorporated into the process of change and this process is not confronted with a precipitate pressure for success on the part of the management.

The experts expect a decreasing significance for the up to now prevailing scenario 1 and a rise of scenarios 3 and 4 with the result of a slight dominance for S3. The significance of S4 is widely debted to the fact that a lot of pilot projects are performed in many of the branch's companies.

To sum it up:
In the light of the experts' judging the **German electronics industry** is in the present stage predominantly following scenario 1 (nearly half of the branch) and to app. a third each to scenario 3 and 4. The experts expect a strong decrease of scenario 1, a weak increase of scenario 4 and a stronger increase of scenario 3. Especially the future dominance of scenario 3 must be seen in the light of the current structure of the work force (female, semi- or unskilled) that will be developped towards a dichotomized structure: internally upgraded and semi-academic, college trained people as the core work force (benefitting of humanization attempts) on the one hand and unskilled restworkers as the peripheral work force (in the middle range substituted by automation) on the other hand.

Taken together, the three German branch assessments, the machine tool branch has the best chances to realize APS on a broader scale, the car industry with no such strong dominance of skilled work displays at least some promising pilot projects whereas such attempts with a comparable scope are virtually not existing in the electronics branch. The two latter branches are thus more dependent on more favourable social circumstances (e.g. a more intensive orientation of production managers towards APS and human resources, etc).
A final comparison with the Japanese and the U.S. branch reports will allow a comparative assessment of the different industrial cultures and their differing capabilities to enable, support or hinder APS design.[32]

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[32] See the Chapter *Synopsis and Recommendations.*

2. Conclusion: On the outside Japanese production system has many features of anthropocentric production (cooperative forms of work, quality circles) and at the same time greatly limited employee rights. This contradictory development will continue in the Japanese producing industry.

Compared to the German case the Japanese industrial culture displays some considerable differences and surprisingly some striking similarities in the shape of the industrial-cultural key dimensions. A comparison of Japanese and European (and North American) social values and attitudes reveals a different priority. Whereas in Europe the individual is at the first rank, work at the second and the organization at the third place, in Japan the order is reversed, the organization has the highest priority before the work which is followed by individuality (JCR p. 24f.). This basic industrial cultural peculiarity impacts almost all below presented phenomena.

The Japanese corporate system is based upon the mentioned values. Within their corporate system, both executives and employees alike see the corporation as the basis of their lives. As such they make every effort in overcoming the challenges and problems which their corporation may face. Whether or not this corporate centred group behavior will continue or whether changing values among the youth and a possibly appearing shift away from "groupism" towards individualism will occur is yet undecided but will surely influence the Japanese industrial culture and thus the industrial structure.

The attitude towards work which we characterized as an important variable accordingly displays a specific shape in Japanese industrial culture: There is no such distinction between work and spare time as in European industrial cultures but instead there is an extremely high degree of social integration of the employees under the companies' goals ("commitment").

A specific Japanese tradition must be seen in the promotion and wage systems. There is no direct connection between the wage level and the job performed. Especially the Japanese promotion system must not be underestimated as an important means to increase commitment of the employees (at all company levels but especially at shop floor level). The promotion system is based on three levels of evaluation (section, department and division) and performed along such items as: discipline, quality of work, plan and scheduling and leadership, etc. This evaluation system obviously impacts the commitment of Japanese workers and also effects the quality of work and the production process as such.

Instead of individual workers predominantly teams solve such questions as job demarcation, task allocation, etc. within the groups which gives them a considerable degree of autonomy and makes them a key element of the Japanese work organization. The manufacturing teams are found in all branches. Though some branches, as the car industry, are (still) largely organized according to production lines they nonetheless have manufacturing teams and quality circles, groups which are responsible for product quality, production improvements, etc.

An important contribution to Japanese competitiveness and a key to the understanding of its industrial systems' excellence is its **educational system**.

The foundation of the Japanese educational system is essentially a 6-3-3-4 structure. The detailed organization of this system provides initially for a public elementary school with six grades followed by the compulsory three-year junior high school. Subsequent to these two phases of compulsory school is the three-year senior high school with a general education as well as vocational training orientation. Upon completion of senior high school, one is entitled to admittance to a four-year college.

In recent years high school has become a *secret* compulsory school. In 1980 a total of more than 40% of the Japanese who were gainfully employed possessed a high school diploma (Teichler 1990, p. 56). The percentage has risen continually since the fifties and is probably higher than the 1980 percentage today. Although the proportion of graduates of vocationally oriented high schools actually decreased continually in favor of the general education tract, this held no negative consequences for company recruitment strategies. On the contrary, this produced job trainees possessing a good all-round education (without pre-vocational, specific knowledge) that could then be supplemented through in-house continuing education to reach a high general and specific qualification level. In contrast to the system in Germany (and in some other European countries), the formal vocational training system in Japan is of little significance. Standardized vocational education courses and programs approximating the German model are almost completely lacking. No (official state) curriculum exists for the in-house qualifying measures, and as a rule this vocational qualification training is completed without a certificate.

To Sum up it can be said that the educational basis of the Japanese production work force is the senior high school level which provides the graduates with basic knowledges and skills; the practical experiences and skills are acquired "on the job" within the companies. This constellation brings about three consequences: **Firstly**, in all industrial branches the average educational level is comparatively high, this enables job enrichment, increasing autonomy (of the manufacturing teams), enlarged responsibility (scheduling, logistics, etc at shop floor level). **Secondly**, there is no job definition and demarcation according to fixed vocations as in Germany, but an extremely high flexibility. According to changing requirements workers are re-qualified by companies' internal o-j-t or courses (without any wage losses). There is a continual change in the job structure which is to a large extent enabled by the educational system without a vocational specialization.[33]

The almost complete lack of an external labor market must be regarded as a **third** consequence. This means the acquired qualifications are only of importance within the company (only a small market value) and justify only company-specific demands regarding wages and career.

For an adequate understanding of the connections between the Japanese education and qualifications system and the employment system, it is important to first outline the essential

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[33] The Japanese industry obviously needs such a flexibility of re-qualification and upgrading because of its chronic labour shortage.

features of the labor and employment system. In its ideally typical form, the Japanese employment system rests on three pillars[34]:

- **the principle of lifelong employment,**
- **the seniority principle as well as**
- **the organization of company unions.**

Closely linked to the principle of lifelong employment is the willingness on the part of enterprises to train their employees. The expectation of a lifelong duration of employment makes the investment in *human resources* both profitable as well as something which can be planned for the future of the enterprise. This high level of readiness to provide in-house training is naturally a direct result of the education system, which almost exclusively imparts general education content so that an obligation exists to convey practical job information to the trainee. In this connection, however, it is also clear that the segmentation of the Japanese labor and employment system comes into effect here with the consequence that the company qualification measures (at their maximum quality) principally benefit the core workforce of large corporations - and, according to a generous estimate, this makes up only about 30% of the Japanese who are gainfully employed (Ernst 1990, 23)! The remaining work and employment arrangements outside of this primary labor market segment are spread over a low-level segment, which consists of approximately 10% extremely unstable jobs (employees in very small firms, the self-employed excluding employees, subcontracted labor, etc.), and an intermediate segment which is made up of more than half of the gainfully employed. As a rule, this segment consists of regular employees in medium-sized and small companies that, due to their function as suppliers, are largely dependent upon the prosperity and business policy of their main customer.

Contradictions inherent to the system are revealed through a somewhat differentiated analysis of the Japanese work and employment system. These characteristics are generally forgotten in western global analysis of the eastern miracle; however, they must be adequately taken into account in the assessment of the prospects of APS described here.

With regard to the production organization and performance the Japanese industrial culture has brought out some features like the *kanban*, which enables the just-in-time system, the *keiretsu* system which is a supplier network that was the crucial element for the world-wide success of the Japanese car industry (because it enabled low prices and high quality) and to a large extent also of the Japanese machine tool building. Other important Japanese institutions like the *kaizen* or the system of continual improvement of the manufacturing process contribute to the Japanese industrial culture and thus contribute to the competitiveness of Japanese industry. Obviously the mentioned features are strongly connected with the educational preconditions of the work-force which is at a high level and can be *improved to excellence*.

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[34] Ideally typical here means that the structural elements mentioned are almost not present at all in *pure culture* and can only be found in forms approximating the model in large companies; and even there they only apply to the core staff.

These very brief explanations may, hopefully, have clarified one point: namely, that no positive effects are to be expected in western national economies if isolated elements of the Japanese system which would seem to guarantee success are copied without considering both their integration within the whole industrial culture and their filigree interactions with other structural elements.

The social institutions and government policies will be exemplified by a rough sketch of the MITI policy.[35] As a fundamental difference to the U.S. public industrial policy the Japanese, particularly the MITI initiates and supports inter-firm cooperations. Inter-firm networks are created with the aim of collaborative technology developments, in the case of the Japanese machine tool building the companies were "pushed" by the MITI to specialize on certain machine types. This enabled the 'specialized builders' to gain productivity and competitive advantages (by realizing economies of scale) in their fields. An intelligent and responsible industrial r&d policy that is not exclusively oriented towards basic technology or pure science can cause strong positive effects, but there must be an industrial cultural predisposition for a policy of that kind.

Especially with regard to the educational systems and the qualification level of the work force which are, in our view, both crucial elements for developing and implementing APS. The shape of the Japanese industrial culture provides some starting points for anthropocentric work and technology systems which have to be developed. This is where society and government policy must act supportively. It seems undecided whether the prospects of the industry will be oriented towards anthropocentric systems (in the sense of our suggested categories) or if industry will follow the path of increasing competitiveness by rising flexibility and at the same time keep the "traditional" cultural patterns which are unfamiliar to the category *anthropocentric* in a Eurocentristic sense.

Taken into account the limited appropriateness of our categories and scenarios, the Japanese experts' assessment of the prospects for APS in Japan suggests the following: The present situation of the **machine tool industry** can be circumscribed by scenario 1. The expectations for the future of that branch are positive; the experts expect a development towards scenario 4.

Despite of a group-orientation and possible positive developments towards rising autonomy (of groups) the experts see at present and in the future scenario 1 as the dominating pattern of the **car industry** - the reasons are similar to those given in the German assessment. The present situation of the **electronics industries** were seen as partly following scenario 2, but for the future the majority of the experts expects a changing orientation towards scenario 1 - even without the intensification of group experiments that are expected for the car industry.

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[35] It is currently difficult to assess but one can expect that the Japanese programme on Intelligent Manufacturing Systems (IMS) will similar to many "historical" MITI activities cause positive effects. Future research should investigate in the Japanese industrial policy as a whole and analyze its incorporation into the Japanese industrial culture.

3. Conclusion: In our sample the weakest development of this trend is found in the U.S. The anthropocentric production concept is only given a slight chance of asserting itself even in the future.

In the first place an assessment of the prospects of APS in the U.S. has to take into account some peculiarities in industrial-culturally determined national traditions. The social assessment of work is contrary to Germany and Japan not recognized as the most influential factor for shaping personal identity and subjectivity (on of the probable reasons might be seen in the absence of a vocational training system like the German one and in a differing value system compared to Japan).

A strong influence on the U.S. industrial culture has the widespread and long lasting success of the mass production system which impacted the job definition patterns, the missing awareness of training requirements (according to the logic of mass production jobs are defined narrowly and as easy-to-learn tasks with the result of a "interchangeability" of low-skilled workers) not only in the classic mass production branch like the car industry but also to a large degree in the electronics industry and machine tool building. Consequently the demand for flexibilization of production cannot as (comparatively) easily as in Japan or Germany follow a strategy of relying on the capabilities of skilled workers (who are continually trained).

To a large extent the mentioned factors are interrelated with the American educational system, the underlying orientation was described above as a *human capital approach.* As a result education is always measured in its benefits and advantages for the individuals and only at a second place with regard to its benefits for common (or companies') "wealth". Thus it is very difficult to improve the "qualificational situation" in the companies collaboratively between employers, unions and government, because there is a marked hostility among the relevant groups.

Basically the system of education and training comprises of two elements. The basic and specialized skills necessary for work are provided by formal educational institutions and task-related skills and knowledges are acquired by a narrow o-j-t (basic 'instruction'). Generally the formal level of education is the high school level (85% of workers are high school graduates) with a varying level of competence (lack of mathematics, relatively high share of illiterates and a deficient preparation for learning). Beyond the secondary high school level there is no systematic path of vocational training. High school vocational education is one possibility, college-based programmes another, but both do not reach the efficiency of apprenticeship programmes which are rare in the U.S. There is very little systematic combination of theoretical and practical skill acquiring. Especially the intra-firm o-j-t is very strictly bound to narrow task-relevant skills and not towards general, unspecific and transferable skills. As a result it is very difficult for U.S. companies to meet the (new) requirements of flexibilization, quality improvement and variants production by using (and developing) the skills of the workers.

Instead of leaning on concepts of continual learning most companies are still bound to the (above sketched) logic of mass production with its particular premises and impacts. It was not before the increased performance of Japanese transplants in the U.S. (particularly in the car industry) that U.S. companies changed their strategy. To some extent intra-firm training was increasing, in the first place this new strategy was followed by large companies (in automobile and electronics sector). The smaller companies lack the resources (financial and experience) to develop their "human capital" and there is no public policy providing support for this problem. As a result the nation-wide skill structure of companies is very heterogenuous.

If we draw these interpretations towards a branch-specific assessment of the prospects of APS we get the following findings.

The U.S. Electronics Industries

The focus of the analysis of this section is on the semiconductor industry. Other sector segments, such as the production of consumer electronics, electro-mechanical products and industrial electronics, will not be examined here since semiconductor production constitutes the area of electronics which is most strongly linked to research-intensive basic technologies, a traditionally powerful domain of U.S. innovation and production structures. Because of both the permanent product innovation and the related continual revolutionizing of the manufacturing processes as well as the working conditions in this area, it makes sense to search more intensively for the prospects of APS right here.

In the past decades the U.S. electronics industry went through a quick succession of different phases of technological and economic development. At least the first three developments mentioned, from the vacuum tube to the transistor to the integrated circuit (IC) and finally to VLSI technology (very large scale integrated) were substantially promoted or made possible through the unique innovation constellation: on the one hand, a high innovation level in the companies that (newly) entered this market, or initiated or contributed to the technological wave and, on the other hand, the powerful demand pull for microelectronics by military enterprises. In the 1970s the semiconductor market finally established itself as a mass market. The leading U.S. technological companies were well prepared for this market not least of all by virtue of the many years of military support. Japan entered the market roughly during the second half of the 1970s, concentrated at first on high-volume production (as with the DRAM chips) and later also on microprocessors and microcontrollers as well as ASICs. The decade from the end of the 70s to the end of the 80s witnessed a decline of the U.S. microelectronics world market share from 61% in 1979 to 40% in 1988, while in the same interval Japan's share rose from 26% to over 50%.

> "The competitive decline of U.S. producers in the machine tool and automobile industries has clearly coincided with the advent of new technical conditions and

> organizational alternatives that directly challenged the existing social organization of innovation and production in these sectors. This pattern is repeated in the semiconductor industry where the paradigmatic confusion engendered by the shift to VLSI technology marks the decisive turning point for U.S. firms in relation to Japanese competition. In the past decade, U.S. market shares in key product sectors have plummeted and U.S. firms have experienced a serious decline in technical leadership, one that extends to the semiconductor equipment and materials industry as well" (ACR, 73f.).

At the latest after the development of VLSI, Japan's technological dominance appeared to also extend over the areas of manufacturing technologies of semiconductor production.

> "Recent U.S. government surveys indicate that Japanese semiconductor producers lead in most critical areas of process and manufacturing technologies for future generations of chip technology. Japanese equipment firms controlled 40 percent of the capital equipment market in 1988 (up from 25 percent only five years earlier) and are projected to gain 56 percent in 1993. That is, U.S. semiconductor equipment and materials producers confront the same erosion of basic technological capability and competitiveness as U.S. semiconductor firms" (ACR, 77).

Innovation and Production Processes

> "Production of dynamic random access memory (DRAM) circuits has been the driver of technological progress within the semiconductor industry for new challenges to device technology and manufacturing equipment capabilities are first experienced within this branch and the lessons applied subsequently in the manufacture of other types of circuit production. Economies of scale did not constitute significant barriers of entry to DRAM production in the main period of the semiconductor industry's growth between 1960 and 1980. R&D capabilities were embodied as frequently in a few key personnel as in large, expensive research departments; production systems were not exorbitantly capital-intesive (rapid product change militated against rigid automation strategies); marketing operations were minimal in supply-driven markets; rigorous product specialization and lean organizational structures were compatible with high levels of return. The constant turnover in leading firms and the growth of large numbers of entrepreneurial start-up companies at the frontiers of technological advance testified to the fact that, while scale economies were not irrelevant to semiconductor manufacture, the primary source of competitive advantage lay elsewhere" (ACR, 80).

An important characteristic of semiconductor production is the large degree of uncertainty and openness in handling and implementing operations in premature stages of new product and production design. In addition, the peculiar features which are connected with the specific product must be considered: development of new, highly complex test routines, new and, as a rule, more cost-intensive processes, etc., which is why the semiconductor industry appears to be a learning economy to a much larger degree than in other sectors.

> "Central to all solutions is the constant refinement of process methods and techniques at every stage of each product run and through each design generation of devices. Learning economies express the relationship between unit costs, successive batch runs and accumulated production experience. As learning improves, yields rise, average unit costs fall, and revenues increase while total manufacturing costs remain constant. Learning economies are not a function of market forces; rather they are partly technology-specific and partly firm-specific. A leading position on the learning curve, therefore, provided a powerful basis for medium-term cost advantages over competitors which allowed leaders high profits early in the creation of the new market and to lower prices below their competitors while maintaining higher levels of profitability as others generated volume production of the same device. Leadership down the learning curve also ostensibly facilitated earlier transition to the next generational advance along the technological trajectory"(ACR, 81).

The implications of this fact for the working processes, the organization of work and qualification requirements are analyzed below. Beforehand, an important leap in the development of semiconductors should be briefly discussed: the development of very large-scale integration devices (VLSI). With the advent of VLSI technology the conditions for semiconductor production changed considerably. In contrast to the previous chip generation, the demand for VLSI chips is no longer oriented so strongly and exclusively to the market price. Instead, "system-level circuit performance, design integration and long-term product evolution assume greater significance for customers" (ACR, 83). Customized solutions according to end-user requirements rather than standardized solutions determine the basic conditions for production processes. This results in increased requirements for flexibility and, with regard to the producer, the necessity to work more closely together with the customer and to set up new, cooperative innovation processes. In the following section we will examine to what extent these particular conditions find expression in work organization, work content and qualification requirements.

Labour, Employment, Qualifications in the Electronics Industry

> "U.S. semiconductor firms have relied predominantly upon a bifurcated labor market strategy of labor force formation. That is, fundamental distinctions in workforce stratification in the semiconductor industry market have directly conditioned the manner in which work coordination and the labor process have been organized at the firm and plant level. It is possible to examine semiconductor employment and occupational structure in some detail as indicative of general tendencies characteristic of U.S. industry as a whole, which are in principle antagonistic to the introduction of anthropocentric practices at the shopfloor level"(ACR, 85).

The volume of employment in the whole U.S. high technology industry has grown continually since the mid-60s and by the mid-1980s had more than doubled. For the area of electronic components previously considered such a positive complete picture cannot be drawn. Significant employment expansion, which was unsteady over the course of time, however, increased employment from 264,000 in 1964 to 684,000 in 1984. Since then a wavelike course has emerged with the tentatively lowest level of 603,000 employed in 1990 (ACR, 85ff.). A glance at the occupational structure of the electronics industries illuminates the significance of non-production employees, i.e. professionals of the scientific, engineering anf managerial fields.

> "[A]t the national level, non-production employees comprise twice the employment share of such strata in traditional manufacturing industries while production labor, more than two-thirds of the total labor force in older manufacturing sectors, constitutes less than one-half of all high technology employees (in Silicon Valley itself, less than one-third). Even more striking is the consistent decline in the share of production labor in total high technology employment over time... [W]hile total production employment expanded by almost 50 percent from 1966 to 1986, the share of production employees in total employment declined from 61.2 percent to 44.7 percent. In the labor-intensive components sector, an 18 percent overall increase in production employment in 1966-86 corresponded to a proportionate decline in its share of total employment from 76.7 percent to 54.9 percent.
>
> The erosion of proportionate production labor employment in the semiconductor industry has been gradual rather than precipitious:over time, the demand for technical, engineering and other non-production employees has risen with each succeeding generation of product development and and fabrication equipment."(ACR, 93f.).

The connection between these structural characteristics and the above mentioned peculiarities of semiconductor products and production processes appears obvious. The particularly strong dependency of extensive technical and science-based innovation and production processes of the semiconductor industry upon highly educated and skilled engieering and technical employees guarantees the latter a large degree of autonomy with regard to work content as well as to their position in the external labor markets, which can be attributed to the relative scarcity. The following table gives an overview of the employment structure in the U.S. high technology industry as it appeared at the beginning of the 1980s.

Table 1: U.S. High Technology Occupation Structure: Gender, Ethnicity and Race

	White Female	Minority (Male & Female)	White Male
Production	38.4%	24.4%	37.2%
Technical	15.8%	14.3%	69.9%
Professional	11.9%	8.4%	79.7%

Source: ACR 1990, p 95

> "Compounding the educational gulf between the different components of the U.S. electronics labor force is an equally fundamental stratification based upon gender, ethnicity and race. ...[the above table] clearly disclosed, on the basis of data for the electronics industry as a whole ... that as the hierarchy of skill, status and income ascends within high technology industry, positions are increasingly occupied by white male employees. Thus, whereas white males comprise a relatively small percentage of production workers (37 percent nationally ...) they predominate in technical positions (70 percent nationally ...) and, even more, uniformly in professional (scientific, engineering and managerial) occupations (80 percent nationally ...)"(ACR, 94f.).

To sum it up, the electronics **production** employment is predominantly a female and minority worker's domaine. An analysis of the share of female employees with respect to total employment in the area of production over the last two decades displays a significant increase in female employment and, at the same time, a decrease in the share of production workers with respect to total employment in the sector (ACR, 97). In addition to gender-based segregation of the employment structure, serious ethnic stratification has appeared since the 1970s. Up to the 1970s the share of Hispanics, both male and female, had continually risen and constituted the largest segment of minorities. Since the 70s, however, the proportion of Hispanics fell in favor of Asians, who today represent the largest male as well as female employee segment. Here gender discrimination also follows the familiar pattern: Asian males in technical and professional occupations, Asian females in production occupations. A general occupational pattern can be depicted as follows:

> "Women tend to be channelled into specific occupational categories not only on the basis of gender distinction but, even more critically, on the basis of race and ethnicity.
> The strong representation of Anglo women in high technology labor force over time sustained in part by their almost unique ability to ascend into the upper reaches of the occupational hierarchy in comparatively substantial numbers. The declining proportionate participation of Anglo women at the level of production is offset by their expanded representation in professional/technical employment. Similarly, a high demand, at least in relation to other minorities, for female Asian professional/technical employees is partly responsible for the extraordinarily rapid entry of Asian women into the high technology labor force. The increasing demand for professional and technical personnel, so evident in 1970-1980 in comparison with the preceding decade, is also a proncipal element in the relative labor force decline of Hispanic women, largely excluded from these rungs of the occupational ladder, and the simultaneous rise of Asian female employment. Thus, a certain erosion of gender-based occupational seggregation within the upper reaches of the occupational structure permits important advances for specific groups of women employed in high technology industry, but only at the cost of rigidifying a still more subtle form of occupational seggregation based on ethnicity *within* the female labor force.
> Race and ethnicity, therefore, serve as a primary axis of differentiation for channelling different groups of women *into* specific non-production occupational categories and between production and non-production employment generally"(ACR, 99).

An important characteristic of the composition of employment arrangements must be seen in so-called *permanent short term* employment which at least for the production workers, in particular those in Silicon Valley companies, can be regarded as the dominant pattern (1990). This structural element is similar to the peripheral workforces, as found in Japan. The consequences that might arise for future automation paths and thus for the work contents and organizational structures are reserved to be subjects of future research in the field.

Its (the electronics industry) present situation and its future prospects, are very heterogenuous. Some fields such as the consumer electronics are very similar to the organization of the car industry, i. e. they are dominantly following scenario 1. The situation in the semiconductor and computer industries is different: An important structural pattern is the short term employment, this is a factor that hinders intra-companies' training efforts. Despite of the difference regarding this point there are some similarities with parts of the German electronics industry which is expected to follow (at least to some extent) the 'dichotomization' scenario (scenario 3). According to the experts' assessment the future of the U.S. electronics industries will be oriented towards scenario 1; there is only some minor probability that it will follow scenario 3.

The U.S. Machine Tool Industry

The U.S. machine tool industry, with its main production segments of metal-cutting and metal-forming machines, has undergone decades of far-reaching changes which are easy to understand in light of the available statistical data.

> "U.S. machine tool shipments (in constant dollars) currently have declined to 30 percent of their peak levels achieved in the mid-late 1960's. The U.S. share of world machine tool production decreased from approximately one-fifth in the 1960s to less than ten percent by the late-1980s, with roughly three-quarters of the shipments sold domestically at close of the decade. During the same period, the U.S. share of world exports has dropped from 23 percent (in 1964) to 4 percent in 1986. Sources vary somewhat in assessing the quantitative dimensions of the problem: the U.S. Department of Commerce (January, 1990) estimated that the value of exports in 1989 were approximately one-half the value of imports in machine tool building, while figures presented by the main trade association, the National Machine Tool Builders Association (NMBTA) indicate that in domestic consumtion imports outsrtripped exports by nearly 3:1 (Table). Figure VI reveals a direct relationship between the retreat of the domestic industry and the dramatic increase in the share of imports in domestic consumption which rose from less than 10 percent in the 1960's around one-half by the late 1980's" (ACR, 42). For Table 2.1 and Figure VI see overleaf.

Analogously to developments in machine production, trade and consumption, employment in the machine tool industry (metal cutting and metal forming) displays a decade of continual decline from the end of the 1960s until the mid-1970s. The 1980 maximum of 108,000

Table 2.1

UNITED STATES PRODUCTION, IMPORTS, EXPORTS, AND DOMESTIC CONSUMPTION OF NEW MACHINE TOOLS (a), 1969 TO 1990

(in Thousands of Dollars)

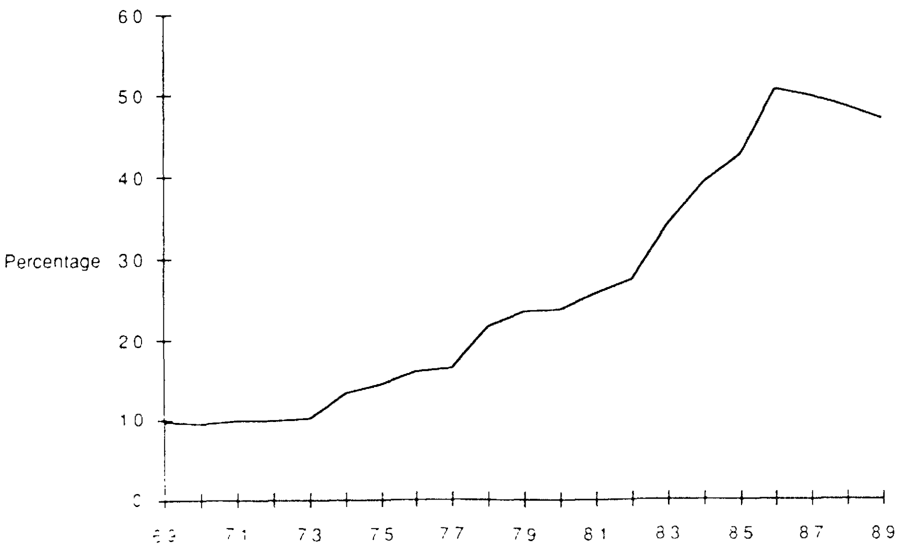
Year	Production	Exports	Imports	Domestic Consumption
1969	1,692,188	242,427	156,122	1,605,883
1970	1,551,777	292,086	131,826	1,391,517
1971	1,057,870	251,532	90,085	896,423
1972	1,269,302	238,135	113,998	1,145,165
1973	1,787,850	325,494	167,057	1,629,413
1974	2,165,937	410,510	270,740	2,026,167
1975	2,406,082	536,659	317,578	2,187,001
1976	2,178,265	514,942	318,304	1,981,627
1977	2,453,423	426,729	400,904	2,427,598
1978	3,142,594	533,094	715,282	3,324,782
1979	4,064,045	619,111	1,043,768	4,488,702
1980	4,812,349	734,135	1,259,802	5,338,016
1981	5,111,253	949,553	1,431,457	5,593,157
1982	3,804,250	574,567	1,217,718	4,447,401
1983	2,144,849	359,037	921,083	2,706,895
1984	2,426,382	373,457	1,318,964	3,371,889
1985	2,682,201	400,453	1,688,693	3,970,441
1986	2,709,800	546,610	2,217,050	4,380,240
1987	2,582,699	586,748	1,968,855	3,964,806
1988	2,858,200	691,025	2,032,052	4,199,227
1989	3,514,200	832,116	2,350,584	5,032,668
1990				

(a) These figures reflect data for machine tools of all values (in current dollars) but do not include the value of used and rebuilt machines.

Sources: NMTBA, The Economic Handbook of the Machine Tool Industry, 1989-90 NMTBA, "Current Industrial Reports, Metalworking Series, MQ-35W," U.S. Department of Commerce Trade Statistics, and U.S. Bureau of the Census, "IM 146" and "EM 522"

Figure VI

Share of Imports in U.S. Machine Tool Consumption: 1969-1989



Source: Calculated from Table 2.1

Table 2.1 and Figure VI quoted in ACR, p. 40-41.

employees was followed by a sharp decline (cuts of approximately one-third) and a slow decline took place from 1984 to 1988 (63,000 employees).

The above mentioned facts and figures sufficiently describe the symptoms of crisis in the U.S. machine tool industry. The diagnoses differ considerably in some cases (Gray 1989). A general agreement exists, however, if it is assumed that the U.S. machine tool industry..

> "...is plagued by an historically narrow basis for technological innovation fueled by defense industry (rather than broader commercial) requirements, suffers from the cyclicity of defense and industrial demand which is only weakly balanced by counter-cyclical strategies, and is crippled by an almost xenophobic domestic orientation of product strategies which leaves the industry particularly vulnerable to short-run downturns in domestic demand.
>
> In addition, the industry suffers from lagging technological innovation. Remarkably, since 1978, the period of the most far-reaching innovation in programmable automation technologies (PATs), the average age of U.S. machine tool stock, in most categories, has actually increased ...
>
> In addition, U.S. machine tool builders are beset by chronic weaknesses in sectoral strategic capacity due to a combination of factors, including fragmentation in production units, and the demand for short-run returns on investment which tend to emphasize quick-fix product solutions to speed revenue flows over more ambitious, longer-term process innovations. Finally, poorly conceived, underfunded, and institutionally weak government policies toward manufacturing industry and technological innovation in general, an dtoward the machine tool sector in particular (including profound weaknesses in education, training and skill acquisition which span the public an dprivate sectors), radically diminish the prospects for recovery" (ACR, 43).

> "It should be noted, moreover, that the industry is not typical in its sectoral organization or its size (given its continued significance as a basic industry which influences capital formation and performance throughout manufacturing industry). The machine tool sector is extremely small and, at the same time, characterized by an increasingly bimodal distribution of firms. Considering the larger scale and more concentrated machine tool building segment of the industry exclusively (and not the myriad job shops or machine shops), according to the most recent figures (based on the 1987 Census of Manufacturers), there are only 435 establishments primarily involved in metalcutting and 217 in metalforming. In addition, firm size is quite small: U.S. machine tool firms average fewer than 150 employees, and register $7 million in sales (some $650,000 of which is based on the sale fixtures, dies, machine tool accessories, and contracted job shop work). Indeed, given its strategic importance, the sector is surprisingly small: based on shipments the industry in its entirety would only rank about 100th in the Fortune listing of individual firms" (ACR, 52).

The small sector size within the manufacturing industry as well as the dominance of small firms within the machine tool sector do not contribute to great innovation capabilities as the final core element for the competitiveness of this sector, which is, to a large extent, dependent upon technological innovations. The, to some extent, misled innovations dynamics of the sector, which until the beginning of the CNC era was expressed, for example, in highly complex control concepts with a rather small degree of reliability, are largely due to the great dependency of the sector on Department of Defense (DOD) and Air Force contracts. The importance of this "leftover burden" has obviously been reduced in the last decades. This reduction then split the enterprises of the sector into those that continued to receive DOD contracts and those for which this was not the case. The latter saw themselves abandoned to the concentrated power of a competition with altered requirements (in innovation and organization), for which their structures, deformed through defense contracting, were poorly suited. This is, however, not to say that defense contracting is a self-service store for the machine tool builders. Rather, we are dealing here with a special area having its own legitimacy and which does not orient itself to the usual rules of market and competition, yet nevertheless also shows signs of crisis.

> "... the inherent cyclicity of defense contracting based on the fundamentally political regulation and determination of demand (a system in the U.S. sometimes referred to as "military Keynesianism") has exposed the U.S. machine tool industry to greater fluctuation in demand than its competitors. The machine tool industry - which is everywhere prone to cyclical fluctuation insofar as machine tool orders are linked to a general pattern of expansion and contraction of manufacturing demand - is therefore chronically hyper-cyclical in the United States. The fact that the largest domestic market for machine tools (and particularly FMS) continues to be the automobile industry (accounting for 40% of total orders booked in 1988 and 1989), with aerospace (commercial and defense) second - both notoriously cyclical industries themselves - hardly improves the picture. This "hyper-cyclicity" (annual or even monthly swings in orders of thirty percent are not uncommon) has chilling consequences for patterns of innovation. It increases risk-aversion considerably, encourages patterns of product rather than process innovation, and leads to marketing rather than engineering or design innovations.
>
> This extremely disruptive and unpredictable pattern of demand also discourages a firm's investment in training programs and system-wide skill enhancement, and destabilizes a work-force which is constantly subject to layoffs and cycles of short-time followed by overtime. As a result there is little continuity in the laborforce: workers are subject to spontaneous layoffs or dismissal, and employers find their most skilled employees will jump to a competitive firm for a marginal improvement in hourly wages or condistions of work.
>
> Finally - and this is most critical from our point of view - the historical ties with defense and aerospace industries and the bimodal configuration of the industry that in part followed from these associations (a few large DoD insiders, a few hundred scattered undercapitalized outsiders reliant on highly competitive abd uncertain subcontracts), have had very serious repercussions for the social organization of production. Simply put, the industry became insular and dependent. Insofar as chains-of-production developed, they tended to bind both large and small producers and job shops to the defense industry, in linear, one-directional patterns and helped orient an industrial culture that was (and remains) very slow to innovate, or appreciate the range and diversity of applications.
>
> There is very weak "user pull" and chains-of-production which consistently engage producers, manufacturers and end-use customers, and which integrate the processes of technology design, transfer, and application are hard to find. Apart from DoD/large

builder connections, there are, for the most part, few ongoing patterns of cooperation. Rather, the industry pattern for most part involves ad-hoc cooperation (if any) between machine tool builders and the producers of controllers. For the major U.S. controller manufacturers, the sales of NC equipment to machine tool builders represents only small part of their electronics production and, unlike their Japanese counterparts, U.S. controller producers - who hardly ever produce machine tools themselves - have no direct experience of the builder's needs (Sciberras and Payne, 1985), much less the end-user requirements. Hence, apart from some recent joint ventures (e.g. between Fanuc and GE), there is minimal coordination between machine tool builders and controller producers, and little "pencilling backwards" of end-user requirements to generate new designs and process applications" (ACR, 55f).

Product and Production Strategies

"In fact, the U.S. industry displays a range of unconnected and not particularly parsimonious or re-enforcing product/production strategies. The unpredictability of markets within the competitive sector (as distinguished from the DoD-oligopolistic sector of the industry) tends to encorage non-standardized competitive strategies. Producers of machine tool components tend to apply low scale, high variety (and high precision) non-standardized production and are, therefore, characterized by small batch production strategies. Job shops tend to be constrained by a set of exacting circumstances: undercapitalization which limits their technological options and localized highly competitive demand structures which encourage narrow specialization in product scope for small and short-term competitive advantage. Thus, the job shop sector is divided between specialist craft work and volume batch production strategies, whith individual shops often vacillating between the two strategies in reaction to customer requirements.

In the more oligopolistic machine tool building and controller producing sub-sectors, the high volume, general purpose markets have effectively been ceded to the Japanese outright or indirectly through licensing agreements. As the origins and development of machine tool building in the U.S. would suggest, the more successful firms rely on high precision, customized equipment and systems intended to meet the demand of aerospece, defense industry, and automobile manufacture. Thus, U.S. firms are competing more within a German than a Japanese strategic orientation: standardized batch production and diversified mass production. However, U.S. firms lack the specialist range of their German counterparts since they tend to be confined to a narrow range of customized markets. Nevertheless, rigidities, strategic incapacity, and the reliance on pure technical virtousity and excessive sophistication continues to plague U.S. firms who lack the necessary chain-of-production linkages which make coherent, rapid and innovative are caught between the new standardized methods of machine tool production pioneered in Japan and the German strategy of manufacturing a wide range of high precision general-purpose and special-purpose equipment for a broad range of industrial applications.

Similarly, U.S. machine tool builders' lack of experitse in electronics has been compared unfavorably with Japanese integration of information technology in machine tool processes and products (OTA, 1984). A National Academy of Engineering study (1983) concluded that U.S. machine tool companies "are frequently more sluggish in

> the design and adoption of new production technologies than many of their overseas competitors". As a result, control systems tend to be marketed as "add-ons" to discrete equipment, and are seldom designed for specific types of machine or manufacturing functions. Control systems manufacturers, on the other hand, appear to have little understanding of, or experience with, the needs of machine tool firms: the National Academy of Engineering has asserted that U.S. producers fell behind Japanese competition in part because control systems producers imposed outdated and inadequate concepts upon machine tool builders (National Academy of Enigeering, 1983)" (ACR, 59).

Key Elements of Enterprise Organization

The above attempted characterization of the sector depicts the general conditions for the organization of the enterprises, which will be analyzed in the following section, for the most part along the dimensions of plant level coordination of operations and work design, with regard to their anthropocentric potential. In the analyses, however, we must take into account the circumstances that

> "in the U.S. machine tool sector, weak industrial cultural expectations about the role of direct manufacturing personnel in the broader manufacturing process, tendencies to resist expansion of job responsibilities where trade unions are present (Kelley, 1988), and traditions of hierarchical and often bureaucratized command structures particularly in multi-plant enterprises (Thomas, 1987), influence the concrete workplace and firm-specific histories of enterprise organization. These factors are crucial in structuring the plant-level outcomes in enterprise organization which frame our discussion in this section" (ACR, 60).

Of particular importance for the analysis of plant level coordination of operations is a differentiation according to enterprise size because the resulting variables reveal significant differences. The small and medium-sized enterprises of the U.S. machine tool sector are mostly family firms that were often founded by engineeers. They are characteristically union-free and have no seniority systems or labor management committees.

> "The cost of investment in new technology and worker retraining in such enterprises is one of the principal reasons for the relatively slow diffusion of computer-based machine tool technologies in this sector" (ACR, 60).

> "In the larger, nearly oligopolistic stratum of machine tool enterprises (particularly machine tool builders and controller producers), more formal organizational structures and co-ordination controller producers will be contained within conglomerate enterprises (whose financial interests are driven by developments in other industrial sectors), re-enforces the tendency for multi-plant enterprises to conform to more complex patterns of enterprise organization. These developments are, in turn, re-enforced further by the presence of credentialed professionals in production control functions, the increasing balance away from manufacturing in the favor of system-wide information and coordination funcions, and the requirements of very high expenditure

> in sunk costs well in advance of any revenue flows from new technological innovation (a pattern which is especially pronounced in the case of FMS). All these developments encourage both a clearer demarcation of responsibilities at the plant level, and more direct financial supervision and coordination at the level of divisional or headquarters management" (ACR, 61).

> "More typically, in the near-oligopolistic machine tool sector, existing survey data suggests that the professionalization of production management, alongside the proliferation of multi-task or systemic technology configuration, encourages decentralization of control (Kelley, 1988) and the compartmentalization of operations. Thus, in the larger firms and, particularly, multiplant firms and conglomerate enterprises involved in machine tool building and controller production, we find the increase in organizational division of labor and a redistribution away from manufacturing of machine purchase, scheduling, and control functions that comparative research within CAPIRN has anticipated (Hildebrandt, 1989). Compartmentalized co-ordination of operations tends to prevail and with it there is a decline in the importance of personalized networks, informal communication, and fluid experience-based operational decision-making" (ACR, 61f).

Work design

In accordance with the initially presented definition of work design, it is not sufficient to discuss work content by exclusively using the key words of *monitoring* and *programming location.* Rather, autonomy, responsibility and decision-making scope as well as self-determination capabilities of workers (and groups) must be made the basis of the assessment.

> "From a social-organizational perspective, therefore, the crux of the matter is the way in which responsibilities for direct manufacturing personnel are allocated, how narrow the areas of responsibility may be, and how accessible to the manufacturing personnel is knowledge of the production system" (ACR, 62).

Nevertheless, the analysis also has to consider the question of programming responsibilities. It seems common sense that among technological conditions particularly organizational and internal labour market structures are of importance.

> "It is not surprising, for example, that the complexity of programming biases the locus of programming responsibilities. In sheet metal work which is less complex than metalcutting, shopfloor workers sometimes rotate though the off-the-floor programming department, for example, and programming by first class machinists for work on lathes (which is technically simpler) is more common than on mills. Similarly, recent evidence suggests that on newer generations of CNC machining, since the programming is simpler and more standardized, the diffusion of programming responsibilities tends to be greater. In addition, the combination of programming with direct manufacturing responsibilities seems greater with customized production in very small batches..." (ACR, 62).

The organizational complexity of an enterprise appears to be especially important for the question of the programming (horizontal and vertical division of the programming tasks and programming locus).

> "The size and complexity of firms largely explains why control over programming is decentralized in some workplaces and not others. Small single plant enterprises...are workplaces where programming responsibilities are most likely to be decentralized. In such workplaces, the chances that machining occupations will include major program-writing responsibilities are better... The larger and more complex the organization, the greater the pull towards centralization of control over the technology...
> If organizational size and complexity were the only determinant of job design, the majority of machining workers presently employed in large multi-plant enterprises would stand little chance of ever having their jobs upgraded by the addition of major programming responsibilities. But the development of new institutional arrangements and the evolution of the technology itself may counter this bureaucratic imperative" (Kelley 1990, 202f).

However, besides organizational complexity, the existence of the seniority principle as well as of union representation in the enterprise influences the job design strategies of management. A recently conducted study brought the following observations to light:

> In nonunion workplaces with no seniority system, the chances of blue-collar programming are higher...than would occur if all NC vintage technology were eliminated" (Kelley 1990, 201).

If there is a union representation in a company the prospects for blue-collar programming are poor and if both unions and seniority system exist, the chances for programming in the production area are even worse (Kelley 1990).

> "It should be emphasized that in the U.S. machine tool sector and in metalworking more generally, the values for the allocation of work tasks (defined in terms of the seven shop floor variables discussed above, including operational time structure, spatial mobility, level of task qualification, etc.) are decidedly technocentric and the machine-user interface is highly standardized, quite inflexible, and opaque. More "democratic" and interactive interface designs, for example, conversational CNC, are almost uniformly rejected as a "toy" or "a waste of time" which undermines efficency, and only in relatively few cases does management permit programs produced on the shop floor (or major edits) to be placed in computer storage as the basic parts program. The diffusion to selected blue collar personnel of programming responsibilities changes nothing basic in the work design" (ACR, 63).

> "For the vast majority of direct manufacturing personnel, responsibility may be limited to the monitoring of a CNC machine tool, supplemented by some subsidiary responsibility on a conventional machine (e.g. deburring), and a quality control function which can be very absorbing when the work is performed to very exacting tolerances. In addition, there is a broad continuum of responsibilities beyond the monitoring operations which may, at management discretion, be assigned to a machinist/machine operator, which includes: set-up, debugging of programs, the changing or replacement

of small cutting tools, the entering offsets or minor edits in the parts program, etc. The distribution of the more privileged programming or systems responsibilities, as well as allocation of the lesser upgrades to basic machine monitoring duties by management prerogative, however, simply underscores and, in a sense, deepens the command structure of work design.
In addition it should be noted that the introduction of FMS (which, as we shall discuss below, is only weakly diffused in the machine tool sector), has only ambiguous consequences with regard to the anthropocentric possibilities of work design. With the introduction of FMS, the PA process (compared to that of the stand alone CNC) further attenuates the connection between the operator and machinery as the level of complexity in problem solving is at least an order of magnitude greater than that associated with the operation of a machining center" (ACR, 63f).

"As the above analysis makes clear, although disparate elements of human-centered work experiences exist within this command structure, there are few indications that the model of diffused work design which is the pre-requisite of both human-centred autonomous subsystems and anthropocentric organization can be found within the machine tool industry or the broader metalworking sector..." (ACR, 64).

"As the discussion of Product/Production Strategies and Enterprise Organization suggest, the much-heralded "collapse" of the machine tool industry - defined in terms of declining competitiveness, lagging technological innovation and adoption, weak definition of international market niche or product-specific comparative advantage, parochialism which focuses counter-cyclical competitive strategies more on rebuild services than on foreign demand structure - is equally significant in social-organizational terms. From our perspective, it is important to stress that these deficits in innovation and competition follow critically from the weak articulation of production chains, and the consequent absence of interactive design culures an dmeso-organizational mechanisms for forging connections among technology design, transfer and use and between PA vendors, manufacturers, and end-users" (ACR, 65).

"In the end, in the machine tool sector, even human-centred autonomous subsystems are extremely difficult to find, much less thorough going anthropocentric production systems which crystallize diffused work design, integrated co-ordination of operations, and multi-task technology configurations in the most advanced, holostic and comprehensive social organizational restructuring of the enterprise. Sadly, while a fascination with technological virtuosity has contributed, ironically, to the collapse of the machine tool sector (by contributing to a weak articulation of chain of production connections between commercial user needs and builder design), the situation with regard to social- organizational innovation is far worse. When it comes to social an dorganizational issues, only low-end solutions abound, and (apart from U.S. firms involved in joint ventures) there seems very little interest in innovation of any kind" (ACR, 66).

The U.S. Automobile Industry

> "The U.S. automobile industry constitutes the classic instance of mass production logic based upon the deployment of specialized machinery to manufacture standardized goods with unskilled and semi-skilled workers in a fragmented and hierarchically organized division of labor with high levels of mechanization" (ACR, 106).

The automobile industry is one of the largest industrial sectors in the U.S. today. Employment in this sector suffered a decline of 13% in the past decade (1979-1989) from a high of 990,000 employees to 855,000 employees. During the same period vehicle production sank from 8.4 million units in 1979, after a temporary increase in 1984/85, to 7.1 million units in 1988. The U.S. auto manufacturers' share of world production sank from 79.5% in 1950 to 25.4% in 1980 (ACR 119). Imports went from 3.0 million units in 1979 to a level of 4.4 million units in 1988.[36] The competitive situation of the U.S. automobile industry is much more favorable than, for example, the machine tool sector. Since the late 80s the *after Japan* learning process has borne its first fruits. Thus today, after dramatic losses in the share of world auto production in past decades, a recovery and partial reconquest of market shares is indicated (Dertouzos et al. 1989, 174) for the U.S. auto industry. Although it must also be noted here that the number of Japanese transplants rapidly increased and continues to increase (estimated at one-fourth of North American production in 1991) with very ambivalent effects which we will speak about later.

The production system that prevailed in the automobile sector until far into the 80s (some characteristics of which are still in effect today) has its historical roots in the 1920s. The foundation of the so-called *American System of Car Building* can essentially be found in Ford's assembly line methods of producing standardized mass products. This basis was, however, refined by Alfred Sloan's (General Motors) approach of decentralized corporate organization and market diversification (broad product range and annual model change) (Dertouzos et al. 1989, 175f.; ACR, 106f.).

The production concept of the American system is based for the most part on the interchangeability of parts produced by special-purpose machines under conditions of high work standardization.

> "Traditionally, U.S. auto firm product design was oriented to the most sophisticated technical solutions compatible with a mass production logic while process design focused on the optimal mechanization and rationalization of work compatible with market trends. Over time, however, it is clear that the inertial tendencies of manufacturing specialization inevitably in history's economically most successful form of production organization have favored process over product design, and scale over scope economies, within the U.S. auto industry. The essential rigidity of the classic mass production system - even minor changes in product design might render extensive capital investment obsolete - is such that Sloanist commitments to the primacy of the

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[36] Two-thirds of the imports originated from Japan, app. one-third from Europe (Dertouzos 1989)

> market and substantive product diversification rapidly and easily degenerated into the essentially illusory cosmetic variations..." (ACR, 110).

Combined with this *cosmetic* form of product variation, there is an interest in achieving a relatively broad product range ("for every purse and purpose") on the basis of an unchanged basic model with as many identical standardized parts (economies of scale) as possible. This strategy corresponds to product development cycles, which are on the average twice as long as Japanese cycles (Jones 1990). We see a decisive influencing factor for product development processes that also differ in quality (for example, generally higher design performance in Japan: fewer engineering hours with shorter lead times) in the specific organization of product development processes. The *American model* essentially proceeds sequentially, i.e. a number of discrete steps (for example, product design, product engineering, process engineering, etc.) which are centrally steered and each step is assigned to a set of experts (within different departments).[37] This linear, sequential progress prevents the integration of process elements which belong together (for example, process engineering and quality control) and which, in line with the above outlined *simultaneous engineering* for the production of synergetic effects, must be handled simultaneously and in a holistic manner.

As an explanation of the above, it must be noted that generally the interests of engineering in U.S. automobile factories usually are still aimed at process design rather than product design. With regard to content, process design predominantly searches for **technical solutions** for the various problems of manufacturing (production scheduling, quality assurance, etc.).

> "This technocentric strategy tends to restrict the industry's market range and weaken its competitive position ingrowth markets (Flamm, 1988) in comparison with the less purely technologically-oriented approach of Japanese and European producers" (ACR, 112).

The realization that it is necessary to comprehend certain problem areas of production, like production scheduling, as organizational problems and thus to search for integrative solutions (that is, production systems as a unity of technical, organizational and work parameters), and not primarily technical solutions, is emerging only very gradually.

> "Strategic reorientation at the level of the firm is focused upon the acquisition and diffusion of embodied technology within essentially unchanged organizational parameters: indeed, implementation of new technologies is commonly considered an *alternative* to organizational change (National Academy of Engineering, 1983; Dertouzos et al., 1989). Within production, new technologies are principally employed to rationalize central coordination of routinized production processes, improve scale economies, expand global business organization, and to effect labor substitution (Graham and Rosenthal, 1986; Flamm, 1988). The application of new technologies tends to be oriented to a relatively marginal enhancement of scope economies within the traditional model of standardized production: while the variety of parts made with the

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[37] By contrast, Japanese product development is organized along inter-departmental project teams and thus transcends traditional intra-departmental decision-making borders.

> same equipment is expanded and final product differentiation widened, the application of flexible machinery remains highly circumscribed. The powerful inertia of the mass production system tends to favor use of automation to perfect design standardization, further specialize machinery and lenghten production runs" (ACR, 112).

The Supply Chain

The manufacturing process in the U.S. automobile industry is divided, as in other countries, into a network of suppliers who supply the assembling company with parts. The outstanding feature of the typical production network for U.S. automobile manufacturers is the principle of *single sourcing*, i.e. only one supplier for each part, and the relationship between supplier and assembler is exclusively price-oriented. This rules out, in particular, long-term relations which could make it possible for the suppliers to extend their function as *executing work bench* in favor of active participation in the design process.

The supplier-assembler networks comprise, as a rule, between 1000 and 1500 suppliers (in Japan between 300 and 350 on the average) that usually receive detailed specifications for components from the assembler. The specifications also stipulate defect rate data and can, depending on how closely the assembler works according to the principles of J-I-T production, also include very precise data for the scheduled date of delivery. This chain of production also follows the sequential process pattern illustrated above, i.e. an internal design and specification process at the assembler's plant follows the external assembly production at the supplier's.

As a result of this clear division of functions, the information flow is kept to a minimum. The goal then is to leave control over the whole process to the assembler. The suppliers are excluded from the innovation process and cannot, as already mentioned, influence product design. Such distinctive structures do not permit the suppliers to add their manufacturing experience to the innovation process, which might be advantageous for product quality (as the Japanese model shows). Moreover, the structures illustrated prevent the development of innovation capabilities by the suppliers (ACR, 119; Jones 1990, 11ff.)

The relationship between the assembler and supplier is increasingly undergoing a change, not least of all as a response to the success of Japanese transplants *across the street*: the assemblers are attempting to reduce the size of the supplier pool, make long-term subcontracts with the suppliers, intensify the information flow with suppliers and, finally, implement cooperative efforts in product design, too, beyond the scope of bureaucratic relations. This strategy may contribute to an improvement of the innovation capabilities of suppliers as well as of the product quality and cost structure of assemblers, while at the same time leaving the underlying dependency and monitoring relations untouched.

> "There exists remarkably little empirical analysis of the relationship between new technologies and changing work organization in U.S. auto plants, and the few existing studies tend to portray conflicting interpretations of current trends. With respect to the areas of materials conversion and assembly, it would seem that existing trends towards increasingly specialized machine applications are generally being reinforced (Walker, 1989). Even where U.S. firms utilize more flexible technologies (FMS), they tend to be used in a more specialized manner than their Japanese competitors (Jaikumar, 1986). CNC machine tools are still diffusing relatively slowly in the U.S. auto industry and research on the location of programming responsibilities in a sample of manufacturing plants generally indicates that, in vast majority of instances, workers receive no programming responsibility at all (around 25 percent of cases) or share responsibility with off-floor programmers and managers (45 percent) (Kelley, 1988, 1989). Thus, pure Taylorist deskilling is only one option employed, but the predominant intermediate form of shared programming responsibilities tends to limit workers to relatively minor and routine interventions, leaving actual control further up the hierarchy. Some requalification is acquired in these circumstances but management strategy focuses nevertheless on increased labor productivity through the application of technology rather than on genuine flexibility and human-centred production" (ACR, 114).

> "The structure of U.S. manufacturing automation market indicates that the pincipal locus of automation to date has been less in the substitution of computer-based technologies for direct labor than in the tasks of materials transfer (the movement of material and components between work stations and plant locations) and production integration or the coordination of the various manufacturing sub-processes. Almost one-half of the total market consists of automated equipment for materials handling (20 percent), process control (12 percent) and manufacturing resource planning (MRP) (15 percent) as opposed to machine tools (21 percent), programmable controllers (3 percent), CAD systems (7 percent) or robots (2 percent) (Kerr, 1985). That is, firms are increasingly utilizing computer-based technologies to automate coordination and information flow (as opposed to the automation of individual tasks) and to seperate these from other tasks in the plant-level division of labor" (ACR, 115).

The relatively low average degree of automation in direct production (compared to Japan) does not, however, exist in a causal relationship with low productivity and flexibility. It appears more likely that the type of automation technology and the type of application determine the performance (productivity and flexibility) to a greater extent than the level of automation. Jones (1990,5) points out that the most successful U.S. auto companies were able to close or reduce the gap to the transplants in a manner that was relatively independent of the level of automation. The critical variable in the improvement of productive performance, therefore, appears to be work organization. In the best-practice GM plants (particularly in the U.S.-Japanese joint project, NUMMI), the formation of *work teams*[38] was, along with other efforts to implement the

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[38] The establishment of work teams requires training efforts as a supplementary measure to enable the workers to do all jobs connected with their area.

principles of *lean production*, especially successful in achieving higher overall performance (Jones 1990,7). With the introduction of work teams, the traditionally dominant Taylorist system of precise and narrow job definition becomes obsolete; in the NUMMI plant, for example, 100 existing job classifications were reduced "into a single job classification for multiskilled workers" (Yoshida 1989, 12). Despite this, however, the share of the U.S. auto labor force included in work teams is very small (less than one-fifth) (ACR, 111). The common practice in U.S. auto plants still appears to be different:

> "Job classifications are specified in exacting and copious detail, a strategy that meshes well in fact with the concerns of scientific management for the one best form of task organization. Since wages also are tied to jobs and not to individual workers, the job classification system focuses worker attention on specific positions (or, at best, on the cascade of individual slots that open up under seniority rules when even on eworker leaves his or her existing position) an dremoves workers and their representatives from other areas of managerial prerogative in the workplace. The definitive, formal separation of tasks specializes workers and jobs from each other and makes it difficult to establish the kind of job re-unification required for enhanced production flexibility. Training systems also tend to focus on narrow job training, as opposed to occupational training in the broadest sense, which, given their restricted ambit, tend to fact to consolidate occupational deskilling over time as workers are unable to adjust to new formal or informal skill requirements" (ACR, 117).

The dominating specific job classification structure was thus stabilized to the extent that it could be used by the industrial partners as an "objective" basis for wage negotiations, etc. In summary, the job classification system must be regarded as one of the most important obstacles to a reorientation of the organizational structure (on different levels of the enterprise) as well as to task definition and allocation.

> "[The] relatively rigid structure of job classifications, work rules and seniority-based career mobility severely constrains any rational project for the creation of more flexible work organization, forcing both capital and labor into largely sub-optimal adjustments that attempt to compensate for these blockages. In order to establish more flexible forms of production, it is necessary for *management* to be able to re-define *individual* tasks and work stations and for *labor* to acquire decision-making powers and authority with respect to the organization of the production process *as a whole*. The prevalent U.S. system of industrial relations locks both management and labor into a form of conflict that provides each group control over the terrain most neededby the other" (ACR, 117f.).

Nevertheless, there are increasing attempts by auto manufacturers to make job design and work organization more flexible, thereby coming closer to principles of *anthropocentric production systems*. Through quality of work life and similar programs not only are work teams established, attempts are also being made both to make organizational structures less hierarchical and to carry out task redefinition. None of these measures, however, has gone so far as to question the principle of the assembly line in favor of group work or the system of fragmented procedures. Japanese transplants are of special importance in this regard:

1. They proved (especially the NUMMI experience) that it is possible to approximate the Japanese level of performance if under certain, essentially unaltered *industrial-cultural conditions* (in the case of NUMMI with the same labor force - however, with new qualification strategies) central principles of the *Japanese System of Car Manufacturing* are implemented. Moreover, this also demonstrates that the problems of the U.S. auto industry are less technological and more of a structural, organizational - and, therefore, essentially industrial-cultural - nature.
2. They compete for market shares that are traditionally controlled by the U.S. auto plants, yet at the same time are a kind of *creative challenge* to the U.S. plants and their production concepts. In particular the fact that the Japanese best-practice transplants are located, as it were, *on the other side of the street* proves that under the basic conditions of U.S. industrial culture it is possible to implement work teams, cooperative organization models, broader task definition, good communications, etc. and thus take a small step towards anthropocentric models of production.[39]

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[39] The geographic proximity of the best-practice examples, furthermore, seems to present a much greater challenge to U.S. car producers than *reports from distant countries*.

4. Conclusion: The Australian industrial culture is amidst a dynamic process of transforming and reorganizing its productive structure. There is some evidence that the evolcing production culture will be more strongly oriented towards APS. An outstanding significance is assigned to Australia as atechnology adopting country.

At first glance Australia does not quite appear to belong to the group of highly developed, high-tech producing countries examined in this study. On closer view one realizes that, in spite of the great geographical distance from Europe, Australia is really not so far from some European countries in a political and industrial-cultural respect. With regard to important industrial-cultural determinants, Australia shows strong affinities to Central European countries (for example, in its dual vocational education system with similarities to the German and Danish systems as to scope and structure).

The excerpts from the Australian country report documented below gain particular significance in their reference to a recently initiated policy of revitalization of the Australian industrial base. This is a process on various levels and in various areas of policy aimed at, among other things, structural improvement of industrial performance, skill formation structure and the raising of innovation capabilities.[40]

> "Australia is currently in the throes of a radical attempt to transform its skill formation system and revitalise its industrial base. Led by the Australian Labour Party with three consecutive turns of office, and strongly supported by sections of the trade union movement (most notably the Australian Metalworkers Union) and the business community, a series of initiatives have been established to transform Australian manufacturing into a dynamic high-skill, high-quality and export oriented sector of the economy. At the level of technology policy there has been a development through the 1980s from an emphasis upon revitalising mature industries and encouraging 'sunrise' industries, to a focus on the building of a 'productive culture' with emphasis on vertical or sectoral policies to establishing industry-wide preconditions for international competitiveness, and more recently to the problems of fostering a strong international orientation in a 'small' industrial country.[41] In the area of skill formation there has been a four phase development of initiatives to support the greater orientation towards high quality international competitive manufacturing through changes in the conditions

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[40] This section does not completely follow the preceding in structure and content: here emphasis is placed on the description and anlysis of Australian culture within the culture/industrial culture in order to work up approaches for assessment of prospects for APS in Australia. Sector analyses are not undertaken in accordance with the sections on Germany and the U.S. because the country report used as the basis concentrates more on the institutional and political elements of the constitution of industrial culture and leaves out here the particular features of Australia as a technology-adopting country. The following sections go beyond sector analyses in documenting important results of the political, institutional, industrial-cultural macro-structures. These can be of particular value for both a world comparison as well as for future industrial policy and educational institution options and strategies within European countries possessing a comparable profile.

governing wages, job classifications, career structures, and skill provisions. This has been characterised in Australia as a move towards a 'managed decentralism' from a previously highly rigid and centralised craft based system.[42]

Some of the conditions in Australia, apart from a conducive political climate, support such initiatives. Despite recent falls in its relative standard of living, Australia is still an affluent country. In 1989 it invested approximately 1.2 % of its GNP in R&D, representing a moderate growth from 1.12% in 1983 assisted by government incentive schemes. Since 1982/3, the manufacturing sector has gradually expanded and increased[43] its relative role in merchandise export earnings from 53% to 55% between 1982/3 and 1988/9.[44] This has occurred with a relatively static workforce of just over 1 million people, and a comparatively strong 16% increase in real value added per person during the period 1982-7.[45] The level of productivity has consequently been increasing gradually, assisted by an increase in investment over the period from 1984-9 (primarily in plant and equipment) of 13% a year.[46] The educational system has a developed research base producing approximately 2% of all the worlds scientific papers and with international prominence in a number of areas. This sector also performs an important function in educating a significant number of graduates and post-graduates from a number of Pacific and Asian countries. Moreover, the country has an extensive training system, with a dual system of apprenticeship, third only to Denmark and Germany in its coverage of the workforce... This increased the proportion of apprenticeships amongst skilled tradespeople from 63% in 1970 to 95% in 1983.[47] From a social point of view, the country is highly unionised with over 55% of the workforce covered by unions and there is an extensive welfare state system including a public health system and relatively low cost access to universities. The country has also operated as a stable and successful democracy since its transformation from a former British colony, and in the recent period of the Labour government has developed a style of consensus politics that includes government, business and unions in peak industrial

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[41] See in particular the outline of these developments in Centre for Technology and Social Change, 1990, **Technology Policy for the 1990s: Lessons of the 80s**, Report for the Department of Industry, Technology and Commerce, AGPS, Canberra

[42] See the discussion in Curtain, R. and J.Mathews, 1990, 'Two Models of Award Restructuring in Australia', **Labour and Industry**, 3,1., pp.62-3

[43] This growth has not, however, been uniform across manufacturing industries. Five industries experienced growth in value added of over 30%, and nine industries less than 10%. The group of industries with the fastest growth rates contain a high proportion of food and fibre processing industries. In those industries producing largely elaborately transformed products, growth rates are slightly above the average for 1984/5-1986/7. The important Industrial Machinery and Equipment and Motor Vehicles and Other Transport equipment were below the average. More recently, the automotive industries have shown signs of improved development.. Overall, however, it is apparent that Australian manufacturing appears to have made little significant movement into higher value added activities..but has been characterised by a significant decrease in labour intensity

[44] Centre for Technology and Social Change (1990), **Technology Policy for the 1990s: Lessons of the 80s**. Prepared for the Department of Industry, Technology and Commerce, AGPS, Canberra, pp.12-13

[45] See Badham R. and Wilson, S.,(1991 forthcoming), **Computers, Design and Manufacture**, Department of Industrial Relations, AGPS, Canberra

[46] Centre for Technology and Social Change (1990), **Technology Policy for the 1990s: Lessons of the 80s**, op.cit., p.15

councils such as the Economic Planning Advisory Council (EPAC) and the Australian Manufacturing Council (AMC).

In addition to these advantages that assist in the social modernisation of the economy, Australia also possesses a set of strong disadvantages. The history and current structure of the Australian economy reveals a strong dependence upon raw material and agricultural exports, a high level of multinational penetration of key sectors (second only to Canada in the OECD countries), and a largely inward looking, fragmented and protected manufacturing sector. After a long period of rising living standards leading to a common view of Australia as the 'lucky country', these structural conditions resulted during the 1980s in a large and increasing national debt and a negative and declining balance of trade. As revealed in Tables 1 to 5, as the share of manufactures in world merchandise trade increased rapidly during this period, the growth in Australia lagged far behind.[48] This phenomenon is even more dramatic once it is recognised that 65% of Australia's largest manufactured exports in 1986-7 were low-value added, resource-based commodities, and the relative value of raw material and agricultural goods has declined compared to manufactures. Half of Australia's exports in 1987 were unprocessed commodities; another 10 per cent could be classified as 'simply transformed manufactures' such as processed food and mineral goods. Only 10 per cent of exports could qualify as 'elaborately transformed manufactures (ETMs) which now dominate world trade.[49] Moreover, in terms of international standards of 'best practice', Australia also ranks relatively low. Although there has been a gradual increase in productivity, this is below the OECD average and begins from a comparatively low level. In terms of the introduction of new computer based technology, Australia also ranks relatively low in comparison to other OECD countries.[50] In addition, on grounds of 'quality', a key source of international competitive advantage in the contemporary era, there are indicators that Australia is also comparatively weak.[51]

In the face of such problems there have been a series of government reports and initiatives in Australia aimed at rationalising and revitalising 'mature' industries and stimulating new 'technology based' industries. Yet the condition of the manufacturing sector places severe restrictions on such initiatives as it is characterised by relatively high levels of protection and an inward looking orientation towards a relatively small home market, with exports strongly biassed towards simply transformed resource based

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[47] Pappas, Carter, Evans and Koop (1990), **The Global Challenge: Australian Manufacturing in the 1990s.** Report to the Australian Manufacturing Council,

[48] Centre for Technology and Social Change, op.cit.,

[49] Pappas et.al., op.cit.

[50] ibid., p.69

[51]. See Pappas et.al., op.cit. p.61/2

goods and the low growth/low value added end of the manufacturing spectrum.[52] The result is that Australian manufacturing is highly diversified, consists of relatively small firms and has a low level of technological innovation. From 1982-7 the number of establishments only declined slightly from 42,700 to 41,000, and.of the establishments employing over 4 people, the average firm only employs 35 people and has a turnover of $4 million dollars.[53] On measures of R&D intensity, rate of innovation, patent intensity/balance, and trade in technical know-how and technology intensive products, Australia ranks low in comparison to other OECD countries.[54] Where higher levels of R&D and more elaborately transformed products exist amongst Australian based branches of multinationals, this is both less impactful on stimulating further development in Australia and less so than if they were domestic.

The result is that Australia could be appropriately defined as a primarily 'technology adopting' rather than 'innovating' country. This is exemplified in four sets of characteristics. Firstly, as illustrated in Table 6, it has a relatively low level of R&D, even when compared to other 'small' OECD countries, and government R&D is a relatively high proportion of this amount. Equally seriously, however, Australian manufacturers have a relatively low level of R&D spent on the selection, acquisition etc. of new technologies, while managers have both an overly complacent and primarily defensive cost-cutting approach to any improvements in this situation.[55] This situation is reflected in the comparatively low proportion of engineers in the workforce, with 50% that of Canada, 52% that of Japan and America, and 60% that of the U.K.[56] The response to this cannot, however, be limited to changing management attitudes or increasing the supply of engineers, for as one recent comprehensive report of the Australian situation observed, supply and demand in this area is roughly balanced, given the existing nature of manufacturing products and competitive strategies.[57]. This leads us to two more conditions expressing and influencing Australia's 'technology adopting' status, firstly the general lack of firms producing high technology and medium technology products, and a relative absence of export oriented high value added international competitive industries that could stimulate dynamic 'industrial clusters' which demand and inspire high manufacturing standards from suppliers and each other.[58] This absence of export oriented manufacturing 'development blocks', as they

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[52] This is a clear reflection of a history which originated in the services provided to the agricultural and pastoral industries, followed by gold and rail. During the 1940s it was given a substantial boost by the need to develop local capabilities during wartime. In the post-war period it underwent a period of expansion, closely linked to the automotive industry, oil refining and chemicals, and the development of public utilities. In the mid 1960's the 'resources boom' provided a further market for heavy equipment. In 1982/3, however, manufacturing industry experienced a dramatic downturn with real value added falling by 9% and employment by 100,000 people. This has been followed, apart from a minor slump in 1985/6, by a period of gradual expansion, with value added recording a modest growth of just over 2.5% a year.

[53] Again, however, it is important to emphasise that this varies considerably between sectors, for example Clothing and Furniture and Mattresses averaged $1-2 million in 1986/7, while in Aluminium smelting it was $148 million

[54] See Johnston and Carmichael,1981, cited in R.Badham and S.Wilson, op.cit.,

[55] Centre for Technology and Social Change, 1990, **Technology Strategies in Australian Industry**, Department of Industry, Technology and Commerce, AGPS, Canberra, pp.1-3

[56] See B.Williams,1988, **Review of the Discipline of Engineering**, cited in R.Badham and S.Wilson, ibid.,

[57] See B.Williams, ibid.,

[58] See Porter, M.E., **The Competitive Advantage of Nations**, Macmillan, London, 1990

have been appropriately termed by Dahlem and taken up by Edquist, Lundvall and Dalum[59], is also apparent in the lack of dynamic sectors of manufacturing equipment producers that could be stimulated by and reinforce the growth of profitable export oriented sectors. This has been revealed in the lack of integration of a large and complex educational and research system with the needs of industry.[60]

In addition to these problems, Australia shares the same difficulties that affect a number of other 'small' OECD countries i.e. the average size of firm is relatively small, and small size is directly correlated with comparatively low levels of R&D, a lower rate of process innovation, lack of technical and management skill etc.; home markets of insufficient size to provide the protected 'seed bed' for future world competitive firms; and a relatively small manufacturing sector with direct implications for the level of public investment in appropriate R&D, education and training etc.[61]

Finally, the technology adopting characteristics of Australian industry are reinforced by the comparatively low levels of education and training, and the lack of attention paid to employee involvement in decision making by management.[62] A lower proportion of the Australian population aged 15 to 24 participates in education than in many other OECD countries, a rate of 36% in 1981 compared to 73% in the United States, and also significantly below the levels of Japan and Germany. Moreover, Australia's overall expenditure on education and training in both the public and the private sector is relatively smaller than most other OECD countries.[63] The lack of a highly effective educational and training system spans the range from the lack of management professionalism, through the relatively low proportion of engineers, to the proportion of highly skilled shopfloor workers...As extensively documented in a recent report for the Australian Manufacturing Council, Australia is characterised by skills shortages in a number of areas and the high levels of employee turnover and absenteeism discourage further investment by firms in skills and training.[64]

Skill Formation and Industrial Revitalisation

In recent years, under the long term leadership of the Australian Labour Party there has been a systematic attempt to address many of the technological and economic problems outlined above, with particular focus on stimulating R&D, promoting technology transfer and diffusion, and transforming the national skill formation structure while

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[59] Dahmen, E., 1982 'A Neo-Schumpeterian Analysis of the Recent Industrial Development of Sweden', in C.T.Kindleberger and G.Tella, **Economics in the Long View: Applications and Cases**, Volume 3, Macmillan, London; Edquist, C., and Lundvall, B.-A, 1989, 'Comparing Small Nordic Systems of Innovation', Paper presented to the Maastricht seminar on National Systems Supporting Technical Prograess, November: Dalum, B., 1990, 'National Systems of Innovation and Technology Policy: The Case of Denmark', Paper presented to the Workshop on "Socially Oriented Technology Policy", Institute for Advanced Studies, Vienna. April 3-4; and Lundvall, B.-A., 1991, National Systems of Innovation (forthcoming)

[60] Centre for Technology and Social Change, 1990, **Strategic Alliances in the Internationalisation of Australian Industry**, Report for the Department of Industry, Technology and Commerce, p.5

[61] See the discussion of small countries in the work of Lundvall and Edquist op.cit.

[62] Pappas et.al., p.73

[63] See Badham. R. and S.Wilson, op.cit.

[64] See Pappas et.al., op.cit.

gradually reducing levels of tariff protection. This has been carried out with the assistance of two sets of initiatives.

Firstly, the establishment of two large government departments: the Department of Industry, Technology and Commerce and the Department of Employment, Education and Training. The formation of the former department has assisted in giving technology a high profile within industry policy and has been responsible for integrating innovation promotion with industrial sector plans, and the latter has facilitated the establishment of a broad ranging plan for changing the Australian system of skill formation.

Secondly, an Accord has been developed between government and the unions, whereby the Australian Confederation of Trade Unions (ACTU) has agreed to restrict wage demands in exchange, amongst other things, for participation in central corporate advisory and decision making structures, examples of the former being the Australian Manufacturing Council and the Economic Planning Advisory Council. Although there is a great degree of scepticism about the ability of unions to utilize these structures to effectively influence technology and industrial policy, in specific programmes union participation is assisted by the favourable social democratic political climate. Of particular interest has been a substantial range of technology diffusion, industrial policy and skill formation initiatives.

Technology Diffusion and Industrial Sector Policies

In the area of technology diffusion the central government initiatives have been the development and coordination of technology transfer services through the establishment of a National Industries Extension Service (NIES) and the creation of industry sectoral plans, in particular the Heavy Engineering Assistance Package. NIES was launched as a national program in 1987 to coordinate and develop Federal and State technology transfer services. The aim is to supply industry extension services to assist small and medium-sized firms to become internationally competitive. It involves and information and referral service, a diagnostic and business planning service to target firms, and improved access to a co-ordinated range of specialist services. As indicated by the change of name of the government Computer Integrated Manufacturing Development Program (to Integrated Manufacturing), and similar changes in title of a number of CAD/CAM technology transfer centres, there has been a dramatic shift in concern away from a 'technology push' for the introduction of high-tech equipment.to the promotion of organizational and skill changes for effective innovation.

The program is headed by an Industry and Technology Council of Federal and State Industry and Technology ministers, with advice from a National Advisory Committee on Extension Services, which has government, industry and union representatives. As detailed above a key feature of socially oriented innovation policies is the integration of explicit social concerns into government assisted technology transfer mechanism. A key aspect of this is the involvement of unions in the Advisory Committee, and in particular the actions of a specialist committee for management and marketing services. This has been responsible for the establishment within State NIES technology transfer centres of a Contribution of Labour programme and representatives to explicitly advise on the adoption of forms of innovation that approximate more towards a skill based manufacturing model.

NIES is also explicitly linked in as a technology transfer service to sectoral programmes promoted by the government, including the Steel Plan, the Car Plan, the Heavy Engineering Adjustment and Development Program, and the Textiles, Clothing and Footwear Plan, and assistance for Information Industries. In terms of socio-economic innovation policy, the $70 million Heavy Engineering Assistance Package has provided an important model of sectoral promotion. The package provided a concessional loan finance scheme that incorporated a management efficiency program, and industry development program, and a skill enhancement program for the recipients of finance. Involved in the project was the government established Australian Industry Development Corporation, with national interest provisions in its charter that can be used by the government to influence the funding of socially oriented projects.

The package was administered by a Heavy Engineering Board with trade union representation, and every application by firms for finance for skills enhancement required the firm to accept responsibility for training beyond the duration of the assistance, consultation with employees over training and job security provisions, and agreement for jointly negotiated significant changes to work practices. In terms of a socially oriented innovation policy, these are important considerations for a union movement presently involved in a move for the nationwide establishment of skill based career paths for workers, in conditions that include job security guarantees and extensive union consultation on innovation and changes in work practices.

Skill Formation

As is now widely documented the effective use and development of new technologies requires a substantial investment in increased skill and training. Yet in industrial cultures such as that dominant in Australia in the past, this may result only in a vicious cycle of skill shortages and underskilling. Employer investment in new skills and training is costly and where there is a high turnover of employees there is frequently an attempt to attain these skills by 'poaching' or immigration rather than the provision of sophisticated forms of on-the-job and external training schemes. In this context, the high demand on skills for the effective development and use new technologies may result in an attempt to enter product markets and use and develop the technologies in a manner that deskills the workforce. In order to avoid both the economic disadvantages of entering such lower value added industries, and the negative social consequences of deskilling and unemployment, the Australian government in collaboration with the trade union movement has become involved in a systematic attempt to change the skills formation system.

This approach have become a dominant feature of government policy since the publication of the Kirby Report in 1985. As a research strategy, it has been formally expressed in 1986 by the Bureau of Labour Market Research/National Training Council publication *Skill Formation in Australia: In Search of a Research Agenda.* As a component of government policy, it has been expressed in the policy statements from the Department of Employment, Education and Training on *Skills for Australia* and

Industrial Training in Australia. The general policy direction has been affirmed by the Tripartite Australian Manufacturing Council in its report *Manufacturing Skills in Australia*, and the tripartite Economic Planning Advisory Council in a report on *Microeconomic Constraints on Economic Growth.* Similar views are expressed in the ASTEC report *Wealth from Skills.* Trade union support for new policy initiatives is detailed in the ACTU's recommendations in *Australia Reconstructed.*

This strategy incorporates three elements. Firstly, the implementation of *broader job classifications and skill based career paths* through changes in the centrally determined 'award structures' that govern Australian industry wages. The most significant development in this regard has been the introduction of a Restructuring and Efficiency Principle in the 1987 National Wage Case i.e. the centralized decision on wage increases made by the Australian Conciliation and Arbitration Commission that is responsible for Australia's 'award' structures and payments. This principle created a 'two-tier' wages system, where flat rate wage increases are accompanied by a further percentage increase if significant changes to work practices are made in order to increase efficiency. This wage case decision has been a central plank in the platform of key unions, such as the Australian Metalworkers Union, to introduce changes in work practices accompanied by skills upgrading, increased consultation and job security guarantees. This history of the national wages system from 1983 to the present has shown a general trend from a negotiated centralised national system of wage indexation to a system of 'managed decentralism' which includes sector level and enterprise negotiations over skills, job classifications, wages and productivity. In August 1988 this was reinforced by the Structural Efficiency Principle passed down by the decision of the Australian Industrial Relations Commission.

The second element of the skill formation strategy is the promotion of corresponding changes in education and training institutions, incorporating *opportunities for retraining and greater participation of industry in systematic and modular training courses*;. As part of a general national review of higher education, there are a number of initiatives to implement: the restructuring of training courses and colleges to incorporate broader courses, more flexibility in the provision of these courses and systems of cross accreditation, greater industry participation in both the definition of the new course structures and in the provision of the training, and a general increase in the modular nature and integration of training in training colleges, technology transfer training organizations, and within firms. All of these measures are intended to assist in the establishment of skill based career paths that represent both an incentive for the individual to invest in personal training, and a compensation for workers forced to undertake retraining for new technology.[65]

The third element of the strategy is the establishment of *forms of consultation and work organization that incorporate greater union and worker participation in the innovation process and the devolution of a greater degree of responsibility and control.* Despite increasing recognition of the central importance of such elements in effective innovation, and their promotion by government organizations such as the Department of

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[65] Mathews, J., 1989, **Towards an 'Australian Model' of Wages-Linked Regulated Structural Adjustment**, Swedish Centre for Working Life, Stockholm

Industrial Relations, this remains one of the most controversial elements of the skill formation package. Although there is increasing evidence in Australia of moves in this direction, there are fears, especially by those unions representing less skilled workers, that these will not provide sufficient security for workers faced by substantial management initiated changes in work practices and pressures.

In the broader conceptions of skill formation put forward by proponents of this approach, all these three factors are inextricably interlinked if 'best practice' organisational methods of high-value added producers are to be adopted. As outlined by Curtain and Mathews, this involves action at three interlinked levels: the industrial relations of the labour process (work organisation, job classifications and work procedures); the industrial relations of skill (career structures and skill formation processes); and the industrial relations of productivity-linked wages systems.[66] It is the integration of all three elements that is a key concern in the NIES technology transfer services, the industry sector plans and the centralised Accord drawn up between labour and the unions.

Skill Formation Initiatives: The Positive and Negative Views

In the context of such initiatives it is not surprising that the Australian debate about the nature and desirability of 'post-Fordist' production cultures is remarkably well developed. In the academic arena it is being strongly pursued in such journals as the *Journal of Australian Political Economy, Australian Quarterly* and *Labour and Industry*, as well as in political science, political economy and sociology conferences in Australia and New Zealand. In the policy arena, it is well represented in the skill formation reports cited above, as well as such recent reports as that by the Australian Manufacturing Council - *The Global Challenge: Australian Manufacturing in the 1990s* (July 1990).

From within this debate, a strongly positive view of the skill formation initiatives and the possibilities of creating a post-Fordist 'new world of work' has been inspired by theorists associated with the Australian Metalworkers Union and others promoting the skill formation process from within the Departments of Employment, Education and Training and the Department of Industrial Relations.[67] For this approach, the changes in world markets and the introduction of new technology create an opportunity for firms and countries to dispose of Taylorist forms of work and create a 'new workplace culture' based on high skills, decentralised responsibility, flexible production and continuous innovation. If Australia is to enter high-quality and high value-added product markets, it will be required to introduce such a culture, with possible significant benefits for the workforce. These benefits range from employment and wages to job enrichment and participation. The changes in skill formation are regarded as appropriately pursued through tripartite negotiations for transforming the centralised award structures into a more flexible and skill enhancing systems of job classifications and career paths. The

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[66] Curtain, R. and J.Mathews, op.cit.,

[67] This is best exemplified in the writings and references of such leading exponents as John Mathews, Richard Curtin and Max Ogden. Apart from the references referred to in the text below, see J.Mathews,1989, Tools for Change, Pluto Press,

formal process of 'award restructuring' is a key plank in this platform.[68] The Accord between the Labour Party and the Unions is perceived as an effective institutional basis for this process supported by a social modernisation of the economy. As Curtain and Mathews, two leading exponents of this viewpoint, argue

> 'award restructuring arises out of a national wage system in transition from a rigidly centralized apparatus to a more flexible system in which enterprise negotiations take place within parameters laid down centrally.' [69]

but, they continue, it is important that

> 'the statutory framework of conciliation and arbitration has remained intact, providing a floor of minimum standards and a means of curtailing resistance, on the part of unions and employers, through a wages breakout...the transition has been accomplished under a regime of falling real wage levels, partly made up by government commitments to increase social wage expenditure on such items as social security and housing. This could not have been possible (short of strong confrontation with the union movement) in a system where the fundamentals of change were agreed at peak council level between unions, employers and government.'[70]

The award restructuring changes are not only related to this new 'social contract' but also to accompanying policies for union amalgamation and rationalisation, and the transformation of the education and vocational training systems to support the new structures. One of the key links between these changes and technology and industry policy are the various industry sector plans outlined above. Of greatest contemporary significance is the development of a new plan for the motor industry by a new research centre for promoting this view of skill formation (Monash National Key Centre in Industrial Relations), inspired by the recent MIT report *The Machine that Shook the World: The Requirements of Lean Production.*[71] During the 1990s, this viewpoint is likely to extend its support to the *promotion of regional and small firm networks* influenced by international research on regional and small firm networks and contemporary technology policy research in Australia emphasising the importance of strategic alliances and industrial clusters.[72]

In contrast to this 'positive view', are a number of critical appraisals of not only the whole 'post-Fordist' literature and approach to industrial change but also the real

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[68] This process has been defined as 'the negotiated transformation of the conditions governing employment, expanding the scope fo such negoations from the external characteristics of work (wages, hours and immediate conditions) to establishing a framework which will make it easier for different forms of the labour process to emerge.' It is claimed that 'Award restructuring, by linking wages with new job structures based on skills acquisition, will free up the external constraints which have reinforced Taylorist forms of work organsiation.', Curtin and Mathews,1990, op.cit p. 62)

[69] Curtain, R.. and J.Mathews, 1990, 'Two Models of Award Restructuring in Australia', **Labour and Industry**, Vol.3, No.1, p.64

[70] ibid.,

[71] Rawson Associates, 1990, **The Machine that Changed the World**,

opportunities open to Australia to improve productivity and the quality of working life through 'award restructuring' processes. As observed by enthusiasts of award restructuring, the movement of unions towards amalgamation has been extremely slow with only a slight reduction in numbers (9 out of over 300 unions), there has not as yet been a definite 'restructuring' of any award but rather a number of separate interim agreements, and that not more than 10 per cent of Australian firms would be likely to move significantly towards the PEA model. In addition, it is fully recognised that there are now relatively well developed *alternative models* of award restructuring, and that it is the model being promoted that determines 'whether flexibility, productivity and efficiency will be sought through the adaptability of a skilled and responsible workforce, or through further hierarchical control and intensification of existing skill and wage demarcations.'[73] Some indication of the range of positions is given in Figure 6[74]. As outlined in Figure 7[75], Curtain and Mathews classify these positions as approximating towards either of two extreme models: the 'cost minimisation approach'(CMA) or the productivity enhancement approach'(PEA). The position of the 'optimists' is that the PEA model is possible, desirable and worthy of promotion in conflict with proponents of the CMA, and that the achievement of substantial changes in key competitive sectors will be magnified throughout the economy as they exert a 'demonstration effect' enhanced by the influence that these companies and unions exert on the rest of the economy.

In contrast the 'pessimists' offer a different view of the limited achievements so far. They are inspired by a stronger emphasis upon the rigidities in the economy and are more fearful of the dangers posed by the CMA model supported by many managers and business associations. Rather than seeing the choice in terms of conflicting models, and the conditions hindering change as 'obstacles to be overcome', the 'pessimists' adopt the 'realistic' position that the obstacles may be too strong, and that what will emerge is more likely a compromise form of the alternative model than a beneficent 'new world of work'. At the level of technology and economic statistics, as we saw above, this is clearly a strong position, with Australia facing severe problems of trade imbalances, low value added exported manufactures, and relatively uncompetitive manufacturing enterprises..

In regard to the specifics of award restructuring, the 'pessimists' adopt one or more of four different positions.. Firstly, it is argued that the degree of real change is likely to be superficial as firms either fail to break established structures or avoid any such attempt, and that the real significance of any changes that do occur is the breakdown of union power and hard won degrees of worker autonomy on the shopfloor through 'direct' participation and 'multiskilling'. In this regard, references are frequently made to

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[72] See J.Mathews, 1990, 'Towards a New Model of Industrial Development in Australia', **Industrial Relations Working Papers**, School of Industrial Relations and Organisational Behaviour, University of New South Wales, Sydney; P.Roberts, 1990, 'Where big is not necessarily better', **Australian Financial Review**, June 28, p.24; and the reports cited above by the Centre for Technology and Social Change

[73] Curtain and Mathews, op.cit., p. 62

[74] Pappas et.al., p.80

[75] Curtain and Mathews, op.cit., p.65

the failure of 'productivity' bargaining experiences of the UK in earlier times.[76] Secondly, it is argued that even if these changes are brought about, the result is more likely to be work intensification, less real worker autonomy and a decline in working conditions. As indicated by some Japanese experiences, this is an ever present possibility and a far greater likelihood when unions are under threat. As they accurately observe, it is easy to get carried away by the rhetoric of change and neglect the extent to which there remain significant reactions against such developments by both managements and unions, the former concerned with traditional labour control and training cost considerations and the latter suspicious of management initiated schemes and concerned to defensively hold onto established negotiated work practices.

In an industrial culture that traditionally reinforces such strategies and views, the process of change is both slow and risky for both sides. Such a climate is by no means the best for exploiting the opportunities for socially oriented innovation in a socio-economic innovation policy. Within individual firms, there have been a number of experiences of 'skill upgrading' accompanied by increasing work pressures and segmentation of the workforce into core and periphery elements.([77] The existence of change is not questioned here. As reported, for example, in the Metal Trades Industries Association Survey of Management-Employee Consultation/Participation in the Metal and Engineering Industries, it was found that approximately 30% of the respondent plants (representing over just one-half of total employment) had some form of employee participation scheme. This growth has been particularly rapid in recent years and comprises both 'top down' briefing groups and 'bottom-round' forums, such as quality circles and autonomous work groups. What has been observed in a number of plants, however, is that the consequent development of JIT systems and group technology often does not succeed in meaningful job enrichment (as multiskilling is blocked by demarcation problems, management hesitancy etc.), and where it does result in delegation of tasks, this is often accompanied by increased 'transparency' of worker efforts and core/periphery splits between more and less favoured workers.[78] , This scepticism about the real significance of new forms of consultation and responsibility finds its counterpart at the central government level in critiques of the effectiveness of the tripartite structures established as part of the Accord to protect worker interests through a broad corporatist approach to industrial change.[79]

Thirdly, it is argued that where such a PEA model is successful, promoted as it is in Australia by relatively strong male dominated craft based unions in the industrial structure, it may only serve to enhance a fragmentation between 'core' and 'periphery' workers, with women, the unskilled, and migrants left worse off than before while a minority become part of a new high-tech labour aristocracy. A fourth critique is made by those who reject such strong contrasts between 'neo-Fordist' and 'post-Fordist', 'neo-Taylorist' and 'post-Taylorist' or 'CMA' and PEA alternatives. The argument made here is that such crude contrasts obscure cross-cutting conditions and the specificities of

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[76] For a critical assessment of the approach see T.Bramble, 1989, 'Award Restructuring and the Australian Trade Union Movement: A Critique', **Labour and Industry**, 2,3,

[77] Bramble, T., 1988, 'The Flexibility Debate: Industrial Relations and New Management Production Practices', **Labour and industry**, 1,2,

[78] ibid.,

change, and therefore do little to provide an effective theoretical base or political strategy for informing change seeking to enhance productivity and improvements in working conditions.[80]

Comprehensive Innovation Concepts Re-examined

Australian initiatives to revitalise industry and improve the skill formation system within a predominantly 'technology adopting' industrial culture raise a number of important issues for the development of comprehensive innovation concepts.(CICs)

Firstly, Australia has adopted in a specific form the change in rhetoric and analyses of work humanisation observed by Badham & Naschold and Elam & Boerjeson in regard to Germany and Sweden... The present situation in Australia may be similar to that outlined by Elam and Boerjeson in the sense that sectors more exposed to international competition are more supportive of the new CICs (such as the metalworkers union). Moreover, a more general favourable union response could be related to the previous widespread lack of employee involvement and partial Taylorist control strategies within management/labour relations in Australia. However, in partial contrast, it could be argued that there has been greater resistance from lesser skilled cross-industry craft unions afraid of their exclusion from the favoured system of skill formation and career paths (such as the ironworkers union). An understanding of these conditions is centrally important in understanding the reaction of different industrial sectors to CIC concepts that often fail to seriously address the problems of extending humanisation criteria into investment strategies in a manner that might allay the fears of sections of the workforce that are for various reasons more sceptical of the value of CICs.

Secondly, an understanding of the nature and permeation of CICs requires an extension of the focus of system design and work organisation research into a broader investigation of national industrial interest group politics as well as the socio-economics of the supply side of the techno-economic system.(education and training system, industrial finance etc.) An appeal for such an extension has been made from different perspectives by such theorists as Wolfgang Streeck and Robert Boyer.[81] If CICs are to be truly **comprehensive** innovation concepts, these must extend beyond the workplace, and even beyond the broader organisational conditions and business strategies of individual firms, into the general political forces that influence the capabilities of change to new production regimes. In Australia, it is clear that the outcome of the skill formation initiatives underway is strongly influenced by the relative strengths and positions of key unions and business associations, as well as the governmental and political climate of change established by ministerial transformations and party politics.

Thirdly, the process of establishing initiatives to promote skill intensive production systems and the creation of high-value added products to 'catch up' world competitive

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[79] Bramble, T.,1989, ibid.,

[80] Hampson, I., (forthcoming), 'Post-Fordism and the Work of John Mathews', **Journal of Australian Political Economy**,

leaders, requires major trade offs between short-term market led allocative efficiencies and long term (innovation-related and growth related) dynamism. As observed by Giovanni Dosi, when a country is a technological leader in a new phase of industrial growth and its social and organisational structures are conducive for their competitive exploitation (as appears to be the case with Japan), these trade offs are relatively insignificant.[82] However, when a country does not have technological leadership and social and organisational structures are not compatible with commercial exploitation and further technological development, painful trade offs will be required - involving selective public industrial intervention, support for home equipment suppliers at the possible expense of home based users of such equipment etc. Free market economics provides relatively little assistance in guiding action in this situation, and attempts at intervention are often caught up in ideological battles over the benefits of 'free trade' versus 'protection'. In discussing the promotion of comprehensive innovation concepts, therefore, the existence of such trade offs must be recognised. Interventions to improve education and training systems, remove outdated forms of work organisation, facilitate internal labour markets and redirect technical and social research, all impose costs as well as benefits on different firms, sectors, groups and institutions. A realistic assessment of these features of promoting CICs in particular countries is required if effective strategies are to be developed. Such a climate is gradually being created in Australia after a lengthy period of attempted reforms.

Fourthly, as revealed in the above description of Australian conditions... the scope for intervention by Australian firms in shaping technological innovation lies primarily at the later diffusion and implementation end of the innovation spectrum. If comprehensive **innovation** concepts are to live up to their name this requires an examination the relative importance of, and significant influences upon, the shaping of technology at different stages of the innovation process - and the manner in which this may vary between industrial sectors and countries.. This requires a more systematic assessment of the degree to which the process of incremental innovation, system customisation and development within user firms exerts a crucial influence on the nature of technical systems capable of supporting (or undermining) anthropocentric production systems.[83]

Some Implications of the Report

From the point of view of anthropocentric systems development, the implementation process will be one of the main stages of the innovation process at which 'technology

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[81] Streeck, W., 1989, 'On the Political Conditions of Diversified Quality Production', Mimeograph LME's International OECD Conference **No Way to Full Employment?**, Berlin, 7 July; and R.Boyer, 'The TRansformation of Modern Capitalism', ibid.,

[82] Dosi, G., 1990, 'Some Notes on Patterns of Production, Industrial Organization and International Competitiveness', Paper presented to the Workshop on **'The Organization of work and Technology: Implicatiosn for International Competitiveness'**, Brussels, May 31-June 1

[83] This phenomenon is illustrated at some length in the case study of CAD/CAM development in Australia which is part of the AusCR and will be further investigated in: Badham, R., (ed.), forthcoming, Special Issue - Systems, Networks and Configurations: Inside the Implementation Process, **International Journal of Human Factors in Manufacturing**. An excellent review of many of these issues can be found in the working papers of the Edinburgh PICT Centre by J.Fleck, R.Williams and J.Webster.

adopting' countries' will be able to shape the technology in accordance with local cultural needs. However, to the extent that they lack the systems and engineering skills to perform this effectively, this potential role in system shaping is reduced. Where there is also a relatively low level of craft skills and employee involvement in decision making, this phenomenon is compounded due to the lower degree of impact made on incremental innovation processes. In part, these conditions may be part cause and part result of the type of products produced or the stage of the production cycle at which the majority of production activity occurs (i.e. concept design, detail design, manufacture, assembly etc.).

In order to break out of this cycle and enhance the development of anthropocentric systems an integrated set of developments are required. This clearly involves:

- the direct promotion of R&D;
- the enhancement of education and training; and
- action to break down industrial cultural and structural barriers to more decentralised forms of work organisation;

In addition, however, it also requires:

- provision of support for design and marketing beyond the home market to encourage more design intensive and higher value added product strategies,
- the encouragement of 'industrial clusters' of world competitive and quality oriented firms or 'development blocks' of user/producer firms and associated research and training infrastructure; and
- the support of appropriate integrated technology transfer measures and infrastructural support for regional and cultural inter-firm networks in order to compensate for the lack of small firm economies of scale in R&D, finance, training and management expertise.

To address these general preconditions for anthropocentric skills formation in the context of the specific industrial cultures of different nation states is the challenge of technology policies worldwide that wish to build upon the 'European' approach . The realistic evaluation of national conditions is an essential element in this enterprise. As has been shown in the case of West Germany, the presence of nation specific institutional rigidities at the labour market level may be an important source of competitive advantage for that country in promoting production flexibility and entering diversified quality product markets. The competitive and social advantages of these and other features need to be assessed in different countries... The importance of the Australian experience is that it has begun to enter such a stage of realism while testing out a number of strategies outlined above. Whether the analyses and strategies that emerge will be up to the enormous task of redirecting the economy remain to be seen" (AusCR, p. 24-35 and 39).

Synopsis and Recommendations

The global trend toward cooperative and work-oriented production concepts corresponds to an internationally widespread type of rationalization. It fits in well with the development of anthropocentric work and technology concepts. The convergence of rationalization and humanization interests thus created opens up economic prosperity and social stability to the European producing industry for the forthcoming development period if this convergence with its synergetic potential is supported and spreads by virtue of an R & D policy in science and technology tending towards the anthropocentric production scenario.

In accordance with the fundamental goal of this study we want to summarize the partial findings and interpret them in the light of industrial performance, thus we ask for challenges of international industrial competitiveness on the one and the prospects of anthropocentric production systems on the other hand. With reference to the crucial industrial cultural elements we will portray some similarities as well as some differences in the industrial cultural profiles of the examined countries. In doing so we concentrate on the national educational institutions as well as on work structures (organisation, job classifcation, etc.) and conclude with some necessary preconditions for anthropocentric production systems.

The analyses of the presented cases give a clear evidence that the industrial cultural key elements influence productive performance and thus the sectoral, national and international competitiveness. For instance, the U.S. machine tool industry lags behind their international competitors (particularly the Japanese and the European). Despite of the basic branch structure which is similar to the respective structure in Japan or Germany (regarding company size, etc.) the productive performance of the U.S. machine tool industry lies below that of the competitors overseas. Innovation capabilities display structural drawbacks which themselves are the result of deficiencies in human resources formation, i.e. in particular in the vocational training system as well as in the general education system. Although the U.S. automobile industry is not lagging behind its competitors as dramatically as the machine tool branch does, it displays similar problems based on the same deficiencies. Even highly automated car manufacturing plants achieve only an average productivity and although the automation technology applied allows high performance flexibility, this potential cannot be realised. The crucial factor again seems to be the educational system (both general and vocational education) which, accompanied by an increasingly undermined but still strong orientation towards Taylorist/Fordist hierarchical organizational structures, are complemented by a system of narrow job classifications. Taken together this elements tend to hinder APS in general and group oriented work experiments in particular. Although the Japanese transplants (often recognised as examples of better practice *right across the street*) played the role of a creative challenge for the U.S. auto industry - there were mighty hindrances for an approximation towards APS originating in the general industrial-cultural preconditions. The future of the automobile industries - not only in the U.S. - thus depends upon the improvement of industrial conditions. This means organizational, qualificational and educational rather than technological improvements. If an anthropocentric shape of work and technology systems can roughly be operationalized as *work organization in teams* (or groups), a *task allocation at the production line* and *flatter hierarchies* supported by *comprehensive communication systems* the realization of this new demands obviously require production workers with **polyvalent skills**, i.e. good general (theoretical) and broad practical (job related, experience-based) knowledge. The new demands furthermore imply broad job classifications and well-defined carreer and promotion systems which are to a large degree independent of job classifications. Particularly the skill and qualification requirements need high-standard and differentiated educational institutions to fulfill the sketched goal.

In order to meet the challenges of the *Japanese System of Car Manufacturing* the U.S. needs for example a promotion in the fields of general education i.e. to raise the average level of basic skills: mathematics and literacy (OTA 1990, pp. 158); and in the standards of vocational training (which in first place means to generalize the very few examples of excellence); but also the German car industry displays deficiencies: less in the area of skills and qualifications but in the organizational field. The German car industry still largely follows the Taylorist/Fordist technocentric organizational pattern of Scenario 1 - partly because of structural disadvantages of the branch: dominance of large companies, and a strong demand for centralized logistics within the companies as well as within the supplier chain. Although we find an increasing number of working group experiments these concepts are not as common as in the Japanese car industry (not even as widespread as in Sweden).

With regard to the machine tool industries, again our industrial-cultural key variables proof to be of crucial significance: The structural advantages of the machine tool branches (in all countries of our sample) can only in those industrial cultures be transformed into an anthropocentric production structure where the education and vocational training systems, and the organizational patterns and traditions are advantageous. In the German case, particularly in smaller machine tool companies the share of skilled workers is outstandingly high. The existence of a highly skilled work force at shop floor level is the basis for the relatively widespread anthropocentric orientation of the branch's production structure. In combination with an advantageous organizational tradition comparatively flat hierarchies are realized as well as broad, more holistic job definitions and organization structures in working groups. - By no means we want to suggest a *one best way* which will automatically enable working and organizational structures that are more favourable for APS. The Japanese and German examples, both successful in their way, proofed that differing structural and industrial-cultural preconditions in combination with branch peculiarities can foster a more anthropocentric production structure.

In contrast to the machine tool branches in the U.S., Japan and Germany, which are - despite of the cross-national differences - most likely to develop towards more anthropocentric production structures, the electronics industries proofed in all country studies of the sample not to be the forerunner in the "race" for APS. In Germany, the U.S. and in a modified shape also in Japan electronics industries are expected to follow predominantly Scenario 1. There is some evidence that especially this branch will to some degree be developed towards a dichotomized structure (particularly in Germany but also in the U.S.). The structural preconditions of the electronics branches in all countrie of our sample are characterized by a large portion of female and semi- or unskilled workers (in the U.S. this pattern is complemented by a structural bias towards ethnic minorities). This structure tends to develop in the future towards a dichotomization into internally upgraded and semi-academics (benefitting of anthropocentric production experiments) and the unskilled restworkers as a peripheral work force. Our basic assumption obviously seems to be verified that the existence of a skilled work force within a branch is of crucial importance for the realization of APS - but the existence or absence of a skilled work force depends upon the branch' s dominant production and work utilization concepts and on the general availability of skilled work within an industrial culture. The last mentioned exigency links branch-specific requirements with the social and political sphere and emphasizes once again the importance of an efficient and widely ramified system of general and vocational education. The following Table gives a synoptic cross-national overview of the educational systems in three countries of our sample.

Table 2: Worker Training Compared

	United States	Germany	Japan
Primary and secondary schooling	Local control contributes to wide range in course offerings and quality	Excellent for those in academic high school; generally good for others	High quality; uniform curriculum; emphasis on rote learning
School-to-work transition	Left mostly to chance; some employers have ties with local schools	Apprenticeship for most non-college-bound youth	Personal relationships between employers and local schools
Vocational education			
Extent	Available in most urban areas	Near-universal availability	Limited; mostly assumed by employers
Quality	Wide range: poor to excellent	Uniformly good	Fair to good
Adult education			
Extent	Moderate; community colleges offer widespread opportunities	Limited but growing	Widespread; self-study common
Relationship to work	Relatively common	Nearly universal	Common
Employer-provided training			
Extent	Emphasis on managers and technicians	Widespread at entry level (apprenticeship) and to qualify for promotion	Widespread at all levels
Quality	Sometimes excellent, but more often weak or unstructured; many firms do not train	Very good	Very good
Public policies	Federal role limited; State aid to employers growing	Governs apprenticeship; supports further training	Subsidies encourage training by small firms

Source: OTA 1990, p. 86

The differing and both successful educational systems in Japan and Germany give reason that it is not the system as such which brings about the success. There is some evidence that future developments towards anthropocentric production concepts (Scenario 4 and 2) are not depending on certain concepts of education but rather manifest an affinity towards the manner and extent of the **integration of general and vocational education**. In our view the essence of such integrated education concepts is the integration of theoretical and experience-based knowledge. It is no big surprise that two formally differing systems like the Japanese and the German meet the requirement of an *Integrated Vocational and General Education*. The Japanese system works sequentally, which means that after a high-quality primary and secondary schooling follows the wide-spread and good o-j-t within the companies with the result of a highly skilled and good educated work force. In contrast, the German path of integrated general and vocational education begins with a relatively low entry level of general education which is raised during the apprenticeships. The apprenticeship programmes combine the supply of general and vocational education and result in highly skilled specialists (some critics argue that the acquired skills are too narrowly oriented at traditional occupational borders).

Although both, the sequential and the parallel paths of integrated general and vocational education systems are successful in the current production systems, future anthropocentric production systems will be based on open job outlines, flattened hierarchies, and increased communication within the companies and thus require a new, extended and continuing education scheme which integrates broad task related skills, social skills (e.g. communicative abilities) and shaping competences with an enriched general education.

In summing up the last sections we recommend: The anthropocentric quality of industrial production can be decisively promoted, though not yet achieved, by means of an anthropocentrically oriented development of technology and work organization in Europe in conjunction with a comprehensive education and qualification offensive using broadly defined and open job outlines (departing from a traditional narrow occupational orientation). Anthropocentric shaping of work and technology can be expanded and transformed in a direction leading to anthropocentric production if, above all, co-determination and an interdepartmental, shaping-oriented statuory framework governing bothe employees' rights and the economy and committed to the guifing principles of humanization of working life.

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