10

SOCIAL CHANGE AND TECHNOLOGY IN EUROPE

INFORMATION BULLETIN N° 10

ROBOTICS

Current events in

Federal Republic of Germany, France,

Italy, Ireland, Scandinavia and the

United Kingdom

November-December 1982.

V/2770/82-EN

COMMISSION
OF THE
EUROPEAN COMMUNITIES

Directorate-General
Employment, Social Affairs
and Education

V/A/2-EPOS

SOCIAL CHANGE AND TECHNOLOGY IN EUROPE

INFORMATION BULLETIN N° 10

ROBOTICS

Current events in
Federal Republic of Germany, France,
Italy, Ireland, Scandinavia and the
United Kingdom

November-December 1982.

Provisional address: Rue de la Loi 200, B-1049 Brussels — Telephone 2351111 — Telegraphic address: "COMEUR Brussels"
Telex: "COMEU B 21877"

This study was realised by the Commission of the European Community as part of its "Programmes of Research". The analysis and the results presented do not commit the Commission.

Information concerning this study can be obtained at :
Mr. Bernard HELIN - DG V/A/2 - Building Archimède I - 7th floor - room 7/19 - tel. 235.78.95.

======================

WHAT IS THE E.P.O.S. ?

The Permanent Employment Committee was in favour of the Commission's proposal to set up an European Pool of Studies and Analyses (E.P.O.S.) in the field of new information technology and employment.

The Pool has three main functions:

- to collect and evaluate completed research and significant developments at national level;
- to compare and circulate the results of such research and developments, by making summaries available to those who take part in political and scientific debates, in particular employers and trade unions;
- to play a more directional role, in future, vis a vis factual studies and analyses.

At the moment, the Pool is essentially working on the preparation of a data bank, on annotated bibliographies, surveys and on the current bulletin.

CONTENTS

PRESENTATION

This presentation is based on a summary of the EPOS correspondents reports. The opinions expressed are those of the authors and do not necessarily reflect the views or policies of the Commission.

In 1982, the use of robotics, previously considered often as futurist devices has now spread extensively throughout manufacturing processes in a number of industrial sectors, mainly in the motor vehiche industry and in engineering. Forecasts on the penetration of these automated processes confirm this analysis.

Number of robots installed

	Germany (1.1.81)	Denmark (1.1.81)	Finland (1.1.81)	France (1.1.82)	U.K. (1.1.82)	Ireland (1.1.82)
Number of robots	1.255	50	100	635	713	1

	Italy (1.1.82)	Norway (1.1.81)	Netherlands (1.1.82)	Sweden (1.1.81)	Japan (1.1.81)	U.S.A. (1.1.81)
Number of robots	700	150	30	1.100	7500-10000	3500-4000

But what are robotics ? On the basis of reports contributed by correspondents from six countries (Germany, Denmark, France, United Kingdon, Ireland, Italy) it was apparent how difficult it is to give a clear and precise definition. In France, the term covers machines that are very different and have wide and various uses. In general, the concept includes only one type of machine : robots.

Robots, according to British industrial standard are "programmable manufacturing tools capable of carrying out a complex series of movements".

However, robotic machines have spread only into certain types of applications, but their impact on employment is sensitive, and their use is liable to increase tension in the future, especially in the motor vehicle sector. A study in this field by the Prognos A.G. Institute estimates that 63,400 jobs will be eliminated in Europe by 1990, which corresponds to the theme of a study carried out by General Motors in the USA which forecasts the loss of 50% of assembly-line jobs by 1986.

Impact of robotics on employment

Germany	United Kingdom	France	Italy	Scandinavia
One robot can take the place of 3.7 to 4 workers	Each robot has made between 0.8 and 6.2 workers redundant	50,000 jobs abolished by 1985	23,000 to 35,000 jobs lost by 1990	One robot can take the place of 0.5 workers

Although the number of jobs lost is large, evaluations must however take other factors into account :

- jobs are created in the robot design, production and maintenance stages;
- these estimates are only valid if all other factors remain constant, which is extremely rare.

Special emphasis should be placed here on the qualitative impact of robotics on employment. A number of skills will disappear, which will require certain personnel to undertake retraining programmes. An equally extensive training programme should also be started for users as well as for the heads of undertakings, work inspectors and trade unions to heighten their awareness of robotics. Apart from the structural transformation of qualifications and skills, it is also necessary to

ERRATUM

P. 6: 7th and 8th lines

Please read :

... A study in this field by the Prognos A.G. Institute estimates that 63,400 jobs will be eliminated in the Federal Republic of Germany by 1990,...

instead of:

... A study in this field by the Prognos A.G. Institute estimates that 63,400 jobs will be eliminated in Europe by 1990,...

stress the importance of organizational modifications, where workers' representatives should be involved.

It should also be noted that at present there is no specific health and safety legislation relating to the installation and use of robots in the Member States of the European Community.

It was also noted that at the present time, the aids granted by public authorities in the Member States for research and development or as aids to investment are still very inadequate if technological backwardness is to be remedied.

*   *   *

EPOS

Tim BRADY and Ian MILES

GREAT-BRITAIN

Mr. T. BRADY
Science Policy Research Unit
University of Sussex
Mantell Building
Falmer Brighton Sussex BN1 9RF (UK)

ROBOTS AND THEIR SOCIAL IMPACT - THE UK CASE

by
Tim Brady with Ian Miles
Science Policy Research Unit
University of Sussex

I. Technical and Economic Aspects of Robotics

(i) Definition of Robot

The term 'robot' can be applied to a wide range of automated equipment found in many factories in many different industries. In UK industry the word has a fairly strict definition - a robot is conventionally defined as a programmable device able to perform a complex series of movements. A true robot must be re-programmable and able to transport parts or tools through a variable series of movements. It can perform these tasks continuously, until it is no longer required to, when its electronic control system can be reprogrammed to perform another set of tasks. This strict definition does not include non-computerised manual manipulators operated directly by humans, or simple 'pick-and-place' machines following a fixed sequence of actions.

Pick-and-place machines are not servo-operated, and rely on machine stops and limit switches for their control, although in some cases they can be reprogrammed (their programming capacity being very limited). These are not low-technology machines, and cost usually between £ 1700 - £ 8500. Servo-controlled robots come in two types. First are those with point-to-point control, where the robot is programmed to move to pre-determined points in space, moving from each point to another in a straight line. These machines have thability to return to a specific point with an accuracy of within 5 thousandths of an inch.

This type of robot is usually (associated with areas where heavy lifting is involved) and prices for this type currently range from £ 11,000 - £ 22,000. The second type of servo-controlled robot is the continuous path type, which stores extra positional data, which is monitored over time so that a smooth continuous motion is possible. These need larger memory units to store the data and are programmed in such a way that every motion carried out during 'teaching' will be recorded and played back in exactly the same way as the original motion. The high technology used in this type of robot is reflected in the price - anything up to £ 100,000. They are lighter and smaller than point-to-point robots and are less suitable for partshandling. Their higher end-of-arm speeds make them ideal for seam-welding and paint-spraying operations.

(ii) The Spreading of Robotics

The number of robots working in the UK at the end of 1981 was 713, according to the British Robot Association's annual census. At the end of 1980 the number had been 371, so there has been a 90 % increase in the robot population in the year. Over 80 % of the 342 robots installed were programmable servo-controlled devices. The BRA estimated that the number of industrial robots in Britain should exceed 2,000 during 1983. Nearly one hundred British companies had installed their first robots during 1981; the tendency is for them to be installed in ones and twos. An exception seems to be the automotive industry which is the largest user of robots with a total of 275 at the end of 1981. Table 1 (below) shows the breakdown of the robot population by industry at the end of 1980, the numbers installed during 1981 and the total in each sector at the end of 1981. The high numbers in the motor industry sector are also reflected in the figures for the usage of robots. The most widespread use in for spot welding - about 23 % of robots are in this category - with arc welding applications, paint spraying and injection moulding, each with about 12 %, coming next.

Table 1 Deployment of Industrial Robots in the UK

Industry	Total end-1980	Installed 1981	Total end-1981
Energy and water supply (inc. coal and nuclear)	6	3	9
Metal manufacture and mineral extraction	1	1	2
Metal goods manufacture (inc. foundries, etc.)	64	11	75
Mechanical engineering	37	19	56
Office and data processing equipment	2	1	3
Electrical and electronic engineering	20	17	37
Automotive and automotive parts	126	149	275
other transport (inc. shipbuilding and aerospace)	20	11	21
Instrument engineering	4	1	5
Food, drink and tobacco	0	1	1
Paper, paper products, printing	0	2	2
Rubber and plastics processing	52	34	86
Other manufacturing	34	6	40
University Research	0	2	2
Unclassified	5	84	89
TOTAL	371	342	713

Source : Auto Industry, March 1982.

It is expected that the next few years will see a large growth in the number of robots used in assembly activities, but this depends to some extent on advances in sensors. There are a number of robots equipped with optical, tactile and other forms of sensory recognition in experimental research use but none in commercial use. The British Robot Association estimates that there are some 15 assembly robots - mostly at university and research organisations. There are plans to introduce an assembly robot into everyday shopfloor production at one of Lucas's factories later this year and this will be the first assembly robot to be used in this way in the UK. The robot will be required to select and assemble two components from trays of size-graded parts - eleven trays of one part and seven of the other.

A report by the technology policy board of the Institution of Production Engineers (I. PROD. E.)[1] suggested a chronological sequence of technological innovation for the UK, including several references to robotics and programmable automation. By 1982/83 sensors for tracking and control of welding variables will be developed and applied. Increasing use will be made of arc welding robots and of specialised wedling equipment. By 1985 direct labour in final car assembly will be replaced by programmable automation - 30 % penetration is likely. Both paint spraying and automatic welding will be carried out in up to 40 % of industry using these processes. By 1986/87 20 % of mass production companies will be using dedicated automatic assembly. Modular robots will exist which will make equipment prices competitive with specially-designed automatic assembly equipment although there will only be a small number of these until 1990. Growth in flexible manufacturing systems (FMS) will lead to an increase in the number of robots in metal cutting and metal forming applications. Developments in sensors will see a rise in the number of robots used for inspection and eventually even maintenance as well as for assembly, packing and materials handling applications.

---

[1] 'Current and future trends of manufacturing managements and technology in the UK', I. PROD. E., 1980.

(iii) Estimation of the Growth of Robotics : 1985 - 1990

A study carried out in 1979 by Ingersoll Engineers in collaboration with the National Engineering Laboratory (NEL) further investigated the application of robotics to industrial processes, research on robotics and the manufacture of robots. Included in the report[2] was an estimate of the robot population for 1900. They estimated that there would be almost 12,000 robots in operation by 1990 of which 2,000 would be in proven applications such as spot welding, plastic injection moulding, die-casting and coating, 3,000 in applications becoming proven in a variety of machine loading/unloading operations and 7,000 in new applications such as welding, fettling, assembly and inspection.

This is thought to be an underestimate, in certain quarters, in view of the fact that, since it was made in 1978, there has been an acceleration in the uptake of robotics in British industry. This is borne out by the latest figures for the robot population. According to the Ingersoll Engineers' estimate of growth, there should have been 523 robots in British industry by the end of 1981 - whereas in fact there were 713. The Ingersoll Engineers' projection of 12,000 robots by 1990 assumed a constant growth rate of 41 % : the actual growth from 1980 to 1981 was nearer 100 %. It is unlikely that this growth rate could be sustained over the whole decade, but even a 50% rate gives an estimate of some 21,500 by 1990. In his paper to the 4th British Robot Association Annual Conference, 1981[3], M.A.M. Rogers used an implied growth rate of 50 % to forecast the breakdown of robots in use in 1990 by application. His estimates appear in Table 2 below.

---

[2] Ingersoll Engineers and DoI/NEL, "Industrial Robots", NEL, 1980.

[3] "Requirements to enable robotics technology to contribute to the revitalisation of UK manufacturing industry", 1981.

Table 2 Forecast of Applications of Robots in Use in Britain in 1990

Application	Number
Spot welding, moulding, die-casting, coating	7,000
Metal cutting, forming	5,000
Welding, joining, fettling	4,000
Assembly, packing, materials handling*	5,000
Special (to process e.g. inspection, maintenance, etc.)	500
	21,500

* This includes mobile robots for warehousing and vehicle loading.

Both these sets of estimates fall short of the actual increase in robot population that has occurred and the 2,000 level is not passed until 1985, whereas the estimate from the BRA after their last annual census was that this level would now be reached sometime in 1983. Both estimates imply a robot population of more than 10,000 in 1990. According to Mr. Tom Brock, executive secretary of the BRA, the robot population is more likely to be about the 10,000 level by 1990, indicating a slowdown in the rate of growth through the decade.[4] The two detailed estimates are summarised in Table 3 below.

Table 3 Estimates of the Robot Population in the Uk 1985-1990

	1985	1986	1987	1988	1989	1990
1. Ingersoll Engineers (41 % growth annually from 1980 onwards)	2,067	2,915	4,110	5,795	8,172	11,522
2. M.A.M. Rogers (50 % growth annually from 1980 onwards)	2,917	4,225	6,338	9,508	14,262	21,393

---

4 Hazel Duffy, "Sharp rise in robot workforce", Financial Times, 10 February 1982.

(iv) Trade and Commercial Balance of Robotics

British-built robots accounted for only 30 % of the robots installed in 1981. This is an improvement on the previous year's figure when some 80 % of robots installed were imported but Japanese-built robots have increased their share of the expanding UK market from 4 % in 1980 to 12 % in 1981. A recent report, prepared by Creative Strategies International[5], predicts high growth rates for the Western European market for robots and expects the UK share of the total market to rise from 16 % in 1981 to 20 % by 1984. Most of this growth is expected to be realised by an increase in the number of distributorships and licensing agreements rather than any increase in the number of UK manufacturers.

The study is fairly pessimistic about the prospects for UK manufacturers in the robot market - "In the late 60s, the UK did have an equal opportunity with the rest of Europe to develop a core robot industry. She did not do this with the result that more than 80 percent of the UK robot population is imported". Despite this pessimism, the number of firms making robots in the UK doubled in 1981 to eight. Britain's indigenous robot manufacturers include Hall Automation (now part of GEC), Mouldmation, Workmaster, Taylor Hi-Tech and Pendar Associates. The American firms Cincinatti-Milacron and Unimation, and the Swedish firm ASEA all have European manufacturing operations based in the UK.

Recently, two British firms signed agreements with Japanese robot manufacturers which will eventually lead to them manufacturing robots in the UK. The Sykes group have formed a joint company with Dainichi Kiko which at present only markets the Japanese products. However, Dainichi-Sykes has plans to assemble parts sent from Japan next year and manufacture a second-generation robot from 1984. Another British firm, Hydro Machine Tools, part of the GOO Group, have an agreement with Fujitsu Franuc which grants them the right to manufacture the

---

[5] "Western European Robotics", prepared by Creative Strategies International.

Fanuc range of robots in the UK.

Fairey Automation will begin manufacturing a new range of robots later this year following the take-over by its parents, Fairey Holdings, of Jonas Øglaend, a Norwegian company. The firm has already begun marketing the robots and expects the whole manufacturing operation to be based in England by the end of this year.

In addition to these three announcements, there have been several licensing agreements between British and foreign companies which cover sales and marketing but not manufacturing. Grundy Robotic Systems act as agent for Star-Seiko, Shinmiewe and Fuji. Tecalemit are distributors of the German-made Niko robots; GKN-Lincoln Electric have an agreement with Yaskawa for the development of welding robots; the Babcock group market a welding robot made by its Italian subsidiary; (a wide range of robots, also made in Italy, is offered by Fairey Automation in addition to the Norwegian Move-O-Matic range). These include the Jobot 10, the DEA Pragma A3000, Camel, Gaitto and Elfin. Lansing Bagnall and Haden Drysys both have marketing agreements with Hitachi, the former through Lansing Industrial Robots which market Hitachi's general purpose and arc-welding robots. Haden Drysys distribute Hitachi paint spraying robots. Lansing Bagnall has also carried out application work on the Unimation Puma robot on electrical wire loom threading and it is thought that this technology will be licensed by them.

The Government is keen to see a British-based robot manufacturing industry which it hopes will be able to supply the ever-increasing needs of other industries for robots and associated equipment. It has been active in encouraging the kind of agreements made between Dainichi Kiko and Sykes and it hopes that this will be the forerunner of other such joint ventures. GEC has held discussions with two Japanese robot manufacturers - Hitachi and Yaskawa - which make electrically driven robots for arc welding and positioning. It may decide to develop its own electrically driven robots through its subsidiary Hall Automation which already has experience of developing hydraulically driven robots of this type.

Wildish[6] has suggested that there are nearly 40 robot suppliers in Britain "in varying degress of readiness to supply. The upshot looks likely to be too many companies jostling for too little work." Survival in this environment may be determined largely by marketing, sales and service capability. This augers badly for British suppliers - unless some of them are successful in these areas of traditional British weakness.

The Creative Strategies[7] study predicts that Japanese companies could repeat their performance in the machine tool business and enter the US and European markets late but with competitively priced and sized products delivered on time. These products could "flood both the US and European markets in 1983-84 ..." IBM's recent move into the robot market is aimed at the late 1980s when the world robot market will be booming at two to three billion dollars compared to the present 170 million dollars. It is thought that IBM sees robotics and factory automation as a new industry for it to dominate in the long run, as the now nearly saturated mainstream computer market becomes less attractive. This would put even more pressure on British robot manufacturers and suppliers.

II. Impact on Employment and Working Conditions

(i) Impact on Employment

The job-displacing effects of introducing robots depend on the particular application the robot is used for. Golding[8] has suggested that there is a "widely-held view that a robot installation replaces on average five people". With over 700 robots now installed in Britain this would mean that some 3,500 jobs have been lost through

---

[6] Michael Wildish, "Robots : a fight for survival", The Engineer, 6 May 1982.

[7] Creative Strategies, op. cit.

[8] Rob Golding, "The robot census is growing as robot senses develop", The Engineer, 4 February 1982.

the introduction of robots. He later notes that "a recent study suggested that 2 % of all factory jobs can be performed by robot and that figure could soar to 35 % with some elementary sensory abilities".

In contrast to this "widely-held view", Dr. Peter Davey, co-ordinator of the Science and Engineering Research Council's robotics research programme, believes that the maximum number of people a robot can displace is one or two, depending on the application. This would mean that nearly 1500 jobs at most had been lost - some 2,000 less than the other estimate. Davey goes on to say that even if 20,000 robots were installed by 1990 - an optimistic estimate - there would only be a loss of some 40,000 jobs and these would be mainly in difficult, dirty and dangerous environments. Furthermore, these losses would be offset to some extent by the 20,000 or so jobs created in maintaining, supervising and controlling that number of robots[9].

Neither of these estimates is clearly backed up by specified empirical evidence. Research conduted in Germany within the framework of the "Humanising Life at Work" programme and promoted by the Federal Ministry of Research and Technology hasincluded actual case studies of robot installation. These suggest that between 0.8 and 6.2 workers had been displaced per machine installed. The amount depended on the number of shifts worked, but there were more staff savings in parts handling than in tool handling and the maintenance and manufacture of industrial robots created considerably fewer jobs than are lost through the use of robots[10].

Some jobs are being created through robotics. The US-owned Control Data is planning to create 500 new jobs in its South Wales factory, many of these concerned with producing automated production equipment[11]. Similarly, 130 new jobs are anticipated in the British-Japanese cooperative

---

9 Electronics Times, 31 July 1980.

10 VDI Nachrichten,16 April 1982.

11 Guardian, 1 February 1982.

venture Dainichi Sykes Robotics, in Lancashire.[12]

(ii) Disappearance and Creation of Skills

The widespread introduction of robots in certain applications will certainly lead to some skills being displaced. Paint-spraying is one skill which may eventually be obsolete in factories, although the skill will still be required outside the manufacturing sector, in repair garages or specialist paint-spraying shops. Some welding jobs will also be lost, again in the automotive sector in particular, but there will still be many welding applications that can only be carried out by humans.

Another application where robots will replace the traditional skills is in the glass industry. A robot installed at the Smethwick factory of Chance Brothers, part of the Pilkington group,has replaced a team of craftsmen in producing radar cones and screens, in a variety of shapes and sizes for defence equipment. The human work involved lifting molten glass from a furnace at the end of an eight foot gathering arm, which was then rotated and manipulated until it was the right shape and texture to put into a mould. The operator knew when it was the right shape and texture from long experience - the apprenticeship for a gatherer can take eight years - and it took nearly two years to 'train' the robot. At first they tried to copy the craftsmen at work, but each man had a different way of doing things. The final solution was to give the robot its own, more consistent, technique. The only human element now needed is the occasional check by a foreman.[13]

Many robot applications in the future will be in semi-skilled and unskilled work such as assembly and materials handling where robots will be able to carry out the often monotonous and sometimes physically demanding work continuously.

---

[12] Guardian, 19 February 1982.

[13] Peter Large, 'Robots do away with apprentices', Guardian, 16 August 1980.

Although skills may be lost in production occupations there are also some areas where there will be a need for increasing skills. The traditional craft skills of the maintenance personnel are unlikely to be sufficient to cope with the ever-increasing sophistication of the atuomatic equipment. The integration of many diverse elements - pneumatic, hydraulic, electrical, and electronic - which are found in modern industrial robots require a broad base of skills. There are few multi-skilled maintenance engineers at present, but as factories become more capital intensive as more automated methods of production are introduced downtime becomes very expensive. The maintenance of the equipment becomes crucial if the benefits of increased productivity are to be realised. There is therefore a need to embark on a training programme to ensure that the correct skills are available to cope with the expansion of the robot population in British industry.

There will also need to be an increase in the technical knowhow of British management if robots are to be successfully introduced. There has been criticism of British management from several quarters on their approach to the introduction of automation. The Creative Strategies report, for exemple, states that "Industry in the UK has been slow to show much interest in robots or in the use of advanced manufacturing techniques... At board level in most major UK companies there is very little engineering experience and attitudes about manufacturing investment are extremely conservative."[14]

Golding notes that "analysis of major robot applications in Britain suggests that greatest single difficulty is finding people competent to build a feasibility study", and quotes John Collins, chairman of the British Robot Association Council, who says "There is a terrible dearth of people able to identify and implement capital investment ".[15] If British managment is to be able to assess the various robot systems, and carry out the appropriate investment then there is a need to ensure that more management receive some sort of technical education.

---

[14] Creative Strategies, op. cit.

[15] Golding, op. cit.

(iii) Impact on Work Organisation

The impact on work organisation varies according to the type of robot application in use. There will be most impact in those areas where the robots have been introduced as part of a manufacturing system rather than as stand alone units performing a particular task. These systems involve the linking of several machines together for batch production of metal components. They may be used to change the whole conception of batch production by producing sets of different components which can be assembled into complete sub-assemblies at the end of the process. The traditional methods of batch production mean that individual components are made in batches and then the machines are set up for another component, which is also produced in a batch etc. These are later assembled, again in batches. The result is that there is often a lot of "work-in-progress". The flexible systems allow the amount of work-in-progress to be cut down by the production of sets of different components thus saving on inventory etc., and giving better production control.

One such system has been running for two and a half years under the SCAMP project (sponsored by the Government as part of its Automated Small-batch Production programme) at the 600 Group. This consists of a line of machine tools linked by eight robots producing turned parts for the group's own lathes . They expect the system to produce parts from stock in three days as opposed to the current average of eight weeks.[16] The development of such systems will involve the increased linking of design and manufacture, through computer-aided design (CAD), process planning and production scheduling and they could be extended in the future to include automatic assembly if and when the technology

---

[16] 'Britain's FMS trailblazersé, Engineering Today, 22 February 1982.

for robot assembly of the components is sufficiently advanced.

In more specific applications of robots such as the use of a robot in the glass-making process the impact is loss wide but there are still changes required in the work organisation to allow the successful use of a robot in these specific applications. The robot in the glass factory resulted in a tightening of the whole production chain. When the experienced craftsworkers were making the glass products a less than perfect quality in the glass could be acceptable because the craftsmen were able to pick out the good bits. The robot is unable to do that so the quality of the glass now has to be uniformly high. As a result of introducing the robot, quality is up and rejection rate down.[17]

(iv) Impact on Working Conditions

Health and safety

Despite the fact that many robot installations are in potentially hazardous environments there is no special legislation with respect to health and safety for robots. At present the main legislation on health and safety is the Factories Act 1961, and the Health and Safety at Work Act 1974. These apply to all industry and are general rather than being specific to any particular type of installation. There are also numerous regulations which are more specific and thus robot installation is therefore subject to numerous legal requirements.

The Government's Health and Safety Executive (HSE) which is responsible for the inspection of factories etc. has set up a robot liaison committee with industry and is training its factory inspectors to deal with robots within the framework dictated by the existing legislation. The HSE feel it is unlikely that there will be any specific legislation in the near future because developments in robotics happen so quickly. This means that any legislation could be outdated very fast and robot users and manufacturers would be bound by legislation that was no longer relevant.

---

[17] Peter Large, 1980, op. cit.

In the absence of any special legislation the Machine Tool Trades Association (MTTA) has published a code of practice. According to Duncan Law from the Production Engineering Research Association (PERA) such a code is overdue. "There is a need for robot manufacturers to improve the safety features on their robots. Some do not even have an emergency stop button."[18]

The MTTA code of practice, which was drawn up in collaboration with leading robot manufacturers and users, may go some way to change things - but here is no legal requirement to follow the code. The code contains recommendations for the inclusion of various safety features including emergency stop buttons - which should be mechanical and not microprocessor based - and devices to stop the robot during the programming process if the teach control unit is dropped.

Shift work, length of the working week, etc.

Robots, unlike the humans that they replace, can work non-stop for twenty-four hours a day, provided that they do not break down and are supplied with the necessary materials to keep them going. It is for this reason that the impact on jobs is greatest in robot applications where shift work is the normal production method. Factories where robots have been installed are thus able to cut down on the numbers involved in night shifts. An extreme example of this is at the Fujitsu Fanuc factory in Japan where the majority of the workforce go home after the normal eight hour day shift having loaded up pallet changers and carousels with the necessary materials to feed the robots which serve the production machinery through the night. The installation consists of 23 NC machining centres and 7 lathes, the latter being served by Fanuc handling robots. The work pieces are transferred from

---

[18] Engineering Today, 7 June 1982.

the store to the machines and through the factory from machine to the inspection area and finally to the finished parts warehouse by means of automatic trailers. The factory is unmanned at night save for one man who sits in the central computer control room where he monitors the whole process.[19]

Such installations have not yet been introduced in the UK and since the SCAMP project (see above) have so far only been run on a one shift basis, the effects on shift work have not been assessed. However, the increased automation is likely to reduce the amount of shift work done by human operators. As a result there will be more time spent during the day in making sure that the robots are fully loaded with work for the night. The increase in productivity that can be achieved by the introduction of robots through their ability to work non-stop are well documented. In Britain, for example, BL Cars was producing seven cars per man per year in 1979 whereas the robot-run Metro line produces 24 cars per man per year. At one stage of the welding process, 14 Unimate welding robots have been introduced, displacing two-thirds of the previous labour force involved in this part of the work.[20] Before robotisation 138 welders were involved, the number is now 38. Even greater labour reductions have been achieved elsewhere in BL.

III. Policies Towards Robotics

(i) Government Policy

Government policy in recent years has shown a growing interest in the field of robotics and automated manufacture. It shows this interest by means of encouraging awareness of the potential of robotics, by providing research grants through the Science and Engineering Research Council and by offering assistance to robot manufacturers and users through various grants and consultancy advice.

---

[19] John Hartley, 'Unmanned by night and manned by day', The Engineer, 19 November 1982.

[20] Laura Cotton, "Micro Makes the Mini", Cadcam International September 1981.

Awareness activities

The Government, with grant from the Department of Industry (DoI), set up the British Robot Association (BRA) in 1977 to encourage manufacturing industry to make full use of the opportunities offered by the industrial robot. The BRA has four grades of membership designed to open up its membership to as wide a participation as possible. Company membership caters for suppliers and manufacturers of robots and associated equipment and potential robot users. A special membership category includes Government departments, research establishments, academic institutions, labour organisations and other non-manufacturing organisations. Associate membership is also available for similar bodies outside Europe and finally individual membership is available. This wide range of membership allows for the interaction of views and information exchange between all the main parties concerned in the development of robotics in Britain. The BRA arranges seminars and conferences where developments in robotics and associated subjects are discussed.[21]

The government has also supported the Production Engineering Research Associated which has held a large number of specialist discussion group seminars. As well as these seminars PERA runs the Robot Advisory Service which is an aid to companies interested in investing in robots (see below).

In a further move to assist dissemination of information about the application and manufacture of robots in Britain, the Government has commissioned a general film from the Central Office of Information. This film is designed to explain and illustrate the potential advantages of robot applications and to dispel 'unjustified fears' about their introduction.[22]

---

[21] 'Robots Friend or Foe ? - A Management Guide to Robots', BRA leaflet.

[22] C.C.W. Adams, (DoI), 'Robotics - A Government View', at the 4th Annual Conference of the British Robot Association, Brighton, May 1981.

Innovation

There have been several measures from the Government designed to promote the use and manufacture of robots in Britain. The first of these was the setting up of the automated small-batch production programme (ASP) in 1978. This was intended to be a long-term programme running from 1978 to 1983 with funding of some £ 14 million, half of which was to come from the DoI and half from private firms, to pay for flexible systems in batch production in British industry. There were problems with the project when two potential companies (GEC and BOC) decided not to go ahead with the introduction of flexible systems and the whole credibility of the scheme was put in jeopardy.[23] Other firms did go ahead with their plans most notably the system built at Normalair Garret and the SCAMP project at the 600 Group. Other systems havebeen introduced at Anderson Strathcylde and at Imhof-Bedco.

These measures provided only a small proportion of the money for investment that was recommended by the Ingersoll report[24], which has recommended that £ 250 million should be spent on the purchase of robots by British industry over a ten-year period together with a further £ 95 million in research, development, engineering and other items. The Government response was to make available £ 2.5 million, over the next five years, to the Science and Engineering Research Council (SERC) to develop second-generation robots. Sir Keith Joseph, the Secretary of State of Industry, said at the time that "the Government sees no need for new initiatives".[25]

However, this attitude changed considerably over the next year with the Government taking more positive steps to promote the installation of and the manufacture of industrial robots. The DoI announced help in the form of an application support package under the Product and Process Development Scheme. Under the terms of this scheme 25 % of the costs of a new process would be met by the Government to help cover tooling, development and installation costs, as well as going toward the cost of the actual robot itself.

---

[23] Peter Marsh 'Japanese robots are overtaking Britain', Guardian, 18 December 1980.

[24] Industrial Robots, NEL, 1980.

[25] 'Robot incentives "not necessary" ', Times, 12 April 1980.

The DoI also set up the Robot Advisory Service at PERA, whereby PERA staff provide a free initial assessment of the suitability of a robot installation. Where there appears to be a case for robot installation, PERA can undertake a full 15 day appraisal on a 50 % cost basis. Some indication of shifts in governmental attitudes was given in November 1981 when Kenneth Baker, Minister for Information Technology, forcefully declaimed in the House of Commons that manufacturing industry would soon face the choice of "automate or liquidate". Since the introduction of the DoI scheme in May about 80 projects had been approved or were in the pipeline.

Further Government aid to flexible manufacturing systems was announced in an extension of the ASP scheme.[26] £ 60 million in grants is to be made available over the next three to four years aimed at establishing a number of flexible manufacturing systems for batch production. Funding will takeplace on a selective basis with a minimum of £ 200,000 per project. About 20 projects are lined up for support, according to the DoI, ranging from £ 1 million groups of machine tools and robots to £ 20 million for a complete factory installation. The DoI expect the average grant to be about £ 4 million. £ 25 million of the £ 60 million is to be available for high risk projects involving considerable R & D, while the other £ 35 million is to be set aside for less risky schemes.

The DoI is also keen to support a British robot manufacturing industry and is currently providing support to the two principal manufacturers, Hall Automation and Unimation. Under the PPDS the DoI provide aid in the shape of a grant for 25 % of the eligible development costs for the design of new robots.

---

[26] 'Government aid for automatic plants', Engineering Today, 1982.

There is some feeling that the DoI applications grants are not sufficient and that the bureaucratic procedures involved in applying for the grants are contributing to the delay in the advance of robotics in Britain. The Creative Strategies report[27] for example says "...manufacturers and users alike believe the 25 per cent grant available for robot purchase is not sufficient and is merely delaying the implementation of possible orders while grant applications are processed".

Research and development

Most of the R & D sponsored by the Government in funded through the Science and Engineering Research Council (SERC), whose Robotics Programme is co-ordinated by Dr. Peter Davey of SERC's Rutherford and Appleton laboratories. £ 2.5 million was allocated to SERC for the development of second-generation robots in the hope that Britain could leapfrog existing technology, in which the lead was clearly lost. SERC will spend about £ 1.1 million in 1982 supporting 22 partnerships between industry and universities and polytechnics. Bodies like PERA are also involved but the industry/academic pairings are the main thrust of the research, which is concentrated in seven main areas. These are visual and tactile sensing and interpretation; co-ordination of mutliple hands and multiple robots; mobility; reduction of size and power consumption; improved load capacity; general purpose hands; and, finally, voice command recognition.

Firms involved in the partnerships include robot users as well as manufacturers and developers of robots or robotics software. Peter Davey says of the pairings "the SERC rarely commits funds for over three years to any project. We have now got over 20 industry/academic partnerships in operation, and all these are due to come up for review. The policy is to continue to back only the best, and we think that the number of robotics centres we support will come out at about ten."

---

[27] Creative Strategies International, ibid.

[28] 'A new robot generation', Engineering Today, 22 February 1982.

(ii) Employer and Trades Union Policies

There is no specific trade union policy towards the introduction of robotics. In its report "Employment and Technology" the TUC said "It is not just a question of accepting the new technology or of fighting it. The issue is how we can maximise its benefits and ensure that its benefits are equitably shared". Mr. Ken Graham, the TUC's assitant general secretary, told the fifth annual conference of the British Robot Association that robots would destroy jobs and the main issue was to ensure the replacement of those jobs by others or to cut working time. Workers will resist technological change introduced against a background of deflationary policies.[29]

The theme of the reduced working week was also the main point in an article written by Terry Duffy, President of the Amalgamated Union of Engineering Workers, in a report on industrial robots.[30] He said "I believe there is no alternative (to the introduction of robots). We have got to find ways and means of competing with the Japanese and we want a shorter working week. Robots provide both." He suggested an international trade union campaign to reduce the working week by ten per cent every five years which would result in a maximum working week of 26 hours in the year 2000, with paid retraining time added. However, the report in which this suggestion appears also says that managements' ignorance and fear rather than union resistance is the chief obstacle to the introduction of robots in British industry.

Rather less welcoming responses are forthcoming from other sections of the labour movement. An activist film-making group, Education Media, includes robotics among the threats to employment and the quality of working life in their New Technology. Whose Progress ?, which is being widely shown among trade unionists.[31] The emphasis in the film is on the ways in which

---

[29] 'TUC warns of resistance to growing use of robots', Times, 12 Mays 1982. For more on Technology and Employment, see earlier EPOS reports.

[30] Terry Duffy in 'Industrial Robots in Japan, US and UK', Inbucon Management Consultants Ltd., Advanced Technology Group, as quoted in 'The 26-hour work week could be here by 2000', Peter Large, Guardian, 3 February 1982.

[31] Reported in Engineering Today and other journals in summer 1982.

new technology is used to enhance management control over the workforce, and the point is made that alternative high technologies might make better use of workers' skills.

The same point is made in a less polemical report from the Council for Science and Society, entitled New Technology : Society Employment and Skill.[32] The convenor of the working group responsible for this report, Professor Howard Rosenbrock, is professor of Control Engineering at the University of Manchester Institute for Science and Technology, where he is leading a project designed to demonstrate the possibilities of designing new technologies so as to make the best of human responsiveness. He argues that while short-term economic rationality may imply a Taylorisation of labour processes, in the longer term even conventional economic benefits might be greater with non-Tayloristic choices. While the politics of new technologies are slow to be articulated, there are prospects here for technoloical design to be incorporated into future planning agreements in a non-zero-sum fashion.

Collective agreements

No information additional to preceeding reports.

IV. Bibliography

References in the text constitute a useful bibliographic guide to the positions of different interest groups and the research literature. CADCAM International is a useful news magazine oriented towards senior personnel involved in automation. Reports on robotics are frequently given in The Engineer; Engineering Today; and there is a quarterly named The Industrial Robot.

A major review of robotics in the UK is due this autumn : J. Fleck, 1982, The Introduction of Industrial Robots (London, Frances Pinter). Fleck is a member of the Technology Policy Unit at Aston University, where a Ph.D. thesis by R. Zermeno-Gonzalez (1980)

---

32 CSS Working Party Report, London, 1981.

The Development and Diffusion of Industrial Robots is also due for publishing, and Fleck, R. Moseley and E. Braun summarised TPU work in the area in a progress report (December 1981).

Another British source - less an overview of practice than a guide to robotics - is G.C. Simons, Robots in Industry, published by the National Computer Centre (1981). Kogan Page publishers offer J. Engelberger's Robotics in Practice (1981). Early next year Pluto Press are expected to publish R. Kaplinsky's Automation in Crisis.

The conference proceedings of the National Engineering Laboratory's Collquium on Robotics (1978) and the annual British Robot Association Conferences cover a wide range of topics.

Anders J. Hingel

ROBOTICS IN SCANDINAVIA

M. Anders J. Hingel
Institute of Organization and Industrial Sociology
Copenhagen School of Economics and Social Science
Howitzvej 60
DK-2000 COPENHAGEN F
DENMARK

INTRODUCTION AND SUMMARY

The Scandinavian countries have in various degrees been applying robotics in their industrial production. Sweden is by far the most advanced in the field. In fact, relatively to its population Sweden counts the highest density of robots in the world, about 1 250 robots in September 1981. Though the other Scandinavian countries have not reached such a figure,also there, robots have been set up extensively. The 65 robots used in Danish industry represent for instance the double of what is the case in France - relatively to the population.

There exist 5 major producers of robots in Sweden, and one in each of the three other countries (Denmark, Norway, Finland). It has to be noted that until 1979 , 52% of the Swedish production of robots was exported.

It is estimated that 2 300 robots will be used in Swedish industry by 1984, and about 6 000 robots by 1990. However, the growth rate of the number of robots is suspected to be around 17% per year at the end of the 80s' whereas the growth rate of the end of the 70s' was more than the double (38%).

As concerns the substitution of workers with robots, one reckons as a general rule that 0,5 worker is spared for each introduced robot. One observes though that the introduction of robots is seldomly followed by dismissals, and workers are generally transferred to other tasks within the firm. In completely new production lines, the replacement of workers by robots comes nevertheless to the fore.

A Swedish survey has shown that the average rate of accidents due to robotics is 1 accident per year for each 40 robots. Seen from a worker perspective, the major faculty of robots is their capacity to eliminate straining working conditions. 80% of Swedish robots were introduced with the declared aim to improve working conditions. For this reason, unions have generally adopted a favourable attitude vis-à-vis the application of robots in industry, but they have stressed at the same time that robots should be subject to specific work environment regulations, and that workers' influence on robotics represents a crucial issue which has to be paid greater attention in future developments.

I. TECHNICAL AND ECONOMIC ASPECTS OF ROBOTICS

Robotics - Definition

A great number of published studies as well as comments which are held on "robots" are not based on a clear definition of this term. Indeed, "robots" are mainly understood as technical aggregates to which the noun of "robots" is ascribed. It would therefore be appropriate to elucidate this term and to differentiate robots from other "machines" such as simple handling aggregates, numerically-controlled (NC) machine-tools and special assembling equipment. Robots have for instance been defined as follows:

> " A robot is a programmed machine for handling, which without continuous supervision, performs the posing of tools or materials according to one or several fixed patterns of movements " (1).

Most frequently though, the features of the possible space of operation, the degrees of freedom as well as the programming conditions are stressed with greater precision. This is for instance the case in the following definition:

> " An industrial robot is a machine which can, without manual control or steering, change the location of materials or tools in a three dimensional space to a great number of alternative points (or along a curve). The location and sequence can easily be altered, and the machine is movable " (2).

In the present report, we shall consider that the latter definition is, explicitly or implicitly, resorted to in most Scandinavian studies and statistics.

---

(1) Rosted, I., Jeppesen, B.P., Nielsen, J., Implemenentering og anvendelse af industrirobotter, Automatiseringsteknik, Teknologisk Institut, København, 1981, p. 5.

(2) Carlson, J. Harms-Ringdahl, L., Kjellén, U., Industrirobotar och Arbetsolycksfall, Kungl. Tekniska Högskolan, Stockholm, 198o, p. 5.

Industrial robots are often subdivided according to their function in the production process :

- handling robots: to fetch, to transport and to deliver materials or tools to a machine-tool.
- processing-robots:by carrying tools a robot performs tasks such as welding, painting, grinding, cutting etc.
- assembling-robots: a type of robot which presently counts among the least current ones (most assembling automats as for instance in the electronic industry are specialized assembling equipments). The present development of visual and sensorial capacities will have a major importance for the spreading of robots which belong to this category.

Spreading of robotics

The increasing application of robots in industrial production has been paid particular attention throughout the seventies. Although no official statistics on robots in Scandinavia are available, we dispose of numerous evaluations of the number of robots presently in use.

Robots in the Scandinavian Industry (1980)

Sweden	1 100
Norway	150
Finland	100
Denmark	50

Source: Veckans Affärer, nr.8, 26/2, 1981

More recently it has been estimated that the number of robots in the Swedish industrial sector amounts to about 1 250 , September 1981 (1). In this field, Sweden remains by far the most advanced of the Scandinavian countries. Moreover, relatively to its population, Sweden has got the world's highest density of robots. The developments which have occured in the other Scandinavian countries have not though shown insignifiant. And Denmark counts for example (always relatively to its population) twice as many robots as France that is about 65 robots in 1982(2).

In international comparisons, the problem of definition becomes even more evident. It is thus said that 80% of the robots in Japanese statistics are so-called pick-and-place units which are not considered as robots in Europe and the USA, and are therefore excluded from the above cited definition (3).

Sweden has been subject to the most spectacular development within robotics in Scandinavia. More specifically, throughout the seventies the number of robots has been increasing with 35-40% per year.

Number of robots in the Swedish industry 1970-81

1970	1973	1977	1979	1981
55	135	490	940	1250

Source: Statens Offentliga Utredningar 1981:10 p. 198; Sten H. (1982)

In 1977, the main users of robots in Sweden were: Volvo, Electrolux, Sandvik, ASEA, Seco tools, Saab-Scania and Facit. In fact, these seven firms used 63% of the total number of robots. And around 73% of the latter could be

(1) Sten, H., Användingen av Industrirobotar i Sverige, Sveriges Mekanförbund, Stockholm, 1982, (mimeo) p. 1.

(2) Interview with two representatives of the Danish Robot Association - Bo Petri Jeppesen, John Nielsen - 15th June 1982.

(3) Jern- og Maskinindustrien, Vol 8/3, 1978

found in firms that totalized 10 or more robots in their production lines. Such an impressive figure of robots in the Swedish industry is thus essentially due to large sized firms. Nevertheless, a statistic on the distribution of robots across plants shows that a growing number of smaller plants introduce robots. Whereas only 16% of robots were met in plants with 10 to 199 employees in 1977, 38% could be found in such plants in 1979. In short, in smaller plants the number of robots has been multiplied by four during these two years, but in plants with more than 200 employees their number has in the same period been multiplied by less than two. We are not in a position to verify if the increase observed in smaller plants corresponds also to an increase of robots in smaller firms, although several sources suggest that this is indeed the case. But many of the plants belong in fact to big firms (1).

The distribution of robots in Swedish plants according to the number of employees (1977 and 1979)

Number of employees	1977	1979
10 - 199	80 (16%)	360 (38%)
≥ 200	410 (84%)	580 (62%)
total	490 (100%)	940 (100%)

Source: Statens Offentiga Utredningar 1981: 10, p. 199.

The distribution of robots between industrial sub-branches reveals that the metal industry, mechanical engineering and the industry producing vehicules use by themselves the majority of robots (88%) in Swedish industry.

(1) Statens Offentliga Utredningar, Datateknik i Verstadsindustrin - Datorstödd konstruktions- och tillverksteknik, Rapport från Data- och Elektronikkommitén (DEK), SOU 1981:1o, Stockholm, 1981, p. 199.

Number of robots in various industrial sub-branches in Sweden (1979)

	Number	
Metal Working Industry	475	51%
Mechanical Engineering	145	15%
Electro-Industry	85	9%
Transport	205	22%
Instruments	0	0%
Other	30	3%
Total	940	100%

Source: Statens Offentliga Utredningar 1981: 10, p.199.

As to the products manufactured, robots are mainly in operation in productions of "components" and "investment goods" - 70% of all robots. The multitude of applications and the facility with which production switch overs can take place, make robots more suitable means of production than transfer lines - in situations of complicated and often changing products. The application of robots in the production of many mass consumption goods remains thus less frequent. The Swedish Commission on Data and Electronics (Data- och Elektronikkommittén) (DEK) has set forth the typical areas of application of robots in the Swedish industry and has compared this with the area of application of numerically-controlled machine-tools.

General tendencies as to the application of NC-machines and industrial robots in Sweden

	NC-machines	Robots
Yearly volume of production	<10 000 units	>10 000 units
Working cycle	>5 minute/unit	< 5 minute/unit
Variance of details	>10 variances	1-5 variances
Switch over of production	2-10 times/week	< 1 time/week
Production series	< 100 units	>1 000 units

Source: Statens Offentliga Utredningar 1981: 10, p.215

The 50 robots which existed in 1981 in Danish industry were used in 20 firms. The majority of these robots were applied in "machine loading", "surface coating" and "handling".

The areas of application of Danish robots (1981)		
applications	number of robots	
Machine loading	23	44%
Arc welding	6	12%
Surface coating	10	19%
Handling	8	15%
Others	5	10%
Total	52	100%

Source; The Industrial Robot n. 1, vol. 9, March 1982

Estimation of their future growth

Estimates relative to the future growth of robots in industry are numerous and reckoned to be inexact. In 1972, a Swedish professional estimation came to the result that 25 000 robots would be in operation by the year 1980! Such experiences call for greater caution not only as regards the estimation of future developments, but also - and first of all - as regards their interpretation.

It has thus been conjectured that future generations of robots can replace 75% of present industrial work (1). Business Week has evaluated the yearly market of 1990 to fluctuate between 23 000 and 200 000 units - the former figure established on the basis of presently existing firms and of stable prices, the latter figure reached in case of bigger computer firms (IBM, Texas Instruments, Digital Equipment) entering the robot market and in case

(1) Johard, C-O., Kostnadskrisen drev fram ny boom-produkt: industrirobotar, Veckans affärer, no 8, 26th February 1981, p.3o.

of prices falling to one-fifth (1). The General Director of Norway's largest firm producing robots (Trallfa), predicts no price reductions, but a segmentation and a specialization on the robot market (2).

The above mentioned Swedish Commisssion on Data and Electronics has published elaborate estimates concerning the application of robots in Swedish industry (3). As a general tendency, this Commission forecasts that the observed increase of the number of robots used in Swedish industry will be falling in the forthcoming years.

Number of robots in Swedish industry 1970-79 and estimates for 1984

	number of robots	yearly average increase of the number of robots
1970	55	
1973	135	35%
1977	490	38%
1979	940	39%
1984	2 300	20%

Source: Statens Offentliga Utredningar 1981: 10, p.426

This last figure of 20% yearly average increase of robots constitutes the result of an empirical survey among users as well as suppliers; it is thus considered that totally 2 634 robots will be supplied in 1984, but on the other hand all robots dating back to the years previous to 1976 will have been scraped before 1985.

Another forecast reveals that in the coming years, robots will be relatively more used in mechanical engineering (from 15% of all robots in 1979 to 23% in 1984) and in the

(1) Statens Offentliga Utredningar, op.cit., p. 348.
(2) Johard, C-O., op.cit., p.32.
(3) Statens Offentliga Utredningar, op.cit. p.413-438.

production of vehicules(from 22% in 1979 to 26% in 1984).

As to the size of firms and plants, it is foreseen that the 7 largest firms which in 1979 used 45% of all robots in Sweden (i.e.42 robots) will in 1984 use 35% (800 robots), but it is not the smaller plants that will benefit from this development. In fact, one estimates that plants with 10-49 employees will see their quota falling (from 32% (300 robots) in 1979 to 22% (500 robots) in 1984), whereas plants with 50-199 employees will increase their share in the total number of robots (from 6% (60 robots) in 1979 to 14% (315 robots) in 1985).

Further, estimates of the development in the years 1985-90 from the same commission show that the number of robots in industry will fluctuate between 6 000 (lower estimate) and 9 000 (upper estimate) which equals to growth rates lying between 17% and 26% at the end of the eighties. The calculation is built upon a number of assumptions as to the upper limit

- the number of netto applications in traditional areas of robotics (welding, machine loading, surface coating etc...) is expected to increase with 20% per year
- applications in new areas (assembling, quality control, arc welding) will amount to no more than 2 000 units (1).

Nevertheless, the commission deems the estimate of 6 000 robots in Swedish industry in 1990 to be nearest to reality and considers this as "undramatic"; "compared to the employment level of 1977, the number of robots should (thus) correspond to 2% of the number of workers" (2).

---

(1) Statens Offentliga Utredningar, op.cit.,p.433.

(2) op.cit. p.436.

Trade and commercial balance of robotics

Robots have been produced in Sweden since 1967. Kaufeldt AG was in fact the first West European firm to produce and sell such machinery. And Swedish firms have since then confirmed their strong position on this market. On about 3 000 robots produced in Western countries in 1981, about 800 were produced by 4 Swedish firms, ASEA, Electrolux, Atlas Copco and Kaufeldt, dominant on the Swedish market. One observes that 55% of robots used in Swedish industry come from five national producers.

ASEA - 7 to 8% of robots used in Sweden

ASEA has produced 500 robots in 1980, about 700 in 1981 (200 mill.SKr) and suspects to produce 2 000 robots per year in 1985. Its division of robot production counts 500 employees. Its export quota is about 90% (1980/81). 16% of robots in West Europa and 5% in the USA come from ASEA.
ASEA's robots have a vast area of application: mounting, handling, surface coating, welding etc...

Electrolux (bought up in April 1981 by ASEA) - 19% of robots used in Sweden

Electrolux has been producing robots since 1970. In 1981 and under the ownership of ASEA, its production amounted to 100 robots mainly for handling and machine loading.
Altogether, ASEA and Electrolux have, until 1981, accumulated a number of sales of 2 000 robots.

Atlas Copco - 1% of robots used in Sweden

A more recently established producer of surface coating robots.
Its production counts around 50 robots in 1981.

Ekström Industri AB - 5% of robots used in Sweden

A "pick and place" robot which may be is too simple an aggregate to be classified as a "robot". This firms is now developing more sophisticated multifunctional robots.

Kaufeldt (at the beginning of 1982 its production restarted under the name Arbot) - 22% of robots used in Sweden

It started as the first West European producer, which by the year 1982 had produced a total of 500 robots mostly applied in macine loading. The firm has changed hands several times and had lately, in January 1982, to suspend its payments; a reorganization took place consequently. Kaufeldt (Arbot) covers about 9% of the West European market of robots.

Other important brands of robots on the Swedish market are the American Cincinnati - Milacron (8% of robots used in Sweden) and Unimation (9% of robots used in Sweden). Relatively to their market position outside Sweden - especially as concerns the latter dominating 35% of the West European market - these firms stand in a rather weak position in Sweden.

This notwithstanding, 80% of robots utilized by Volvo before1977 were delivered by Unimation. Moreover, Volvo has recently signed a contract of 100 Cincinnati for its Volvo 764 production line. It should also be noted that Volvo has itself developed, produced and, on a limited scale, sold a type of robots especially conceived for handling of materials. 100 robots of this type have, until now, been sold outside the firm.

Also the Norvegian firm Trallfa plays an major role on the Swedish as well as on the world market. It represents respectively 17% of the West European market, 6% of the American market and 10% of the Swedish market. Since the start of its robot production at the end of the 60s', this firm has sold 600 robots mostly applied in surface coating processes. One has to stress that 90% of its production is exported and its yearly production is about 100 units.

Below a general overview of the Swedish trade-balance of robots in the Swedish industry is given.

Production, import, export and supply
of industrial robots in Sweden (1979)

	until 1975	1976	1977	1978	forecast 1979	accumulated number&value
national production						
number of robots	540	150	275	315	460	1 740
value (mill.SKr)	47	29	58	73	102	309
export						
number of robots	85	65	120	190	245	705
value (mill.SKr)	10	14	29	50	59	162
import						
number of robots	120	15	25	40	54	254
value (mill.SKr)	20	4	7	12	15	58
supply						
number of robots	575	100	180	165	269	1 289
value (mill.SKr)	57	19	36	35	58	205
Export quota (value)	21%	48%	50%	68%	58%	52%
Import quota (value)	35%	21%	19%	34%	26%	28%

Source: Statens Offentigar Utredningar 1981: 10, p.178.

Also in Finland do we find a national production of robots in the firm called Rosenlew.

Robots aiming at applications in plastic founding processes have been promoted and sold by the Danish firm Bjørntoft og Søn, the only Danish firm producing robots. The robot market in the latter country is, generally speaking, dominated by the same firms as is the case in Sweden: ASEA, Electrolux, Trallfa, but also Japanese robots can be found.

II. IMPACT ON EMPLOYMENT AND WORKING CONDITIONS

Impact on employment

The Swedish social-democratic "programme for a data-policy" provides an example of consequences on employment induced by the use of robots in the Swedish automobile industry. 1 200 employees were affected by the introduction of robots in a specific firm, and until now the workforce has been reduced by 100.

> " But at the same time it became evident...that the 1 200 employees could, by a complete application of data-technology, be reduced to 18! " (1).

One has also referred to the spectacular 50% reduction of the 37 000 employees in General Electrics after the introduction of robots in its production; and one reckons that 75% of employees in industry can be replaced by future robots with sensorial and visual capacities (2).

The ability of robots to supersede workers is thus understood as being manifest. And numerous cases sustain such an assertion. A Danish case-study reveals that in half of the investigated firms (3 out of 6), managers put forward the "reduction of wage costs" as the primary motive for introducing robots (3).

---

(1) Socialdemokraterna, Datorer på människans villkor - Program för datapolitik, Stockholm, 1979, p.31.

(2) Johard, C-O., op.cit., p.31.

(3) Rosted, I. et alii., op.cit., p.2o.

A general rule which is often set forth tells that 0,5 worker is spared for each introduced robot (1).

A Swedish study assessed for example that the 130 robots which came into operation in the years 1976-77 in Sweden superseded an equal number of workers, but at the same time 65 jobs were created (supervision of robots, reparation and maintenance) (2).

On the other hand, the earlier mentioned Danish study proved that in no case was the replacement of workers followed by dismissals of workers. In all Danish cases, workers were transferred to other jobs within their plant (3).

The report from the Swedish Data and Electronic Commission provides an estimate as regards the forthcoming substitution of workers by robots. It forecasts that 5% of assembling workers in industries manufacturing computers and office machines, domestic equipment, automobiles and motors will have been replaced by 1990. The present 25 000 assemblying workers will thereby be subject to a cut down of 1 250 in their workforce (4). However, the commission puts emphasis on the point of view that

> " nothing seems to indicate that the total level of employment should follow a negative direction as a result of the introduction of new techniques. (...) The level of employment (...) depends in a high degree on the employment policy which is carried out " (5).

---

(1) Östberg, O., Projektplan: Industrirobotar - Arbetsmiljö - Konsekvenser. Högskolan i Luleå, 1978 (mimeo) p.1.

(2) Rosted, I. et alii., op.cit., p.67.

(3) op.cit. p.53.

(4) Statens Offentliga Utredningar, op.cit., p.433.

(5) op.cit. p.272.

In another report, the commission also stresses that

> " no danger for employment will be present as long as productivity increases resulting from the introduction of data-technology are effectuated in order to enforce actions for developing new products and services " (1).

Qualifications

Both analytically and empirically it has been shown how the introduction of robots - as well as other types of new technology - severely challenge former qualification demands in production. Required skills and professional experiences are redistributed between former and new work functions, and tend to become even more abstract, standardized and formalized.

A Danish study on qualification demands examined in ten firms the major work functions, that is, programming, operation and supervision of machines, loading and unloading of tools and materials, maintenance, fault detection and reparation (2).

The programming work-functions vary according to types of robots and control systems. Two examples of programming are given. The first example where programming takes place at a distance from the robot by a relatively simple manual or automatic (digitalizer) registration of co-ordinates, demands the following qualifications: product- and product variety knowledge, a good sense of colours (details of the product are often multi-coloured), planning capacity (the choice of opetion sequences), faculties for operating auxiliary tools (i.e. for example a digitalizer), and data disciplin.

---

(1) Statens Offentliga Utredningar, Industrins Datorisering - Effekter på sysselsättning och arbetsmiljö, Betänkande av dataeffektutredningen, SOU 1981:17, Stockholm, p.67.

(2) Clematide, B., Olesen, K., Mikroelektronikudviklingen og Kvalifikationskrav - med særlig hensyn på CNC-værktøjsmaskiner og industrirobotter, Erhvervspædagogik, Teknologisk Institut, København, 1982, p.46-49.

Another example is given where programming is done by the robot itself by series of corrections in case of deviations from a standard programme. In this situation qualification demands in the programming function are more manual and more craft-related; qualification demands cover then: technical knowledge of the robot and its capacities, technical sensitiveness, general manual faculties etc...

Consequently rather different qualification demands are required depending on the technical composition of the robot system. In cases where the "play-back" method is applied (a registration of workers' "manual" work process, which is for example used by the Trallfa robots), the "programming function" requests quali-lifications of a highly experienced worker. Moreover, the qualification demands of <u>reparation</u>, <u>fault detection and maintenance</u>,functions are generally described as beying the following: a profound technical knowledge of the robot, diagnostic capacities, knowledge about the use of various auxiliary tools, certain manual capacities in the execution of mechanical precision work etc...

As to the <u>operation and supervision</u> of robots the report concludes that importance is attributed to <u>elementary manual faculties</u> and to <u>work motivation</u>.

The conclusions of a Swedish case-study on the development of qualification structures due to robotics in welding read as follows:

> " The role of the welder has been taken over by the worker who feeds the robot. This worker does not need more knowledge about welding than what is necessary to control the welding-result. The welding method has been built into the programme. But the programmer increases his knowledge on welding techniques " (1).

---

(1) Statens Offentliga Utredningar 1981:17, op.cit.,p.65.

The concrete qualification demands from employees working with robots will derive from the technical composition of the system and from the specific organization of the work process. Therefore questions like, does the supervisor of the work process also control the product, does he make programmes, reparation, maintenance etc..., become here essential.

Organization

In the above cited Danish case-study on robots, an account is given of 4 examples of the organization of work by robots.

DIVISION OF LABOUR AT WORK WITH ROBOTS

FIRMS	programming, test of programs	work preparation, tool preparation	operation & supervision of robots, loading & unloading	control of the product	maintenance, reparation, fault finding
A	XXXXXXXXXXXXXXXXXXXXXXXXXXX		XXXXXXXXXXXXXXXXXXXXXXXXXX		XXXXXXXXXXXX
B	XXXXXXXXXXXXXXXXXXXXXXXXXXX		XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
C	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXX		XXXXXXXXXXXX
D	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX

Source: Clematide B. and alii, 1982, p.31.

As it is shown in the table two characteristics stand out. In none of the firms, are the functions with the highest qualification demands "maintenance, reparation and fault detection" integrated with any other function. And in none of the firms are the functions "operation and supervision, loading and unloading" and "control of the product" integrated with "programming" and "preparation" functions. Apart from these exceptions, all combinations of work functions can be found.

The organizational implications of the two mentioned basic partitions of work functions are of major importance. One can for instance remark that from such an organization it results that the control over the concrete execution of the production is, to a greater extent, transferred from the workshop (workers, foremen) to higher hierarchical levels in the firm (programmers, engineers). Union organizations claim a more "democratic work organization" that comprises a higher integration of work functions. A Swedish report from the Ministry of Labour lays stress on the fact that new technology offers new possibilities for building up new forms of team and group work thanks to the co-operation between various groups of employees which would be based on an enlargement of professional knowledge.

Impact on Working Conditions

Health and Safety

At the end of 1978 did the Swedish Metal Worker Union (Svenska Metallindustriarbetareförbundet) carry out an inquiry on work accidents related to work with robots. Until now it remains the only Scandinavian study of the kind. Answers from firms using a total of 220 robots (half of all robots used in Sweden) were received . The conclusion of the study was that the average rate of accidents with robots amounted to 1 accident each year for 40 robots (1). Results show that many of these accidents occured when the operator was situated inside the restricted area of robots trying to cor-

(1) Carlson, J. et alii, op.cit., p.7.

rect technical faults or occupied with cleaning.

The aim of bettering working conditions constitutes generally an important ground for the introduction of robots. A Danish study states that in the examined cases "the wish to improve working conditions was in general predominant"(1). A Swedish study on the setting up of 600 robots came to the conclusion that 80% were introduced in order to fight bad working conditions such as monotonous work (40%), work under high temperature (10%), "heavy work (10%) etc...(2).

In general we observe rather few manifestations of improved working conditions after the setting up of robots. One of the reasons for this , can be found in the fact that robots are often placed in the same bad work environment than the former machines. Another reason results from the fact that robots may remove some of the physical strain from work, but they tend on the other hand to create a new strain of a more psychological nature. Work with robots has a tendency to be monotonous, one-sided, physically straining, short cycled, non-developing, stressing and unqualified work (3). It has even been said that robots tend to be used in so-called "improvement deteriorations" of working conditions (4).

It is especially the stressing side of work with robots which has been emphasized:

> "Work tasks with robots represent an unfortunate blend of long lasting monotonous and sporadic actions, to perform in short periods,demanding a high level of attention and alertness"(5).

---

(1) Rosted,I. et alii, op.cit., p.2o

(2) Sten,H., Industrirobotinventeringen i Sverige, Sveriges Mekanförbund, Stockholm, 1977 (mimeo).

(3) Östberg,O. op.cit., p.4.

(4) ibid.

(5) op.cit.,p.11.

In Scandinavia robots are subject to the same regulations as "machines" in general. Work environment regulations concerning specifically robots do not exist yet. The Swedish National Agency of Work Environment (Arbetarskyddsstyrelsen) has got however plans for providing such types of regulations.

Let us examine the recommendations of the already cited Swedish work group of the Technical University in Stockholm on work accidents resulting from work with robots.

> "Purchasing and installation of robots : in the purchasing situation shall the question of workers' protection be taken up which requires among others the seller's obligation of information. It has to be made clear if it is the seller, the installator or the employer (of the buying firm) that shall carry out pre-protection of the robot.
>
> The lay-out of the workplace : the workplace shall be provided with an effective screening and the operation-panel shall be situated outside the operation-area of the robot. In the programming, lighting shall especially be satisfactory.
>
> The robot-design : an emergency stop shall exist. It shall make sure that dangerous movements are stopped, that discharging is effectuated and that working materials are not released if it implies any danger for the personnel. It shall also be the rule that restarting only can take place by means of an operation-knob. A special operation-knob conceived for starting up the machine shall exist, and automatic starting shall not be possible (...) The travelling part of the robot shall be coloured in a distinctive way and a signal - operated by automatic control - shall exist with the function

to inform when the robot is in motion and when it is about to move.

General protection rules : the need for the personnel to be located inside the operation area of the robot when the robot is not discharged , shall be eliminated whenever it is possible. Mounting of equipment shall only be executed when the robot is discharged, and adjustments when the robot is both discharged and situated in a predetermined position. Programming shall be achieved from an operation place outside the operation-area of the robot, and while the system is discharged. Only personnel with special education can be allowed to programme and only for one hour at a stretch. A special inspector shall be responsible for the security of robots in the firm. The various producers of robots should standardize the parameters that describe the characteristics of robots." (1)

The need for such regulations has often been expressed. And its has especially been stressed that the ongoing development in the field of robotics towards robots with sensorial and visual facilities (like they already exist with the PUMA-robot from Unimation) will present a new type of risk for the employees who on their side enhance their demands for work environment regulations within this specific field (2).

---

(1) Statens Offentliga Utredningar 1981:17, op.cit., p.13o.

(2) Carlson, J., op.cit., p.19.

Shift Work

In cases of substantial investments in robots (or other types of automation) "shift-work" is often considered as an integrated element in the reorganization of production. In other situations where only one or a few robots are introduced such a restructuring of working hours seldomly takes place. The relative importance of the invested capital is thus frequently presented as the basic argument for the setting up of shift-work.When working in one shift, machines are only used during 17% of the hours in the year; in 2 shifts 29% and in 3 shifts 50% of the hours of the year (1).

The introduction of robots induces socially, physically and mentally straining work such as shift work,proved to be harmful by numerous studies. But on the other hand, it is also expected that in the long run robots and other types of automation processes lead towards the disappearance of shift-work. Robots and other types of automation technologies make it thus possible to man the machines during the day shift,and subsequently,to let the machines work alone at night.The machines are therefore loaded and unloaded, maintained,and the production planned etc...in the day time.At night as well as during work pauses during the day, the machine produces autonomously. In Sweden one describes this type of work(time) organization as "production with reduced manning" (produktion med begränsad bemanning). Saab-Scania for example applies such a system in several of its plants (2).

---

(1) Statens Offentliga Utredningar 1981:17, op.cit., p.121.

(2) Affärsvärlden, 26th January, no 4, 1982; Östberg,O., Sverige robottätast i världen, Forskning och Framtid, no 3 1980, p.25.

III. POLICIES TOWARD ROBOTICS

Government policy (Research and Development)

Research and development in robotics has been subject to governmental attention in most Scandinavian countries although its has never represented a priority area.

R & D in robotics has amounted to nearly 19% of the the total sum allocated by the Swedish National Board for Technical Development (Styrelsen för Teknisk Utveckling) (STU) to research and development in the field of "computer based construction and manufactoring techniques" in the years 1972-79. Altogether about 4,3 mill. SKr have in that period been attributed to R & D in robotics, in comparison for example to 9,5 mill. SKr given to CAD/CAM techniques.

Financial support from the Swedish National Board for Technical Development (STU) in the field of computer based construction and manufacturing techniques 1972/73 - 1978/79 in thousands of S. Kr.

	1972/73 1975/76	76/77	77/78	78/79	Total
Research					
-robots			350	388	911
-other (CAD/CAM, NC, CNC, DNC, etc.)	1 209	841	1 751	2 687	10 231
Industrial Development					
-robots	459	1 222	466	915	3 276
-other (CAD/CAM, NC, CNC, DNC, etc.)	505	1 052	1 471	3 970	8 027
Total	2 173	3 115	4 038	7 960	22 445

Source: Statens Offentiga Utredningar 1981: 10 p.298

The Technical University of Linköping (Linköpings Tekniska Högskola (LiTH) represents one of the important institutions in research and development regarding robotics. These research programmes are financially supported by STU and have been directed especially towards the development of assembling-robots (1).

Direct co-operation between public research institutions and producers or between producers and users of robots is seldomly seen. Swedish producers of robots look more at these public insitutions as "sources for recruting personnel" (2).

In Norway research and development is mainly concentrated at SINTEF and at the Central Institute of Industrial Research (Sentralinstitutt for Industrial Forskning) (SI), both being financed by the Norvegian Technical-Scientific Research Council (Norges Teknisk-Naturrvitenskapelige Forskningsråd) (NTF). Contrary to Sweden, an extensive co-operation takes place in Norway between the mentioned research institutions and the producer(s) of robots. This is the case for the Norvegian firm Trallfa and even for foreign producers settled in Norway such as Volvo for example.

As far as Denmark is concerned no research and development in the field of robotics seems to take place, except in the sole producing firm Bjørntoft og Søn. The Technical Institute of Copenhagen (partly financed by the Technology Council) has been playing an active role in the application of robots in Danish industry. And the Department of Automation Techniques within this Institute has thus been working in this field for the last ten years. To this Department the newly formed Danish Robot Association (Dansk Robot Forening) has recently been connected (3).

---

(1) Johard, C.O., op.cit. p.33.

(2) Statens Offentliga Utredningar 1981:1o, op.cit., p.191.

(3) The Industrial Robot, vol 9/1, 1982, p.5.; Automatiseringsteknik, no 11, 1982, p.6.

Unions' attitudes

Generally speaking, Scandinavian union organizations look upon robotics within industry in a favourable way. Most unions stress the necessity for an even stronger effort as regards the application of new technology in industry in order to be able to improve the international competiveness of industry. Brigitta Frejhagen from the Swedish LO has thus asserted that

> " Indeed new technology eliminates jobs, but the real risk is that we lose even more jobs if we do not use new technology " (1).

Certain "doubts" do although manifest themselves among workers and their union representatives within firms. The cited Danish study on "the industrial implementation and use of robots" comes to the conclusion that shop stewards and employees "in many cases ... and at the beginning, regard industrial robots with scepticism, based both on the fear of dismissals and on a mistrust as to the capacities of robots to perform the work-capacities in question in a satisfactory manner" (2). Workers seem in fact very often to cast doubts on the capacities of new technology. A Swedish survey showed for instance that 90% of metal workers in rolling-mills did not believe that their work tasks could be automated (3).

One of the major reasons for the positive employee and union attitude vis-à-vis robots lies in their capability of diminishing straining physical working conditions.

---

(1) Johard, C-O., op. cit., p.33.

(2) Rosted, I. et alii, op.cit., p.54.

(3) To rslin, J., Arbetsorganisation avgör om automatiserat jobb blirr mänskligt, Arbetsmiljö, no 5, 1976, p.12-14

In 1975, a Swedish representative of LO reckoned that 80 000 jobs in Sweden were characterized by such bad working conditions "that there existed very good reasons for introducing robots" (1). In order for robots to be able to fulfil such a work improvement mission, it appears though imperative that the development and use of robots are regulated thanks to work environment regulations and that unions and their representatives have got a say on decisions about robotics within the firm.

The Council of Nordic Trade-Unions (Den Nordiske Faglige Sanarbejdsorganisation) (NFS) has put forward directives for the use of computers and computer-based equipment in which robots are explicitly referred to

" - Computers and robots shall be set up within firms on work environment grounds as well as on productivity grounds.
- Data-techniques must play an important role in work environment research (...)In order to diffuse research experiences, an international co-operation is indispensable.
- Computers shall not be used so that they induce an increasing need for shift- and part-time work.
- Working condition directives should constitute the background for the design of computer terminals and other data work places.
- A diminished vulnerability of data-systems shall not be obtained at the expense of a deteriorated work environment.
- An international union co-operation is required in order to exchange experiences and to present claims on the way data-techniques can be used in concordance with union demands as to a bettered work environment " (2).

---

(1) Östberg, O., 198o, op.cit., p.25

(2) Nordens Fackliga Samorganisation, Riktlinjer för Nordisk Fackligt Arbete med Datafrågor, Stockholm, 1979, p.21.

Collective agreements and workers' influence

The introduction of robots like the one of new technologies is regulated as to information, consultation, negotiation and training rights by numerous agreements and Acts. We are not aware though of any specific "robot agreement" in Scandinavia.

In Norway the setting up of robots will thus mainly be regulated by The Frame Agreement on Technological Change and Data Systems (LO-NAF)(1981) and the Work Environment Act of 1977; in Sweden mainly by the Act of Co-determination at Work of 1976, The Work Environment Act of 1977 and by the so-called Development Agreement of 1982 (LO-SAF-PTK); in Denmark mainly by The Co-operation agreement of 1977 (LO-DA) and its additional agreement , The Technology Agreement of 1981.

We shall not here present in great detail these Acts and agreements (see Bulletin n°9), but only outline their general characteristics related to the issue of robotics in industry. All three environmental Acts prescribe the setting up of various formal forms of organization concerning work environment improvement actions within firms. The Security Group in Denmark, the Security Committee in Sweden and the Work Environment Committees in Norway will thus play a crucial role in the regulation of working conditions connected to the introduction and use of robots in the single firm. A similar and often overlapping function has been attributed to the extensively created special commissions on technological change in the firms through the various co-determination, co-operation and technology- agreements and Acts.

It should nevertheless be pointed out that in no case will the employees have a real say as to the choice of robots , their lay-out and their ways of use. An extensive right of information rights as well as different degrees of consultation and negotiation are recognized, but no obligation to conclude rests upon the parties. The employer's right "to direct and distribute work" is thus preserved.

The introduction of robotics as well as any type of technology unknown to the employee calls thus for special attention as to the obtention of information. The use of specialized and advanced techniques requires also great bargaining skills and a high degree of expertise on behalf of employees' representatives. It has to be remarked that the exchange of knowledge on robotics plays a prominant part in the above mentioned recommendations from the Council of Nordic Trade-Unions.Therefore,knowledge on robotics, its developments, its consequences and its possible ways of use is thus collected and diffused to union members. In Denmark, the Union of Semi-Skilled Workers (Specialarbejderforbundet) has, for instance, initiated a research project financed by the Council of Technology, i.e. the so-called PUMA-project, aiming at analysing future technological developments in the iron and metal industry and at producing information material to the union. A number of such "Info - Packages" on robotics have recently been produced. (1).

As we have seen throughout this report, robots are often introduced because they represent an economically sound way of eliminating bad working conditions. A danger appears here in the fact that such a direct positive consequence tends to overshadow a more "holistic" evaluation of possible consequences. As an illustration of this point , let us quote an extract from a Swedish official report:

---

(1) Fagbladet, 1oth April, no 7, 1982.

" An investment in industrial robots is seldomly made in order to replace an old machine. One seeks instead often to eliminate too straining work-tasks. The results, consequent to the setting up of robots are in general the same : working conditions are improved, monotonous work-tasks disappear etc...But through the accumulation (of robot installations), the whole production technique is changed, and over that employees have only got a minimal influence " (1).

****

---

(1) Statens Offentliga Utredningar 1981:17, op.cit., p.161.

Selected Bibliography

Afdelingen for Automatiserings (1978), Jernets Fremtidsprojekt - Automatiseringsteknik, Teknologisk Institut, Copenhagen.

Carlson, J., Harms-Ringdahl, L., Kjellén, U. (198o), Industrirobotar och Arbetsolycksfall, Kungl. Tekniska Högskolan, Stockholm.

Clematide, B., Olesen, K. (1982), Mikroelektronikudviklingen og Kvalifikationskrav - med særligt henblik på CNC-værktøjsmaskiner og industrirobotter, Erhvervspædagigik, Teknologisk Institut, Copenhagen.

Johard, C-O. (1981), Kostnadskrisen drev fram ny boom-produkt: industrirobotar, Veckans Affärer, 26th February, no 8, p.3o-33.

Karlson, U. (1975), Industrirobotar tar över tunga svetsjobb, Verkstäderna, 15th October, no 13, P.35-38.

Niemi, A. (198o), Nästa robotgeneration kan se, Forskning och Framtid, no 3, P.29-33.

Nordens Fackliga Samorganisation (1979), Riktlinjer för Nordiskt Fackligt Arbete med Datafrågor, Stockholm.

Socialdemokraterna (1979), Datorer på människans villkor - Program för datapolitiken, Stockholm.

Specialarbejderforbundet (198o), Teknologiens udfordinger til Fagbevægelsen, Copenhagen.

Statens Offentliga Utredningar (1981), Datateknik i Verkstadsindustrin - Datorstödd konstruktions- och tillverksteknik. Rapport från Data- och Elektronikkommitén (DEK), SOU 1981:10, Stockholm.

Statens Offentliga Utredningar (1981), Industrins datorisering - Effekter på Sysselsättning och Arbetsmiljö. Betänkande av Dataeffektutredningen, SOU 1981:17, Stockholm.

Sten, H. (1977), Industrirobotinventeringen i Sverige, Sveriges Mekanförbund, Stockholm. (mimeo)

Sten, H. (1982), Anvädingen av Industrirobotar i Sverige, Sveriges Mekanförbund, Stockholm. (mimeo)

Östberg, O. (1978), Projektplan: Industrirobotar - Arbetsmiljö - Konsekvenser, Institut for Arbetsvetenskap, Högskolan i Luleå, Luleå. (mimeo)

Östberg, O. (198o), Sverige robottätast i världen, Forskning och Framtid, no 3, p.18-25.

M. P. PIACENTINI

ITALY

M. P. PIACENTINI
Istituto di Economica
Facolta' di Statistica
Via Nomentana 41
I-00161 ROMA

TECHNICAL AND ECONOMIC ASPECTS OF ROBOTICS

PROBLEMS OF DEFINITION

The definition of a "robot" is still the subject of some controversies in the technical and scientific community in Italy, and it is hard to see, from the specialized literature on the subject, any universally accepted solution. The controversies mainly concern the delimitation of a more or less extensive field of operations and characteristics defining the robot, and of the boundaries separating it from other applications of electronically controlled technologies to manufacturing processes,such as the numerically controlled machining tools and "special purpose" automated plant machinery.

In a recent conference organized by SIRI (Societá Italiana di Robotica industriale), a leading scientific expert defined the robot as : " any system endowed with an electronic "brain" , and operating apparatuses which allow an interaction with the external world". * Such a definition is more general and has a wider field of application than the more traditional concept of the "industrial robot", which essentially consists in specific, electronically controlled apparatuses "oriented towards the manipulation and processing of parts and instruments in discrete manufacturing activities". The basic components of such a machine are seen to be therefore: a) a system of electronic controls which enable it to memorize cycles of operations; b) operating apparatuses, which can be more or less closely assimilated to an antropomorphic description of "arms and hands"; c) a powering system (hydraulic, electric, etc.); d) in more advanced applications, "sensorial" devices (positional,image processing, tactile, etc.) which are able to interact with the environmental conditions and to feed back information to the control centres.

---

* Prof.M.Somalvico,of the Politechnic of Milan. The Conference "Stato attuale e prospettive della ROBOTICA IN Italia" was held in Milan,4/5 March 1982.

These characteristics should be sufficient to separate industrial robots from other kinds of automated machinery, (such as numerically controlled lathes, or simple" pick and place " mechanical arms). Obviously, the concept of "industrial robot" is still somewhat limited, if, following the more general definition given above, we can imagine the future dissemination of robots outside manufacturing processes (e.g. military, agricultural, domestic, etc.); however, since the effective impact of robots is limited, for the moment, to manufacturing applications,we shall restrict our considerations to the present state, the perspectives and the implications of the spreading of industrial robots. We shall also omit further details on possible classifications of robots (e.g. according to the control system, the level of "intelligence", etc.), which are better described in specialized pubblications. *

THE RISE AND SPREAD OF ROBOTICS

In the absence of continuous statistics and of a universally accepted definition of the robot aggregate, comparisons in time and space of the dissemination of robotics are often not wholly reliable. The oldest statistics refer to the mid-seventies and more recent surveys normally give figures for I980. From less than I00 robots in operation at the beginning of I975, the number of industrial robots in operation in Italy, by the end of I980, was thought to be over 700, excluding the simpler "pick and place" manipulators. This means a rate of increase in volume terms of more than 50% yearly in the period, while the rate of expansion of the market in monetary terms has been estimated at over I00% per year. In I98I Italy's share of the whole West

---

* See, for example, P.Vicentini et al. "Parametri e classificazioni", in SIRI-AIRI, "Stato attuale e previsioni di sviluppo della robotica industriale", I979.

European market was about I5%; in terms of production, its share is however higher given its net export performance.

The forecasts for the future,drawn on the basis of simple projections of trend values have proven to be often unreliable in the recent past; we may quote, however, an estimate of a 7-fold increase in the size of the Italian market in the period I98I-90, from I0 to 70 million constant dollars;(the values for the whole of Western Europe are, respectively, 65 and 350). *

A more structural and detailed overview of the impact of robotics in specialized applications is however necessary, if we want to go beyond the generality of overall figures. In Italy, as elsewhere, the automobile industry has represented, in the recent past, the most important field of robotized technologies. In recent years, over 80% of robots have been used in the engineering sector broadly defined(mechanical,electro-mechanical, vehicles, etc.)and car production would account for fromI/3 to I/2 of this figure, as a European average. It appears, although the sources to which we refer are not wholly comparable, that the proportion of robots used in the car industry has been higher in Italy than in other countries. This has also meant a relative specialization of the italian producers in specialized robots designed for well-defined phases of automobile manufacturing (e.g. servicing of the forging presses, spot-welding, painting); fields in which they have also reached good export performances and an international reputation. However, an excess of specialization may, in the longer run, also represent a moment of weakness from the pointof view of international standards,whereas other countries (e.g. Japan), characterized by a more diversified home market for applications, may enjoy a wider experience in faster-growing sectors and a more

* See "Mondo Economico", 25/II/8I: "Rapporto mese: Automazione industriale".

flexible structure of supply. Press-servicing, welding and painting represented some 80% of total robot production in Italy, as against 20% of other applications for assembling purposes, while the figures for Japan for example indicate a more diversified pattern of production. However, there are indications of a growing effort, by Italian firms, to develop more flexible and general-purpose robots (e.g. the project being developed by DEA of Moncalieri, in a joint venture with General Electric, of the flexible assembling robot "Pragma 3000").

Beyond a general forecast of a growth rate of production in volume of some 20% per year in the eighties, a more serious comprehension of the potentialities of the spreading of robotics would require a careful investigation of the applicative sectors,in order to see which processes are more likely to be extensively robotized in the near future. As to our knowledge, the only extensive research in such adirection so far published in Italy is the one undertaken by Prospecta * , on which we will draw heavily also for the section on employment forecasts. Processes within some sectors (mainly automobile and electric domestic appliances) have been analyzed in detail in this study, with the evaluation of the percentage incidence of repetitive and standardized tasks particularly suited for the substitution of operatives by robots. The results are summarized in the estimate of a qualitative index of diffusion of robots in I990 as compared with the situation in I979. Mainly, the diffusion of robots in these sectors should consist, in the near future,- beyond the present impact which is essentially limited to the above-mentioned specialized phases (welding,etc.)-, in the extension of their use for assembling operations and relative servicing, such as the automatic insertion of electrical

---

* A wide extract of the research "Robotica ed occupazione nel settore metalmeccanico", coordinated by M.Unnia, has been published in "Quaderni di Industria e Sindacato", n.6/I98I.

and electronic components, and the feeding and unloading of mechanical parts in assembly operations.

Beyond this relatively brief time-perspective, a more massive involvement of successive generations of robots with a higher "intelligence" and ability content in other phases of manufacturing processes may be foreseen, although it becomes hazardous to give quantitative or even qualitative estimates. *

It should be remembered, at this point, that robotics in its narrower definition represents only a part, albeit the most dynamic and promising part, of a more general dissemination of electronically controlled automation in industrial processes. The further diffusion of numerically controlled machining tools and the developments in specialized plant automation which are not strictly to be included within the sphere of robotics will maintain their importance in the future. After all, the value of the production of robots accounted, in 1980, for some 25 billion Lire out of a total of 800 billion Lire's worth of turnover for the whole of the broader sector of instrumental electronics and automative applications for industry in Italy.

THE STRUCTURE OF THE MARKET

The total sales turnover of robots in 1980 was estimated to be around 25 billion Lire, with exports for 15 billion and imports for 5, with a net trade surplus, therefore, of some 10 billion Lire.

This export performance is quite impressive, especially if compared with the almost generalized prevalence of Italy's net export deficit in the sectors of electronics and

---

* AIRI (Associazione italiana ricerca industriale) has been publishing technological scenarios for the year 2000 for various sectors, in which the likely developments of robotized technologies are described.

informatics applications and components.

An explanation for this surprisingly good performance could lie in the fact that the robot is a composite good, in which mechanical and electronic components and skills are more or less evenly balanced. Italy has been traditionally a net exporter of machine tools and instrumental mechanical products,holding the fourth largest share in the world market, and some 50% of national production is sold abroad; the development of robots therefore represents a process of diversification and technological improvement of more traditional mechanical skills. The good export record, however, should not make us forget some of the weaknesses of the Italian industry, such as: a) the dependence on foreign suppliers for most of the electronic components and therefore a high import content of the production of the sector, concerning almost all LSI components and half of the remaining electronic hardware and software; b) the excessive concentration in specialized fields of the market.

In the pattern of growth of the robot industry in Italy in the seventies and in the present structure of the producers' market we can see two main segments. The first segment is represented by the specialized firms wholly controlled by greater industrial groups, which were developed essentially as a way of providing an internally controlled source of supply of instrumental goods along a vertically integrated production cycle. This is in particular the case of COMAU for the FIAT Group, and of OSAI for the Olivetti Group. COMAU was constituted in 1973 through the merger of smaller companies already providing instrumental inputs for FIAT; it operates through more than 10 establishments in the Turin area, and is perhaps the major European producer of automated devices for mechanical industries (mainly, but not wholly, robots). Although providing for the internal

7)

requirements of the parent company, about half its total sales turnover comes from exports ("Robogate" systems for the welding of car bodies have been widely exported). The specialization of OSAI is the assembling of electronic components (Robot "Sigma"). Both COMAU and OSAI have recently concluded agreements for joint-ventures in research and development with American companies (General Electric and Westinghouse respectively).

The second line of development of the robot industry in Italy is represented by the small/medium sized independent companies, either with an older specialization in other fields of automation or newly constituted. DEA of Moncalieri has represented perhaps the leading company in this group, with the highest level of growth performance and technical sophistication of its products. Although it had this excellent record, DEA ceased to exist as a wholly independent firm in June 82, when an agreement was reached with the STET holding group (in which the State has a controlling interest). Under this agreement, STET gained a 70% share in the company. Since the STET group already controls other firms in the fields of applied electronics (ELSAG, also producing automated instruments and Selenia, producing mainly electronic equipment for military purposes), the group thus constituted will represent the major financial concentration in Italy in the sector of instrumental electronics.

We must add, at this point, some 5 other small independent producers, employing fewer than I00 operatives each(Jobs, Camel, Gaiotto, Elfin, Prima Progetti). Finally, the production of limited-sequence robots is carried on by firms with a prior specialization in specific processes, such as Basfer for painting and Norda for pick and place operators.

As will be specified in a later section, the Italian robot industry has grown essentially as a private venture with little financial or other support from the State.

It is estimated, that international competition should bring, in the near future, to a higher concentration of producers at the European level,leaving less space for small-scale independent initiatives, although these may resist through specialization in limited segments of the market. An ability to devote at least 8% of turnover to the financing of research and development is considered to be an essential condition for maintaining internationally competitive standards. The case of DEA, with a good endowment of skills and an international reputation, but with serious financial constraints on further development, is perhaps a typical case of the Italian scenario.

IMPACT ON EMPLOYMENT AND WORKING CONDITIONS

IMPACT ON EMPLOYMENT

There is a growing volume of literature on the quantitative impact of robotization on employment in Italy, although only a little of it uses an original methodology and direct field research, while the rest is mainly limited to surveys of Italian and foreign work on the subject. The most extensive survey was carried out in the already mentioned study by the Prospecta group: although the direct survey and the interviews within this research are concerned only with the automobile and domestic appliances sectors, there is however an attempt to extrapolate the results to the whole of the engineering sector.

The overall impact of robotization on employment levels should be considered as a summation of interrelated factors. Many surveys, concerned essentially with case-studies of the modifications in the work process arising from the introduction of robotized technologies, are limited to the assessment and measurement of the impact of direct substitution of manual workers with robots. For example, analyzing the operation of welding processes in car plants, a comparison is made between the old and the new technology as regards the manning levels. This approach, though valuable, cannot allow extrapolations to wider aggregates, since it overlooks all the possible indirect effects in other phases of the production cycle which may flow from the technological change introduced in one particular section.

In addition, a more complete assessment of the overall effect on employment levels and job content should take into account further factors of interrelation, such as: a) the productivity effect: the direct substitution of men by robots may extend its effects if robotization in one section means an increase in the overall productivity of the process(e.g.

owing to the reduction of the effects of high rates of absenteeism in a key section of the productive process); for any given level of output, the total labour saving will be greater than the simple displacement of direct workers; b) the production and servicing of robots will create jobs, with a consequent positive contribution to the overall balance of employment.

In conclusion, the extrapolation of employment forecasts over time requires, at least, three types of assessment:
a) a technological assessment, concerning the technical feasibility of particular tasks and processes to be more or less extensively robotized within the period;
b) an economic assessment of the growth of demand and overall productivity which will determine the labour requirements given the technical standards;
c) a social assessment: the elimination of tasks does not necessarily mean a parallel elimination of employment, if the social conditions of work change in the meanwhile(e.g. introduction of work-sharing, changes in working time,etc.); the velocity of diffusion of new technologies will in any case be influenced by social and organizational factors.

Evidently, it is very difficult, even in an extensive research, to collect sufficient evidence and forecasts in all these fields.

As regards the technological assessment, the research conducted by Prospecta gives an estimate of the proportion of repetitive tasks that could be robotized or otherwise automated within ten years in the various sectors of the engineering industry. An assessment of the diffusion of robots is then made for the period I98I-90, and the results are then adjusted for the effects of "indirect" and "occult" factors beyond direct substitution, applying methodologies and coefficients already utilized in foreign studies (e.g. by SOFI and Battelle Institut in Germany).

If we confine ourselves to the overall figures which

emerge from the survey, and omit further details on the criteria of extrapolation, we reach a number of 23,000 to 33,500 jobs suppressed in the period 8I-90 as the result of the introduction of robots in the engineering sector, out of a total employment of some 860,000 in medium to large sized establishments employing more than one hundred operatives. If we consider the wider labour displacement effect of all technological improvements (diffusion of all types of automation), the number of jobs lost increases to a range of 85,000 to II0,000.
A few comments may be appropriate at this point:
a) Robotization is thought to account for only about I/3 of the total labour saving brought about by all forms of automated technologies;
b) the estimate that the introduction of robots will destroy some 4% of jobs in ten years would make the impact of robots a rather secondary source of concern with respect to other factors as regards the overall employment prospects in industry;
c) the effects of possible compensative measures are not taken into account;
d) the conditions and trends in the growth of the market and of overall productivity of labour,- also as an effect of the trends in working time, etc.-, remain decisive, and the alternative hypotheses on this point do not appear to be clearly specified and forecast in this and other surveys currently available.

As against robot-induced job losses, the additional employment in the robot producing industry is estimated. The range given for additional jobs in the same period is between 3200 to 4500, which would reduce the net fall in employment due to robotization to a deficit of 20 to 30,000 jobs.

It should be kept in mind that these figures refer to an extrapolation for medium and large sized enterprises in the engineering sector: the diffusion of robots and other forms of automation to smaller enterprises would obviously increases these totals. There is in addition no assessment or forecasts available for other sectors of industry, such as clothing, footwear, mining, where the feasibility of the diffusion of robotized technologies is often mentioned.

Beyond this rather general research, we may quote a few examples of case- studies, which have concerned almost exclusively the car industry. * The diffusion of robots in FIAT has surely been the case which has attracted the most attention. In synthesis, the robots have been extensively utilized in car production since I977 in the following processes:

a) the "Robogate" system for the spot-welding of car bodies. It consists essentially in the cooperation between specialized welding automata (Comau's Polar robots) and "robocarriers" which transport the car bodies between welding stations under the control of a central computer. The system has been effectively operating, after an experimentary phase, since I978 at FIAT's Cassino and Rivalta plants. It is estimated that the manning requirements for the productive section concerned has been reduced from 50 to 6 men.

b) The automation of the forging presses. At present, about I/3 of the presses at the Mirafiori plant are automated, with robots carrying out the feeding operations. The manning requirement of an automated press is 4 workers, as against 24 of the manual operation.

c) The gradual improvement of painting robots(Basfer). At present, only the last phase of finishing is still manually operated.

d) Digitron systems for the insertion of the engine into

* C.Ciborra, " L'automazione nell'industria dell'auto", in Sapere, I/79; M.Ciatti, "Nuove tecnologie e forza-lavoro: il caso FIAT", in Sapere IO-II/80.

the car- body during assembly-line operation. Also in this case,"robocarriers" and insertion automata cooperate. The organization of the assembly line above and below the robotized point has remained virtually unchanged, and total labour-saving effects seem to have been negligible. An improvement in the working conditions from an ergonomical point of view is claimed.

The estimates for the total employment impacts of these innovations vary. In a recent conference, a FIAT Director for work organization asserted that only some 1500 jobs had been eliminated and this was fully compensated by the increase in employment at COMAU and other affiliates. * Other estimates speak of some 3000 jobs lost. If we consider that today FIAT is producing roughly the same number of cars with over 15000 fewer workers than three/four years ago (precise assessments are difficult, owing to the varying incidence of the short-time week, "cassa integrazione", etc.), it can be seen again that robotization has not for the moment been the major factor in the overall process of employment reduction, at least in its direct effects.

IMPACT ON WORK QUALIFICATION AND ORGANIZATION

Since robotization has so far affected repetitive, operational tasks in manufacturing processes, the manpower negatively affected has evidently consisted of semi-skilled or unskilled direct workers. Since the residual work process becomes essentially one of supervision, maintenance and emergency intervention in a situation in which direct processing is accomplished by automata, the operatives should possess the essential skills for understanding the control mechanisms

---

* Ing.Besusso at the conference "Nuove tecnologie, organizzazione del lavoro e professionalità emergenti", Olgiata(Rome) 30/3/82.

of the process together with the ability to deal with interruptions, emergency repairs, etc.. This requires essentially a mix of mechanical skills and understanding of electronic control system. In the last four years, some 5000 workers at FIAT have been involved in " requalification" cycles in order to reach the standards required by the new technologies; however, the management itself is rather pessimistic about the retraining potential of the mass of semi-skilled or unskilled manual workers. Only 5 to I0% of these workers are considered to possess the "cultural and technical" background necessary in order to be requalified.

Robot construction is at the present a small-batch, specialized production in which electronic and mechanical skills are widely required. However, the increase in the employment of skilled workers (programmers, mechanical fitters) in robot production should be more than offset by the reduction in the requirement of skilled workers in other fields of the productive processes because of the spreading of other applications of microelectronic technologies(e.g. the use of computer-aided design reducing the need for draftsmen).

There is a fair degree of controversy about the ultimate effects of robotization on conditions and organization of work, the upgrading or downgrading of skills for the residual workers, the consequences on the bargaining strength of the workers. The impact of robotics in major industrial plants such as FIAT's should be understood also as an answer to the high level of industrial unrest which characterized Italian industry at the beginning of the seventies. Stoppages and claims were often centered on the organizational aspect of the production process and working conditions (e.g. repetitive tasks in assembly-line operations, the lack of possibilities to acquire skills and "job satisfaction" within the traditional organization of the work process, etc.). "Job-robotation" has been, at this point, welcomed by some commentators as essentially a way of eliminating the need for low-skill, and often toilsome labour in those tasks or processes which would not admit any form of job enrichment. "Job-robotation" and "job-rotation", i.e.the requalification of the remaining workers who would have been allowed to gain in skills and satisfaction through mobility towards less atomized tasks, were seen therefore as complementary and not conflicting objectives. Both processes were finally seen as an improvement with respect to the traditional "Taylorian" forms of work organization.

The lack of any effective opposition by the Unions in the late-seventies to the introduction of robotized technologies shows how this argument of ergonomic advantages of the robotization was at least partially shared by management and workers' representatives.

This rather optimistic view has been attacked on several fronts. On the one hand, it has been argued that, since robotization would only affect some sections of the production process while traditional manual assembly operations were maintained in other sections, robotization would often mean a worsening of the work conditions of the residual manual workers (e.g.through speed-up), while no other significant improvement of the work organization in these non-robotized sections could be detected. Robotization, finally, would have meant, more often than not, only a horizontal transfer of operatives from one task to another, without any upgrading of skills except for a small minority. Another line of argument consists in the complaints about the loss of bargaining power and control over working conditions by organized groups of workers: the traditional points for shop-floor bargaining, such as the work-load, manning, incentives, would become irrelevant, with a consequent loss of power and identity for local level union organizations. Robotization, in such a framework, would not be seen as an overcoming of Taylorism, but as a more sophisticated form of it, where " the independence of the organization from the workers" is pushed to a higher degree, with no possibility of opposition and control.

Among these often conflicting points of view, the Italian

Trade unions have been carrying out a difficult task of mediation, although their more official documents and statements , which often give equal weight to the "positive" and the "negative" aspects of the new technologies, risk sometimes appearing somewhat vague and non-committal.

IMPACT ON WORKING HOURS

Robots, unlike men, can work continuously, and their effects on the displacement of direct labour are multiplied by the number of shifts. A discontinuous process, typical of mechanical production, becomes potentially apt to be operated in a continuous fashion,like, say, a petrochemical plant. In addition, it is widely acknowledged that the costs of investment in new technologies would not be justified if the plant were not allowed to work for at least two 8-hour shifts during the day. This is perhaps one of the factors which has for the moment checked the spread of new technologies to smaller workshops characterized by a single-shift operation.

It is clear that any form of work reorganization, concerning modifications in the forms of regulation of the work flow and of working hours, must entail a reorganization of the shift-system if it is to have any impact on employment levels. The 36-hour week, arranged as 6 hours of work for 6 days with 3 daily shifts would theoretically increase total manning requirements by a factor of 1/3, with respect to the traditional system of two 8-hour shifts in a 5-day week. The main objection is perhaps that the implied increase in labour costs and productive potential are not justified, particularly in a time of widespread underutilization of capacity owing to the weakness of demand.

However, any other form of reduction of working time (e.g. a 7-hour day) would risk not having any effect on employment, while increasing costs,at least for those processes where the manning levels for each shift are rigidly determined by technological constraints. The Trade unions in Italy, when drawing up their national bargaining platforms, have advanced the general claim of a 35-hour week to be reached by 1985, leaving to the sectoral or local levels the task of defining the particular forms of the reduction of the working week.

As for the other possible forms of change in the patterns of work, the only concrete proposals concern at the moment the regulation of part-time work. The present impact of part-time work, essentially limited to female clerical work, does not seem to have a chance of significantly influencing the patterns of work in industries where the diffusion of robotics is taking place.

POLICY TOWARDS ROBOTICS

GOVERNMENT POLICY

The lack of a specific programme of public support for research and innovation on robotics in Italy has always been seen as a serious handicap for the development of the national industry. In industrial policy documents and in the criteria of sectoral allocation of public incentives (IMI funds for applied industrial research, the Law on Technological Innovation of17/2/82), robotics does not receive a specific mention and comes under the wider heading of "Instrumental Electronics and Automation". Public funds to support theoretical and fundamental research on robots are largely insufficient, with less than 1 billion Lire in 1981 allocated to the laboratories of the universities or of the National Research Council (CNR). The promotion of applied research by firms and relative financial incentives are more effective, and it is estimated that development projects for some 200 billion Lire have been approved and are in the process of being financed by incentive schemes in the fields of automation, although the specific share of robotics is not precisely known(20% ?). The smaller enterprises operating in the sector have often complained of their difficulties in getting access to public funds and special credit facilities, although the new regulations reserve a quota of 15% for smaller scale operations.

Technical and industrial operators also often complain of the lack of a public or semi-public specialized research institution, which might provide relevant orientation and technical advice for the definition of investment projects. The case of IPA in Germany is often quoted as an example, and Japanese industrial policy is pointed to as a positive model. At the recent congress of the Society for Robotics (SIRI) the need for a "National Finalized Project for Robotics" to coordinate research efforts ,was heavily stressed.

THE ATTITUDES OF EMPLOYERS AND TRADE UNIONS

Apart from their general statements, the attitudes and expectations of employers on the introduction of robots clearly emerge from the answers to surveys and interviews that have been conducted on the main motivations behind the choice of investments in robots. From the results of some 80 interviews effected in a research promoted by SIRI, * we find that the increase in productivity and the elimination of toilsome and dangerous work were the most prevalent reasons given for the introduction of robots. Other reasons given, in decreasing order of importance, include the improvement in the level of control of the process and the workforce, the greater flexibility of the production process, the improvement of quality standards, the lack of availability of suitable labour.

The increased flexibility of the production process in robot operation with respect to "rigid" automation technologies, often quoted in the technical literature as the decisive improvement introduced by robotization,does not seem to have received, in the Italian case, a widespread confirmation. Although there are significant exceptions, like FIAT's Robogate system where the flexibility of the robots over the different types of car models is said to have brought a significant capital saving, still the majority of robots are too narrowly specialized for their technical flexibility to be cost-effective. It seems as if we were still quite far from the realization of a fully "flexible manufacturing system". In these conditions, ergonomical and "work and productivity control" motivations predominate; the two arguments are not evidently contradictory, since toilsome work has often implied labour unrest and high rates of absenteeism.

We have already mentioned the various attitudes by workers' groups vis-à-vis the spread of robotics, in the section on work organization. Rather than repeating general statements, we shall give a freely translated resumé of the remarks contained in the Prospecta research, which in

---

See M.Flego:"Probabile evoluzione delle caratteristiche e delle applicazioni dei robot:i risultati di due indagini nazionali" in Industria e Sindacato, 29/2/80 our opinion clearly summarizes the present state of mind amongst workers representatives.

> " The trade union views robotics in the wider context of the organization of work, an area in which traditionally it has tried to exercize control and influence. In the past, the introduction of forms of rigid automation and numerical controls in the factories, and of computers in the offices, was characterized by very limited opposition. Changes in the balance of strength between management and unions nowadays cause the unions and workers to adopt attitude of increased mistrust. Two factors are at the root of this attitude: the fears for employment levels and alarm at a substantial change in the conditions of work, which does not involve a positive revaluation of professional status except for restricted groups of workers.
>
> Two non-homogeneous attitudes thus prevail: general agreement where robotics reduces the incidence of toilsome and alienating tasks, and a critical attitude where the increased productivity of the production induced by robotization creates a dychotomy between some jobs that are impoverished in their content and subordinated to the machine and others that are enriched by the superior functions of programming and control of the machinery.........
>
> The unions are threfore moving along the following lines: generalized reduction of working hours, higher pay and grading for the more unconfortable jobs that are still linked to the older types of work organization, bargaining over productivity levels within the new robotized organization."

As an example of the Unions' attitude towards robotics we may remember the FIAT agreement of June 1977,exactly at a time when the introduction of the new technologies was entering its operational phase. There was no direct

---

* "Quaderni di Industria e sindacato", 6/81, op.cit.,p.17

opposition to the change in itself, and sometimes there was fruitful bargaining over the timing of the innovation; bargaining over employment levels was conducted for the company as a whole, with the negotiation of short-time, retraining periods, "Cassa integrazione", etc. Also in the case of the 1979 Olivetti agreement, in which a substantial reduction of the work-force because of labour-saving technologies was at stake, the Unions sought to offset job losses by demanding alternative investments and training projects financed by the firm or by the public authorities.

These attitudes may well change in future, as trends in unemployment worsen, thus rendering forms of external compensation for technologically-induced job destruction less available and less credible.

BIBLIOGRAPHY

AA.VV. " Rapporto mese. Automazione industriale:il robot va in fabbrica", Mondo Economico, n.45/81

O.Caravini, G.Caravita " La seconda rivoluzione delle macchine utensili", Mondo Economico, n.10/1979

M.Ciatti "Nuove tecnologie e forza lavoro: il caso FIAT", Sapere 10/1980

C.Ciborra, S.Salvini, U.Violano " Il robot industriale", F.Angeli, Milano 1976

C.Ciborra " Il robot nell'organizzazione del lavoro", Sapere, 7/1977

C.Ciborra " L'automazione nell'industria dell'auto", Sapere, 1/1979

C.Ciborra, P.Migliarese, P.Romano " Aspetti economici ed organizzativi nei modelli di inserimento dei robot industriali", Controlli numerici, macchine a c.n. e robot industriali, nn. 5 and 6 /1981

D.D'Ascenzo " Il post -taylòrismo é iniziato con i robot ?" Impresa e Società, n.9/1980

D.D'Auria " I robot industriali:automazione,produttività e occupazione", Industria e Sindacato, n.14/1978

M.Di Nola " La rivoluzione dei robot", Mondo Economico n.25/I978

M.Flego " Probabile evoluzione delle caratteristiche e delle applicazioni dei robot: i risultati di due indagini nazionali", Industria e Sindacato, n.9/I980

I.Franchetti " Alcune esperienze di robotica in Alfa Romeo", Industria e Sindacato, n.14/I978

V.Moreggia " L'evoluzione del robot come macchina e nelle applicazioni", Produrre, N.7-8/I98I

A.E. Palagi	"Problemi di inserimento dei robot nei sistemi produttivi", Impianti n.I0/I979
PROSPECTA	" Robotica ed occupazione nel settore metalmeccanico", Quaderni di Industria e Sindacato, n.6/I98I.
M.Rollier	"Il caso FIAT", Rassegna Sindacale n.64-65/77
SIRI/AIRI	" Stato attuale e previsioni di sviluppo nel campo della robotica industriale", Milano 1979
SIRI	" Stato attuale e prospettive della robotica in Italia", Milano I982
M.Unnia	" Robotica come business, supporto pubblico e coinvolgimento sindacale", Industria e Sindacato, n.9/I980
P.Varvello	" Lo stato attuale e le previsioni di evoluzione dei robot in Italia", Informatica'70, n.7/I980
P.Vicentini	" Impatto dell'applicazione dei robot in fabbrica", Produrre, n.7-8/I98I

AUTOMATED MANUFACTURING IN IRELAND

Department of Industrial Engineering,
University College,
Galway.

L. Brennan
J. Browne
M. E. J. O'Kelly

Automated Manufacturing in Ireland

This paper considers the impact of developments in the machine tool and robotics area on Irish manufacturing. These developments have been greatly influenced by the rapid growth of microelectronic and computer technology over the past decade. Manufacturing is a diverse activity which ranges from the extremes of high continuous volume production through mass production to small batch production. Among the tasks which can be undertaken by machine tools, robotics and microelectronic based devices are:

(i) The controlled movement of materials, components and products.

(ii) The control of process variables such as temperature, pressure and humidity.

(iii) The shaping, cutting, mixing and moulding of materials.

(iv) The assembly of components into sub-assemblies and finished products.

(v) The control of the quality of products at all stages of manufacture by inspection, testing or analysis.

(vi) The organisation of the manufacturing process, including design, stock-keeping, dispatch, machine maintenance, invoicing and the allocation of tasks.

Our attention will be confined to numerically controlled and computer controlled manufacturing tools used in direct manufacturing operations. The indirect use of computers in manufacturing or "computers for manufacturing support" in such areas as production control and scheduling, materials planning and maintenance management will not be covered.

Numerical Engineering is the term used to refer to the overall area of:

Numerical Control - NC

Computer Numerical Control - CNC

Direct Numerical Control - DNC

Numerical control is the control of machines and equipment directly from numerical information. The first successful control of a machine tool directly from numerical information was demonstrated in 1951. Numerical Control is a method of automation that preserves the flexibility of numerical instruction. The movements of a machine, most often a machine tool, are controlled by instructions written numerically and read automatically as numbers by the NC system which controls the machine tool. The early NC machines incorporated permanently connected (hand-wired) control systems.

Computer numerical control involves the incorporation of a computer into the NC system in place of the conventional special purpose built control system connected to it's machine tool. Hard-wired systems are relatively inflexible in that new developments can be incorporated only by rebuilding the control unit and its associated equipment. Computer control of machine tools belongs to what is termed soft wired control and this may be achieved by a mainframe, mini or micro computer.

Direct computer control is a more recent development. It involves the use of a computer for the direct control of several machine tools. It usually includes an overall control of a management system including management functions such as production planning and work scheduling.

NC machines are essentially versatile general purpose machines suitable for the manufacture of a variety of components in small batches. Compared to conventional methods NC manufacture reduces floor to floor times with the reduction of setting times and operation times. It gives greater management control simplifying the work of the Production Planning and Control Departments as accurate job times can be determined. The Quality Control and Inspection function can also be simplified since once a program is tested operator fatigue or carelessness no longer affect the machining operation.

In manufacturing systems involving manually operated machine tools, the three dimensional design is translated into shape and size on a two dimensional drawing which is then analysed for manufacture in the production planning department. In the final stage the drawing and production planning information is interpreted and the part machined by an operator using his acquired skill and knowledge. In many cases considerable discretion is left to the operator, in for example, the choice of speeds and feeds.

In a manufacturing system involving numerically controlled machines these stages are modified and much more closely related. The main changes relate to production planning and manufacture since the manufacturing information must be presented in numerical form so that it can be interpreted by the machine/control system.

The mix of skills required for NC machines is substantially altered over those used with more traditional machine tools. The skill required of the actual machine operator is reduced. Programming the machine (part-programming) and certain aspects of maintenance require skills not used with more traditional machine tools. The quantitative effect on employment is difficult to assess. NC machines may be introduced to retain competitiveness rather than to increase output. In such cases the introduction of NC machines is likely to have a negative effect on employment levels. Many companies investing in NC machines in Ireland are just setting up operations and have decided to use these tools either for volume reasons or for reasons related to the quality of finished product.

Developments within Numerical Engineering itself have resulted in a certain merging of the skill requirements of those involved. Part-programming at one stage of the evolution of Numerical Engineering was a very special skill, not easily acquired by the traditionally trained skilled craftsman who operated conventional machine tools. Nowadays with computer aided design packages the job of part-programming has been considerably simplified.

With the coupling of adaptive control (machines adapting the cutting conditions to optimise the performance), group technology (grouping together of technologically similar parts for manufacture) and cellular manufacture (grouping of machines and operators to enable all the machining work to be done on all the workpieces going through the cell in contrast to functional layout of single purpose machines) industry has been provided with a very versatile tool capable of manufacturing a variety of complex components in small batches. These cells require a wide range of skills and a committment to group working which leads to job enlargement and job enrichment. A further development leads to the concept of flexible manufacturing systems "As Pressman and Williams point out, flexible manufacturing systems incorporate many individual automation concepts and technologies into a single production system. These include automatic materials handling between machines, numerical control machine tools and CNC, computer control over the materials handling system and machine tools (DNC) and the principles of Group Technology (GT). FMS is designed to fill the gap between high-production transfer lines and low-production NC machines".

There are no flexible manufacturing systems as such in Ireland at the present time. Some research work is being undertaken in this area at one of the university colleges particularly related to simulation of such systems. It seems unlikely that there will be any flexible manufacturing systems operating in Ireland in the short term. It is reasonable to assume that FMS will come to Ireland through technology transfer from some company from abroad setting up operations in Ireland.

According to the N.B.S.T. Report on Microelectronics at least 26 firms in Engineering and 11 firms in Electronics are using NC machine tools. A further 20 firms in Engineering and 8 firms in Electronics have indicated that they expect to introduce NC over the next five years. These machines are mainly the older type NC machines but a number of companies are using CNC machines. However, there are no DNC systems in Ireland.

During the 1980's the few firms who have made extensive use of NC will start the move towards DNC. However, it seems unlikely that there will be a fully automated DNC plant in Ireland before 1990.

Ireland has attracted a number of high technology firms in the electronics industry over the past decade. Many of these manufacturing plants use a very high degree of automation in such areas as PCB stuffing and testing. In addition a number of process type industries have become more automated over the years e.g. brewing and chemicals.

There is no research institute in Ireland primarily concerned with working on automated manufacturing. The Institute for Industrial Research and Standards has done some work in this area and there have been isolated studies carried out by individual academic researchers. Three of the university colleges and one of the institutions of higher education are giving courses in the area of computer aided design to engineering students. CAD is used in Ireland particularly by the integrated circuit manufacturers of the Electronics industry and to some extent by the larger engineering firms. Microelectronics Applications Centre (MAC) offers a specialised service in CAD in the area of microelectronics.

Robotics in Ireland

If one takes the following definition of a robot: "An automatic position controlled reprogrammable multifunctional manipulator having several degrees of freedom capable of handling materials, parts, tools or specialised devices through variable programmed operations for the performance of a variety of tasks" (I.S.O. Definition) there is only one robot working in Irish industry. The application is a simple materials handling operation associated with an injection moulding process.

There are a number of reasons for this relatively low level of application of robotic technology in Ireland. Ireland has very little of the large scale traditional industrial activities which up to now have been major users of robotics worldwide. There is no heavy mechanical engineering industry in the country and car production is at a level where the economics of robot use are not compelling. It is known that studies are currently under way by the major car manufacturers to assess the possible use of robotics. It is unlikely that market conditions are right at the moment for a substantial investment in robotics by car manufacturers. Paint spraying and welding are the most established application of robotics. However, in Ireland, these industrial processes tend to be associated with small scale operations. Robots have often been associated with heavy and hazardous work but such work is not characteristic of Irish Industry.

Policies towards Robotics

Up to recently the technological awareness and sophistication of Irish Industry was not high. Over the past few years great progress has been made in upgrading the technology of Irish industry through increased resources being devoted to technical and technological education and through the process of technology transfer to the country by high technology companies abroad setting up operations in Ireland. By supporting the setting up of a number of industrially oriented research and development groups, generally associated with third level educational institutions, the Government in recent years has encouraged the use of microelectronic technology by Irish Industry. Although robotic technology, per se, has not been specifically assigned to any particular research group some interest in robot research has been shown by a number of the colleges. At least three third level educational institutions have acquired experimental small scale robots. Engineering students are being exposed to microelectronics including robotics as a production technology in many of the colleges.

There have been a number of seminars and conferences held over the last year or so on manufacturing systems including the use of robotics. These have been primarily directed towards the general education of manufacturing management and the engineering profession. There have also been a few demonstrations of equipment by robot manufacturers. However, Irish engineers and manufacturers interested in the use of robotics would tend to seek advice abroad from foreign manufacturers as there are so few people with robot design or use experience in the country itself.

No legislation has been passed specifically related to the industrial use of robots. Trade Unions and Employer Groups in Ireland have not taken up any particular position about the application of robotic technology. This is probably due to the likely low employment displacement effects the technology will have on the economy in the short term.

Neither has there been much pressure on the government to fund research studies on the impact of robotic technology. The major study by the National Board for Science and Technology (N.B.S.T.) on "Microelectronics - Implications for Ireland" stated that (in reference to the use of robots in the engineering/ electronics industry) "the applications with the most substantial labour-displacement implications - automated batch production and automatic assembly - are unlikely to have much relevance. However, some labour replacement can be expected, although seen in the context of the whole industry, it is likely to be very small".

Future Prospects - Robotics

No official forecasts of robot use in Ireland have been made. A number of commercial companies have become agents for foreign manufacturers of robots. There should be an increase in applications particularly in the engineering industry over the next few years. However, such applications that do occur are most likely to be simple in nature involving, for example, handling/transfer operations.

A few companies are considering setting up automated storage and retrieval facilities incorporating robotics.

The employment impact in the short term of robotics should have very little direct effect in Ireland because of the nature of industrial activity and the likely number of applications. However, there must be some concern for the employment impact in the medium to longer term. Developments currently taking place in robotic technology will have a major effect on manufacturing assembly work. A very large element of employment in Irish industry, including the newer electronics and health care industries, is concerned with manual assembly operations.

However, Ireland could benefit from the expansion in the market for robotic parts and systems. A few companies are already involved in this market e.g. one company supplies special purpose motors to robot manufacturers and another supplies servo control systems. This indicates that there are challenges and opportunities for Ireland arising out of the increased use of robots.

A particularly encouraging example of the employment impact of robotics is the recently announced Hyster project described below. Whether such opportunities will balance out the negative effects on employment of developments in robotics in the medium to longer term is difficult to say at this stage.

Hyster Plant to be located in Dublin

A major breakthrough by the Industrial Development Authority has been the decision by Hyster Company of Polland, Oregon, USA to set up a plant to manufacture automated materials handling equipment and systems in Dublin for world markets. The agreement between the Company and the IDA provide for the setting up of a research and development centre, a manufacturing operation and an administrative headquarters. A substantial number of engineers will be employed and the total employment in the project is expected to be over 1000. The total cost of the project will be in the order of Ir£50 million.

The following types of equipment will be manufactured:-

Automated storage and retrieval systems (AS/RS)
Automated horizontal transportation
Materials handling robots
Automatic guidance and control systems.

The initial focus of the project will be on research and development. According to the Chairman of the Board of Hyster Mr.W.H.Kilkenny "Our agreement with the Irish Government will make it possible for us to offer the most comprehensive range of equipment and engineering for automated handling of any manufacturer in the world". Kilkenny stated publicly that the company was impressed with the high level of expertise now available in high technology industries in the country and with the level and supply of technological graduates from Irish colleges.

The I.D.A. has prepared a package of incentives specially designed to encourage the setting up of high technology plants like Hyster in Ireland. The I.D.A. in recent years has developed the concept of the 'complete business' in its negotiations with companies from abroad. This concept involves not only the setting up of the manufacturing function in Ireland but the marketing and research and development functions as well.

Impact on Labour Force

The impact on manufacturing employment in Ireland of automated manufacturing processes including numerical engineering, robots and new technology generally is initially likely to be more qualitative in nature than quantitative. The Government has embarked on a programme of expansion of Irish Faculties of Engineering and Technology which will lead to a doubling of the output of engineers in the 1990 when compared to 1980. It will fall on production and industrial engineers to justifying the use of robots in manufacturing. These engineers will need to have a thorough knowledge of production processes and systems. New skills, particularly those of computer modelling, will be required of those called upon to design the complex manufacturing systems of the future which will incorporate robots.

At the technician level the more widespread use of automated manufacture will lead to a demand for personnel with diagnostic rather than manual skills. There has been a dramatic increase in the resources devoted to third level technical and technological education in Ireland over the past decade. Output of certificate and diploma graduates (sub-degree graduates) is expected to increase by about 160% from 1979 to 1989. AnCo - The Industrial Training Authority have considered the training implications of the introduction of new technology and robots and have already given some training modules in these areas. One of the training centres has an impressive array of numerical controlled machine tools.

To date, Irish Trade Unions have generally adopted a positive attidude towards technological change, provided that workers are kept informed of proposed developments and are seen to share in the increased productivity arising from these developments. However, despite the availability of state grants to support research and development work the record of Irish Industry in the area of research and development is poor. Investment by

Irish industry in research and development work is less than half (at 0.8% of G.D.P.) of the average of other EEC countries. Efforts are being made to improve this position but it must be remembered that only 5% of manufacturing firms in Ireland employ more than 100 people. All this points to the conclusion that for some time to come Ireland is likely to be a follower of trends set abroad rather than a leader when it comes to manufacturing technology.

Bibliography

1. Report: 'Science Budget 1981'. National Board for Science and Technology, Dublin, 1981.

2. Paper: 'Robotics in the U.K.'. The Industrial Robot, Vol.8, No.1, pp.32-38. (March, 1981)

3. Paper: Yoshitani, Y. 'The Background and Present Status of Computer Usage in the Japanese Iron and Steel Industry'. Computers in Industry, Vol. 1, No.4, pp. 263-275 (October, 1980).

4. Paper: Ross, M.H. 'Automated Manufacturing - Why is it taking so long?'. Long Range Planning, Vol. 14, No. 3, pp. 28-35 (1981).

5. Report: 'Micro-electronics - The Implications for Ireland'. National Board for Science and Technology, Dublin 1981.

6. Report: Brennan, L. 'The Employment and Training Implications of Micro-electronic Technology'. Published by AnCO, Dublin, September, 1980.

7. Paper: 'Why manual assembly will be with us for many years to come'. The Production Engineer, pp. 34, (June, 1980).

8. Paper: Nof, S.Y. et. al. 'Effective Utilization of Industrial Robots - A Job and Skills Analysis Approach'. A.I.I.E. Transactions, Vol.12, No.3, (1980).

9. Paper: 'Robots are coming to Industry's service'. The Economist (August 29th, 1981).

10. Paper: Bruijel, N.J., 'Management problems in Manufacturing'. The Industrial Robot, Vol. 8, No. 3, pp. 162-165 (1981).

11. Paper: Brennan, L. Browne J., O'Kelly, M.E.J., 'The Robots are coming'. Technology Ireland. Vol. 13, No. 3, pp. 23-26, (July/August 1981).

12. Paper: Brennan L "Implications of Robot Technology for Irish Industry" 12 ISIR/6 CIR. Conference June 1982.

13. Computer Aided Manufacture, J. Browne, M.P. Fitzgerald, J. Harhen, M.E.J. O'Kelly - The Technology Series, National Board for Science and Technology Dublin 1982.

14. Pressman and Williams "Numerical Control and Computer Aided Manufacturing". J. Wiley and Sons Inc. 1972.

THE ECONOMIC AND SOCIAL IMPACT OF ROBOTICS IN FRANCE

by

J.P. Jeandon and R. Zarader

J.P. Jeandon and R. Zarader
Université de Paris Nord
U.E.R. de Sciences Economiques
Centre de Recherches en Economie Industrielle
Avenue J.B. Clement
F-93430 VILLETANEUSE

THE SPREAD OF ADVANCED AUTOMATION IN PRODUCTION

FROM THE MYTH TO THE REALITY

AN INCREASING NUMBER OF DIFFERENT TYPES OF MACHINES

Robotics, which is a branch of electronics (1), is a synthesis of different technologies for the purpose of acting on materials. There is no official definition of robotics, the terms covers different types of machines with different industrial applications.

ROBOTICS

Computer-assisted DESIGN equipment	Manufacture			
	Industrial data processing for controlling continuous processes	Automated or discontinuous production equipment		
Computer-assisted (CA) drafting	- Computerized controllers - effectors	- Numerically controlled machine tools (NCMT)	- Manipulating robots - Mini and micro computers	- Flexible product-tion lines
Computer-assisted (CA) design	- Programmable automated equipment - mini-computers	- Machining centres	- Programmable automated equipment	
Computer-assisted manufacture (CAM)				

It is necessary to distinguish between systems which are used to help to design other systems, and automated production equipment.

---

(1) J.H. LORENZI, O. PASTRE, J. TOLEDANO : "La crise du XXème Siècle" Paris, Economica, 1981.

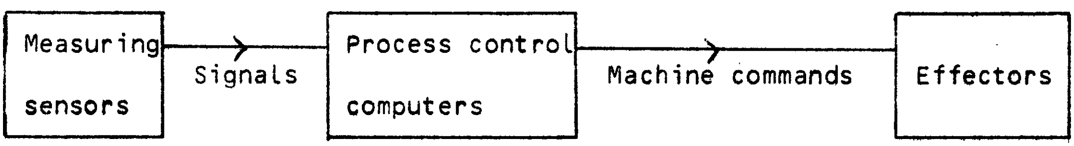
Computer-assisted design. By this is meant "all the data-processing aids used in designing an industrial product, from the original specification to production start-up" (1). A CA-design system is made up of the following :

- a computer
- a conversational-mode graphic consol
- a plotting table which produces the plans
- conventional computer peripherals and media
- specialized software

The development of automated industrial equipment, originally derived from various technologies, such as mechanical engineering and electrical engineering, is now converging towards a single technology, namely data processing hardware technology, i.e. :

Industrial process control computers

To automate continuous processes, it is necessary to combine three different types of techniques in order to organise and/or manage production :



The process being controlled can be optimized by means of mini-computers or programmable automated equipment.

Numerically controlled machine tools

"In the generally accepted sense of the term, a machine is said to be numerically controlled when it operates automatically or semi-automatically on coded instructions", according to the definition supplied by Pierre BEZIER (2).

---

(1) Y. LAFARGUE : "L'utilisation de la robotique dans la production et ses perspectives d'avenir". Report to the Economic and Social Council, 1982.

(2) Pierre BEZIER : "Emploi des machines à commande numérique", Masson 1970.

A numerically controlled machine tool is made up of the machine tool proper and a controller which controls the system. Movements about the various axes are controlled electronically.

The development of machining centres dates from 1978. These are NCMTs equipped with a device which automatically changes tools and with a feed device which sets up and removes workpieces while other workpieces are being machined.

Robots and manipulators

According to the definition proposed by the International Organization for Standardization, "An industrial robot is a multi-purpose, programmable manipulator whose position is controlled automatically, which has several degrees of freedom and which is able to grip materials, parts, tools or specialized equipment in order to make them undergo programmed operations". However, this definition will not put an end to the debate about what is and what is not a robot.

Three categories are usually recognized, the category chosen depending on the level of development attained, namely :

- simple manipulators, which are automatic devices with two or three degrees of freedom (1) and which carry out simple operations;
- programmable automatic manipulators, which integrate data which they then reproduce in the form of programmed operations. They carry out operations with between 5 and 8 degrees of freedom and are controlled by a memory;
- advanced or intelligent robots, which coordinate the sensors, the computer and the effectors in real time by a computer. Its purpose is to optimize the use of NMCTs and to increase the speed of operation of programmable handling systems such as conveyors and robots which transport parts and assemblies.

Flexible production lines

A flexible production line is a production line which is controlled in real time by a computer. Its purpose is to optimize the use of NMCTs and to increase the speed of operation of programmable handling systems such as conveyors and robots which transport parts and assemblies.

(1) The degrees of freedom correspond to the capacity to take up a position in space : three degrees of freedom are necessary to reach any given point.

REAL BUT UNEQUAL SPREAD

Process control computers

In 1980, the total French market for process control computers was worth 800 million francs. The increase in the number of individual industrial computers is characterized by a tendency to use smaller systems. This development is linked to the fall in the average price of computers.

INCREASE IN THE NUMBER OF PROCESS CONTROL COMPUTERS INSTALLED IN FRANCE

	PRICE CATEGORY (1)				
Year	(2)				
	Very small	Small	Medium	Total	Yearly increase
1963	-	9	6	15	
1965	-	20	23	43	
1967	2	76	30	108	
1969	13	170	87	270	
1971	56	376	135	567	+ 38.5 %
1973	176	741	163	1080	+ 24.5 %
1975	400	1268	144	1812	+ 15.5 %
1977	932	1506	110	2548	+ 30.5 %
1979	2087	957	28	3072	+ 32.5 %
1981	3275	1117	-	4392*	+ 8 % (3)

Source : Syndicat national des fabricants d'ensemble d'informatique de bureautique et de leurs applications télématiques.

(1) Very small : between 50,000 and 250,000 FF (1981 francs)
Small : between 250,000 and 1,600,000 FF
Medium : between 1,600,000 and 7,000,000 FF
Large : more than 7,000,000 FF (this category only exists for management systems)

(2) Number of units installed at 1st January

(3) There would seem to be two reasons for this figure, namely :
- a slowing-down in industrial investment;
- the development of programmable automated devices and mini-computer which are not counted in these figures.

These statistics are incomplete, since mini- and micro-computers which can be used for industrial process control have not been taken into account.

However, the spread of this equipment is very much restricted to certain industries, with nine sectors accounting for more than 80 % of the equipment used (1), namely :

- chemical industry
  electrical goods industry
  metallurgical industry (production and first-stage processing)
  oil refining
  paper industry
  food industry
  mineral processing
  oil and gas production and processing
  water supply and processing

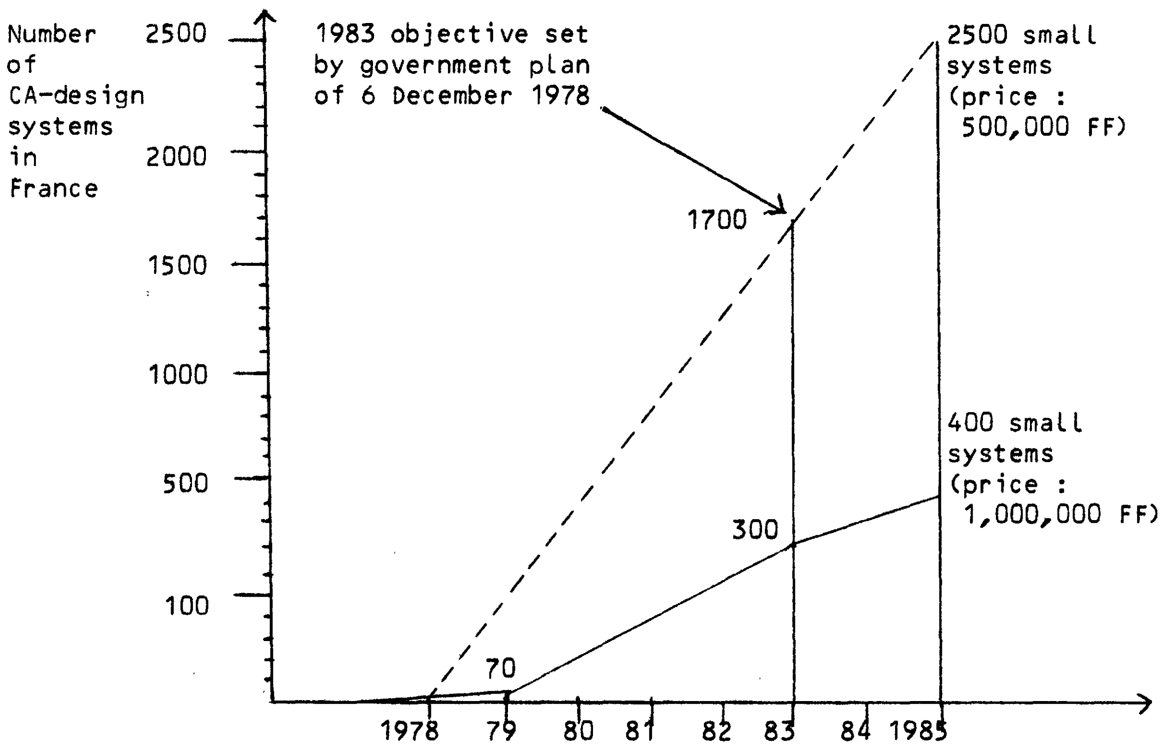
---

(1) Stanford Research Unit

The study published by Geneva Papers (1), which gives the extent to which this automated equipment was in use at various dates, shows that this pattern of distribution for the various industries is very stable.

Computer-assisted design systems

In 1981, the French CA-design was estimated by DIELI at 185 million francs. However, the only reliable survey of this sector dates from 1979, when the total number of systems in service was estimated at 70. This estimate does not include very small CA-design systems, a rapidly increasing number of which are being used for very specialized applications (2).



The 70 CA-design systems in service were divided between the following activities :

- electrical and electronic construction
- transport
- aerospace
- shipbuilding
- architecture
- engineering
- design

(1) O. PASTRE, D. MEYER, J.L. TRUEL, R. ZARADER : "Informatisation et emploi : menace ou mutation ?". La Documentation Française 1981.

(2) op. cit.

There are two main criteria for the future spread of CA-design in the various branches of industry, namely :

- the proportion of design work

  The distribution of draughtsmen in each industry gives a good approximation of the potential demand. Of the 142,500 draughtsmen counted, 49.3 % are concentrated in 3 industries and 74.8 % in 7 industries;

- The ability to finance expensive equipment

  CA-design is mainly introduced in industries which have sufficiently large design departments.

However, falling costs should enable increasing use of CA-design to be made in two sectors in which it is not at present used, namely :

- mechanical engineering and capital goods industries;
- industries in which design represents a large part of the activity, such as the clothing, footwear and furniture industries.

The DIELI forecasts (1) project a growth rate of the order of 40 % per year.

CA-DESIGN MARKET (in millions of dollars)

	1978		1985	
	World	France	World	France
SOFTWARE (*)	40	3	160	20
HARDWARE	300	20	1300	120
TOTAL	340	23	1460	140

(*) In actual fact, the software would seem to represent between 50 and 60 % of the costs of a CA-design system. In this table, the software represents only between 10 and 15 % of the cost, since only the cost of the software invoiced with the machine is shown, excluding the software programmed by the user firm.

This development remains problematical to the extent that technological, political and economic considerations have to be taken into account.

---

(1) The above-quoted use of robotics in production.

Numerically controlled machine tools

The first numerically controlled machine tool was presented in Europe in 1965 at the European machine tool exhibition in Paris. At that time, research was being carried out in the French arsenals and aerospace industry. In 1967, Renault produced a drafting machine and a milling machine which were both controlled by the same computer.

In this crisis-ridden sector, the number of NCMTs manufactured in France remains low, even although they represent an increasingly large share of the machine tool industry's turnover.

	1970	1974	1977	1980
Number of NCMTs produced in France	-	535	579	1236
Share of total turnover represented by NCMTs	3.5%	9.3%	16.6%	19.8%

The total number of NCMTs in France is estimated at 10,500 in 1980. It is difficult to estimate the distribution of NCMTs among various industries because of the large number of imported machines (1).

NUMBER OF NCMTs INSTALLED IN FRANCE

USERS	1970	1974	1980
Mechanical engineering	28%	35%	-
Machine tool manufacture (included in above category)	(15%)	(8%)	-
Motor-vehicle manufacture	13%	22%	-
Aerospace	20%	20%	-
Armaments	9%	8%	-
Other	30%	15%	-
TOTAL	1000 NCMTs	2200 NCMTs	10,500 NCMTs

From this it can be seen that the machine tool manufacturers' relative share has decreased, these being the first to have equipped themselves with NCMTs. It can also be seen that three sectors predominate, namely :

- aerospace
- motor-vehicle
- armaments

---

(1) O. PASTRE, D. MEYER, J.L. TRUEL, R. ZARADER. op. cit.

The relative value of installed NCMTs in the aerospace industry will probably decrease in the future.

There are still relatively few NCMTs in use in small and medium-series production. Faced with this situation, the French government has decided to set up a "machine tool plan", which provides for an increase in the number of NCMTs from 10,500 to 26,000 between 1981 and 1985, representing a rate of increase of 45% per annum.

FRENCH NCMT MARKET (in units)

PROVIDED FOR IN THE "MACHINE TOOL" PLAN (annual increment) (1)

MARCHINES	1981	1982	1985
Lathes	1000	1000	2400
Machining centres	250	250	1500
Milling machines	250	250	750
Other machines	500	500	900
Total NCMTs	+2000	+2100	+5500

This is an ambitious plan, since this increase is dependent on the financing capabilities of the firms concerned and on their ability to find markets for the increased production.

ROBOTS

Although the automation of large-series production has potential applications in many industries, these applications are still at an early stage of development and have not yet been widely adopted. The total number of robots and manipulators installed varies considerably, depending on the definition used. An estimate made by the "Agence pour le Développement de l'Informatique" puts the number of robots and manipulators installed in France at 1st January at 38,635.

NUMBER OF ROBOTS INSTALLED IN FRANCE AT 1/1/1982 (2)

TYPES	Number	Average unit Price	Total value of installed units
1 Programmable, slaved, continuous	120	FF 600,000	FF 72 million
2 Programmable, slaved,	500	FF 500,000	FF 250 million
3 Programmable, non-slaved, general	2,000	FF 200,000	FF 400 million
4 Programmable, non-slaved, forge and injection	6,000	FF 50,000	FF 300 million
5 Simple mechanical transfer	30,000	FF 20,000	FF 600 million
6 Intelligent robots	15	?	?
TOTAL	38,625		1,622 millions

(1) Machine tool development programme (Ministry of Industry). Dec. '81.

(2) Source : estimate made by ADI (Agence pour le Développement de l'Informatique).

The total number of robots installed in France is thought to be 635. This figure is confirm by a recent Ministry industry estimate, which puts the 1981 value of the market at 200 million francs.

Forecasts of the increase in the number of manipulators and industrial robots installed in the future all vary just as much.

Forecasts of the number of robos installed in France (1)

HYPOTHESIS	1983	1985	1990
Frost and Sullivan study	1200	3000-4000	10,000
Tokyo symposium study	800-1000	2000	5500

There is a large difference in the forecasts for 1985 and 1990, since these estimates are based on very different hypothesis about the future trend of robot prices.

Forecasts of the number of programmable automated machines and industrial mini- and micro-computers present less of a problem here there are fewer technological data to deal with.

Applications (2)	1978	1985	1990
Programmable automated machines	700	5,000 to 10,000	20,000 to 30,000
Mini- and micro-computers for large-series production	1000 (number of units, 1977	5,000 to 10,000	20,000 to 30,000

Forecast of the growth in the number of large-series production mini- and micro-computers and programmable automated machines in France (1)

The projections for the numbers of different kinds of units show that the degree of automation in large-series production will remain low until at least 1985.

---

(1) O. PASTRE, D. MEYER, J.L. TRUEL, R. ZARADER. op. cit.

(2) idem.

Analysis of the distribution of machines among different industries remains difficult, given the wide range of large-series production processes. DIEBOLD's estimates for France confirm the distribution of robots and their penetration in different industries in Japan, a country which is very advanced in this field. These estimates are as follows :

- motor-vehicle manufacture : 30% of robots installed in France
- mechanical engineering : 15%
- electronics : 11%
- metals processing : 20%
- electrical engineering : 7%
- materials and ceramics : 4%
- raw materials industry : 4%

Flexible production lines

In 1981, the flexible production line is more of an objective than a reality, there being only two such flexible production lines in France, namely :

- 1 Caterpillar flexible production line at Grenoble
- 1 Renault Véhicule Industriel flexible production line at Bouthéon.

Short-term project - 1 flexible production line for Peugeot SA at Meudon in 1983.

Long-term projects - government grants have been requested for 18 other projects.

The purpose of a flexible production line is to increase productivity in the small- and medium-series production parts. There are a large number of industries which could make use of flexible production lines in their production process, but the cost remains a major obstacle to their adoption. Estimates for the increase in the number of flexible production lines in France between 1980 and 1990 forecast that a limited number of very small flexible production lines will be produced.

FORECAST OF THE GROWTH IN THE NUMBER OF FLEXIBLE PRODUCTION LINES IN FRANCE BETWEEN 1980 AND 1990

DIFFERENT TYPES OF AUTOMATED FLEXIBLE PRODUCTION LINES

	Make-up	Unit value	N° of units installed between '80 & '85	N° of units installed between '85 & '90
American-style "heavy" solution, eg Bouthéon (RNUR) or Meudon (PSA)	+5 complex machine tools with guided carriage transfer; heavy reliance on industrial data processing	40 to 50 million FF	8 to 12	12 to 25
"medium" solution	5 maxi machine tools designed for palletizing; simple transfer methods + DNC*	10 to 15 million FF	10 to 20	20 to 30
Japanese-style "light" solution	2 or 3 NC machines + handling robots	2.5 to 5 million FF	10 to 30	30 to 45
Flexible, automated assembly lines	Feed system + robots + programmer	1 to 10 million FF	10 to 20	30 to 70

Source : inquiry carried out by DIEBOLD for CODIS, January 1981

The introduction of robotics has a threefold effect on production, namely :

- a broadening of the automation base to include discontinuous large-series production, and now also to include discontinuous, small-series production;
- an accelerated pace of conversion of automated production systems, which are usually rigid, into flexible systems;
- most importantly, the raising of major industrial relations issues.

* Direct Numerical Control

CONTROL OF ROBOT PRODUCTION : A SOCIAL GAMBLE

Control of the production of automatic equipment is a priority decision both from the point of view of the economics (substantial increases in productivity, development of captive markets), planning (control of production areas and distribution networks) and social considerations (choice in the organization and conditions of work, improving the quality of the working environment.)

The spread of robotics has created a hierarchy in world production.[1] While some countries[2] are controlling their production or part of it, other countries[3], although they have established a presence in certain gaps in the market, have deficit trade balance in automatic machines.

Major disparities are evident in the production of automated goods :

	Robots 1980	NCMT 1980	CAD 1979	Flexible manufacturing 1981
Japan	7500-10000	50 000	-	25-100
U.S.A.	3500- 4000	70 000	400	10-25
Sweden	1000	3 650 (*)	60	4
West Germany	900	25 000	-	10
France	300	10 500	70	2

* 1979.
Source : Robots : Swedish Committee on Electronics
NCMT : Y. Lasfargue op. cit.
CAD : Development of robotics and social policy in Sweden.
Computer-aided manufacturing : An international comparison. National Academy Press. Washington DC 1981.

---

1 J. Lequement 'Les robots : en jeux économiques et sociaux'. La Documentation Française . 1981.

2 USA, Japan, Sweden

3 France, Britain, Other European countries and, to a lesser extent, the Federal Republic of Germany and Italy.

Pressure from the exporting countries makes itself felt in three areas :

- gradual acquisition of mass-produced robotic equipment,
- extension of areas of application and control of the industrial process,
- development of partnership plans or continuation of the European firms.

This strategy is based on trade representation agreements, which have been multiplying rapidly since 1980 and, less frequently, agreements relating to production under licence. About ten trade representation agreements have been signed in France under the aegis of Japanese manufacturers.[1]

---

[1] J. Lequement 'La connaissance et la maîtrise de la filière robotique'. Contribution to the robotic system effort. Ministry of Research (1982).

However, since the beginning of 1982, agreements relating to production under licence have been signed by European firms in a subordinate relationship to North American firms, which has had the effect of intensifying the technological pressure.

In addition to this dependence in terms of know-how there is an economic dependence.

France's trade balance with regard to robotics is very much in deficit : more than 50% of robotic equipment is imported.

POSITION OF FRENCH FIRMS MANUFACTURING ROBOTIC EQUIPMENT ON THE FRENCH MARKET (1)

Component	Demand	French manufacture	Of which under licence	Imports	Imports plus manufacture under licence	Exports	manufacture-exports
Receivers, transmitters	100	65	20	35	55	25	80
Analysers	100	40	15	60	75	10	50
Indicators Recorders	100	70	10	30	40	15	85
Regulating equipment	100	75	10	25	35	20	95
Speed regulators	100	60	15	40	55	15	75
Regulating valves	100	55	20	45	65	15	70
Remote transmission	100	90	5	10	15	22	112
Relays	100	80	5	20	25	20	100
Programmers	100	70	10	30	40	20	90
Programmable robots	100	70	10	30	40	17	87
Industrial computers	100	55	10	45	55	25	70
Analog computers, simulators	100	80	5	20	25	20	100
Interfaces	100	60	5	40	45	15	75
Peripherals	100	30	5	50	75	10	40

1 SEDES/EIPE Report : Technological research and industrial independence : robotic equipment. April 1979.

- The French electronic components industry is lagging seriously behind : integrated circuits represent only 45% of component production, while they account for 70% of the world market. The trade balance has deteriorated badly, with the import/export ratio falling to 70%.

- Seven North American firms hold 70% of the world market in computer-assisted design systems.

- The machine-tool sector is going through a crisis : the production of numerical control machine-tools represents only 19.8% of the total turnover of the metal working machine-tools industry. Yearly imports of numerical control machines-tools represent 55% of the French market.

- IBM is the leading firm with 18% of the market in industrial mini-computers.

- French robot manufacturers supply less than one third of robots used in France. This situation is not irremediable. The major robot producer in France, the Renault group, through its subsidiary ACMA, is one of the few manufacturers active in the area of intelligent handling.

This situation is creating many social problems. Manpower in the machine tool sector has been cut by 25& since 1974. Employment must no longer be perceived as an effect but as an objective :

- guaranteeing national independence means first of all creating jobs among producers of automated equipment goods;
- controlling the industrial process means going on to control social change in terms of both quantity (employment) and quality (organization and work content).

<u>Research : A major trump card</u> ?

The research situation deteriorated seriously between 1969 and 1980 in France. In 1969 France's research effort (2.1% of GDP) was greater than that of the Federal Republic of Germany (1.8%) and Japan (1.6%). In 1979 France was devoting only 1.8% to research, as against 2% in Japan and 2.2% in the Federal Republic.

The new research policy is more ambitious : the proportion devoted to research in the GDP is to rise to 2.5% from 1985. the objective of 2.5% of GDP is to be symbolic, not mythical. Promoting research makes no sense unless one first answers the question : "Promoting what research ?"
The research potential in automatic control engineering and robotics was of around 250 to 300 researchers in 1981. This puts France in third place in the world rankings.

The two tables below describe the main institutions and centres of research in automatic control engineering and robotics [1].

STATE-FUNDED RESEARCH IN ROBOTICS

Ministry of Defence	Ministry for Industry	Ministry for Research and Technology				Ministry of Education – Research Effort	
ONERA National Office for Aerospace Studies and Research	CNES National Centre for Space Studies	CEA Atomic Energy Commission	ANVAR ADI Agency for the Development of Automatic Data Processing	INRIA National Research Institute in Automatic Data Processing and Robotics	CNRS National Centre for Scientific	Research in the Universities	Research in the Institutes of higher Education
CERT (Toulouse) SOLARIS project (pilot factory robotized in space)	Toulouse	Technical Section for Protective Equipment and Dosimetry (STEP) Remote operations The VIRGULE robot (radioactive environment) The MERITE robot (piping) The PIADE robot (decommissioning) The MIRR robot (reactor inspection) The MA 23 robot (remote handler) The MAM robot (climbs walls) The MA 23 OCEANO robot (minus 6 000 metres) The PLAZ vehicle (minus 6 000 metres, collecting modules)	These two bodies assist both research and development initiatives (see table on State aid)	Systems automation Data processing Dialogue (man/machine) The SPARTACUS robot (for handicapped persons)	Section 2 : Automatic data processing, automatic control engineering and systems analysis LAAS (Toulouse) (HILARE robot) IRISA (Rennes) LAM (Montpellier) LAIM (Marseilles) LPM (Orsay) V103 (Montpellier) INSERM LAB Besançon LAI (psa Lyon) LMA Besançon LMEC (Chatenay) LMP Poitiers LTS (Centrale Lyon) LAN (Nantes) LIMSI (Orsay) LAG (Grenoble) LITP (Paris 7) etc.	P. Sabatier (Toulouse) Compiegne Bordeaux etc...	ENSEEINT Toulouse ENSAM (A and M) ENSMP (Mines de Paris) INPL (Nancy) ESIEE ENSEM (Nantes) Centrale Lyon IMAG (Grenoble) INSA (Lyon) etc.

THE MAIN CENTRES OF RESEARCH INTO THE USE OF ROBOTICS IN INDUSTRY

FIRMS			COLLECTIVE CENTRES		
Privately owned	Nationalized	In the process of being nationalized or where the State is taking a majority interest	Industrial Technical Centres	IFP	ADEPA
Remote engineering ACIP/Kremlin robotics SORMEL CEM CESS (Signals and Electrical operations The ANDROMAT robot (remote handling for heavy loads)	Renault SNIAS ELF-Aquitaine The TIM robot (service and maintenance remote handler) La Cahline (subsidiary of the CEA)	MATRA CGE THOMSON	CETIM (Technical centre for the engineering industries) CERMO (Study and research centre for the machine tool industry) ITF Textile Institute of France CETIH (Technical Centre for the clothing industries) CTIF (Technical centre for the founding industry) etc.	French Oil Institute Research into the automation of refineries	Agency for the development of automated production See the table on 'Aid to Industry' (little research, a great deal of development)

Comments : The Renault research centre, which is composed of about 90 people, accounts for 50% of industrial research into robots and robotics.

The industrial research centres are taking part in the ARA project.

The main bodies engaged in State-funded research in robotics are traditional research bodies (CNRS, CEA, CNES, etc.). The main effort has been supported by the CNRS, which groupes together a number of research centres. Finally, there are two spcialist bodies active in this area : the INRIA and the ADI.

The INRIA is responsible, more particularly, for four tasks :

- undertaking basic and applied research,
- creating experimental systems, notably by bringing together at national level teams drawn from the laboratories of publicly- and privately- funded bodies,
- organizing international scientific exchanges,
- ensuring at national level, through training, the provision of information or any other means, the transfer and dissemination of knowledge and know-how[1].

Side-by-side with these publicly-funded and semi-publicly-funded laboratories, the research centres of firms are developing. The Renault research centre is the largest (50% of industrial research into robots and robotics). This firm is developing a large-scale policy in the area of research. It has set up the DDA (Delegated Directorate for Robotics), which is staffed by 90 employees. This research structure works in close association with SOFERMO where engineering studies are concerned. Renault is orienting its research along four major axes ;

- receivers,
- engineering aspects,
- control language, the creation of a complete robotic system,
- a complete robotic range.

---

(1) Y. Lasfargue, op. cit.

One should also add the industrial technical centres. Set up by skilled staff in the various industrial sectors, the technical centres are for the most part governed by the Law of 22 July 1948 and function by virtue of the parafiscal tax paid by industry as a proportion of turnover (1% to 4%). These centres are pursuing their activities around four broad areas :

- applied research
- advice and intervention
- technical documentation
- vocational training.

The organization of research in robotics shows a great variety of approaches. The Directorate-General for Scientific and Technical sanctioned 49 agreements in robotics, 41 in 1980 for automation and robotics. Research topics concerning robotics are very varied.

The aim of the ARA project, under the aegis of the Directorate-General for Technical and Scientific Research, set up in 1981, is to bring together and coordinate the research programmes of laboratories in the universities, institutes of higher education and industrial laboratories. It represents between 30% and 50% of French research into robotics depending on the sector and thus constitutes an equivalent full-time staff of more than 100 researchers. Four major areas of work have been defined :

- advanced remote operations :	FF 1.2 million
- engineering and technology for robotics :	FF 1.25 million
- general robotics :	FF 1.5 million
- flexible manufacturing shops :	FF 1.0 million

Although the research structure in robotics is a solidly-based one, it is scarcely oriented towards the attendant social problems. The example set by other European countries demonstrates the need to act at the initial, research level in order to frame a lasting social policy for robotics. Many studies have shown that a certain form of work organization was inherent in the very construction of any automatic machine. Through failing to monitor the manufacture of products in the early stages, one is obliged to act at a later stage in the process [1].

---

1 O. PASTRE, N. DINCBUDACH, J.P. JEANDON, P. MANCHION, U. MULDUR : "32 proposals for a medium-term social policy for computerization". CPEI.

France had some leeway to make up in the area of research; the objective of 2.5% of GNP thus appears to be an end in itself. However, the leeway does not exist in all areas. It is unquestionably greatest in the area of ergonomic research. To give a rough idea, a recent OECD report estimated that research in the field of social development in France in 1977 accounted for 1.5% of the overall research budget. In the United States the percentage was 2.9% and in the Federal Republic 4.8%.

However, ergonomics is not a homogeneous whole. Data-processing ergonomics has been almost exclusively the ergonomics of hardware. This has meant losing sight of a fundamental aspect that software, just as much as hardware, very largely predetermines the conditions and organization of work. Automatic data-processing ergonomics must therefore also be an ergonomics of software. Three teams in France (INRIA, BISSERET, IRACT at Toulouse, CNAM of Montmollin) are developing reserach in this area.

If promoting research means providing a lasting solution to the economic crisis, developing ergonomic research means providing a lasting solution to the social crisis.

ACTION BY PUBLIC AUTHORITIES : STANDARDIZATION

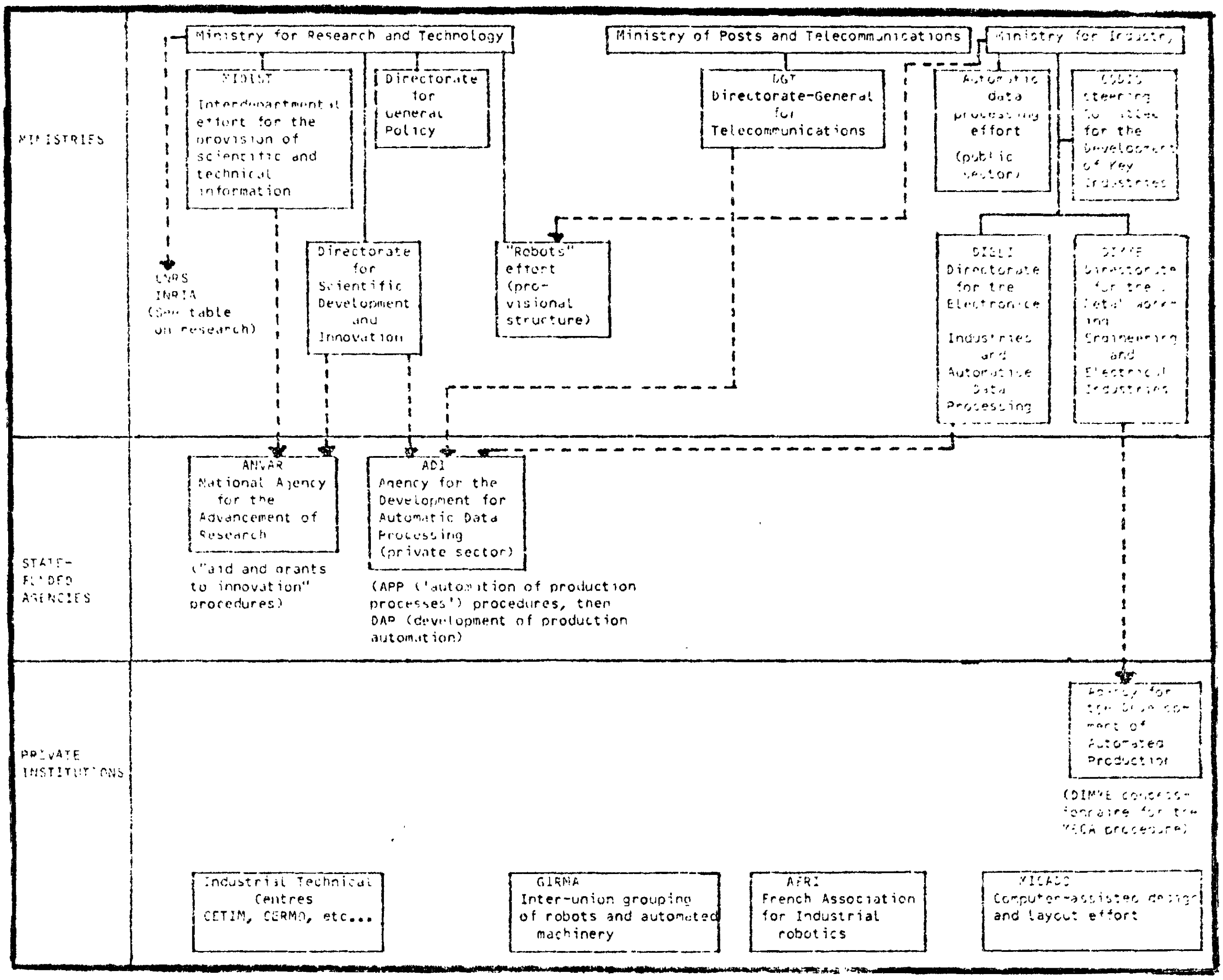
"The under-equipment of many French firms and, in particular, of small and medium-sized industries in robotics has prompted public authorities to develop a policy aimed at promoting the introduction of robotic equipment into industry and to take action not only with respect to demand but also and, above all, with regard to supply [1]." Since 10 May large funds have thus been released to support the robotics effort.

---

1 M. SAHBUT D'IZARN, Director for the Electronics Industries and for Automatic Data Processing at the Ministry for Industry in Y. Lasfargue, op. cit.

However, before describing these measures, we must draw up a list of the institutions active in the field of robotics [1].

INSTITUTIONS ACTIVE IN THE FIELD OF ROBOTICS



1 Y. Lasfargue, *op. cit.*

What is surprising is, more than anything else, the extraordinary spread of initiatives and funds granted to various bodies. This is occuring at three levels :

- The MECA procedure (promotion of advanced-design machinery and equipment), supervised by the National Agency for the Development of Automated Production (ADEPA) is designed to encourage employers and, in particular, small and medium-sized undertakings to use advanced-design machinery. Employers may keep the equipment or return it at the end of the trial period. Between 1976 and 1980 this procedure resulted in the installation of 400 numerical-control machine tools.

  The budget allocated to the MECA procedure rose by 66% in 1982, from FF 90 million in 1981 to FF 150 million.

- The DAP procedure (action for the development of production automation) is managed by the Automatic Data Processing Agency (ADI). Its object is to bring about an improvement in the performance of production tools through the use of automatic data processing systems and automatic systems and to develop the use of electronics in French industry.

  In 1980, out of 120 applications for subsidies, 38 applications submitted jointly by a user and a manufacturer were accepted in respect of a sum of FF 15.5 million. In 1982 this aid rose from FF 14 million in 1981 to FF 20 million, i.e. a 43% increase.

- The "robotics billion" was a subsidized loan granted to firms, rising to up to 70% of investment made between 1 January 1981 and 31 December 1982 in robotic equipment. However, a major proportion of this sum has been devoted to conventional investment.

Development contracts

These contracts are concluded between the Steering Committee for the Development of Key Industries (CODIS) and firms, within the framework of priority fields of activity.

An initiative to promote robotics has been adopted and split into four main fields, with priority accorded to flexible manufacturing :

- flexible manufacturing shops,
- industrial robots,
- assembling machinery,
- components for robotic equipment.

The purpose of these contracts is to acquire initial experience in order to develop the French market. Unfortunately, this initiative has contributed to the large-scale use of imported equipment.

In December 1981 seven contracts were signed, with State aid amounting to FF 50 million.

Aid for new products

The function of the National Agency for the Advancement of Research (ANVAR) is to make aid available to make innovation grants. Innovation aid is granted to firms and research bodies which draw up a programme of expenditure relating to all or part of the innovative process. 108 innovation grants were accorded in respect of a total of FF 162 million in 1979. 1 040 grants representing a total of FF 548 million were made available in 1980, although the proportion allocated to robotics was only 10%. The innovation grant made by ANVAR to firms employing fewer than 2 000 workers seeking outside funds and skills has shown the same trend : 1 756 innovation grants were made available in 1980 in respect of an overall sum of FF 12.8 million.
In 1981 a total of FF 480 million in aid and grants was envisaged, with around 10% being devoted to robotics.

Three comments need to be made concerning the activity of public authorities up to May 1981 :

- this initiative for the development of the robotics industry was launched belatedly. The first practical measures date from December 1979 with the creation of CODIS;
- it is a demand policy, more than anything else, which has been developed by public authorities. Many "pilot schemes" have remained at the

experimental stage, and this has led to a sharp increase in imports of automated equipment goods;

- this demand policy has not been a social policy for computerization. A genuine policy of use must also take account of the problems of standards, in particular, ergonomic standards. Standardization is the necessary route from pilot scheme to mass production. It is thus a key component in any development policy.

The activities of the public authorities since 10 May have consisted first of all in increasing the budgetary allocations for robotics :

- boosting the budgets of aid to industry (up 104%)
- aid to research (up 29%), for instance, the budget for the ARA project will rise from FF 5 million to FF 7 million (up 40%),
- sizeable increase in the budgets of the ADI (up 20%), ANVAR and innovation aids (up 70%),
- "computerization" plan (up 78%),
- "machine tool" plan : FF 2.3 thousand million.

However, it is not enough to increase State aid. In this area, nationalization, doubling the State's "market share", represents a major component in a social policy in the field of robotics.

TRADE UNION PROPOSALS

A very clear dividing line separates here the Force Ouvrière (F.O.) (Workers' Front) and the Confédération Générale des Cadres (C.G.C.) (General Confed. of Supervisory and Managerial Staff, on the one hand, and the Confédération Générale du Travail (C.G.T.) (General Confed. of Labour) and the Confédération Fédérale du Travail (C.F.D.T.) (Federal confed. of Labour), on the other hand, with the first two confederations rejecting negotiations on the very content of technology; the only debate relates to a subsequent stage, namely, the implications in terms of jobs[1].

---

[1] For further information; see : "La France avant le 10 mai". Bulletin N° 1 of EPOS.

The C.G.T. and the C.F.D.T. are giving evidence of a less defensive strategy and have each published an analysis of the impact of the new technologies in industry[1].

Although the two trade union conferations are unanimous in recognizing that robotics is an economic reality, the aim of which is to move material around in an optimal manner throughout the manufacturing process and thus to increase output and boost productivity, the proposals differ markedly. In the case of the C.F.D.T., "controlled and supervised by man, democratically planned, the new technologies can become an instrument in a new leap forward, within the context of a different type of development".

- First and foremost, thinking concerning the new technologies needs to be organized at all levels of economic life. The Pays de Loire region has brought this need to the attention of the Regional Economic and Social Council in the form of an opinion. However, thinking on this issue must become more widespread, particularly at company level, by making information and debate on new investment and its implications a sine qua non. Further research should be undertaken concerning the enhancement of the quality of life at work as a result of innovations in production.

- It should be possible to negotiate trade union supervision over various areas :
  - monitoring of investment, from before it is committed,
  - monitoring of investment at the time when new equipment is being installed,
  - monitoring at the factories of manufacturers of robotic equipment.

- The Trade unions must demand genuine consultation and the ability to negotiate nationally and by firm the introduction of new technologies into industry.

---

[1] C.F.D.T. : "Nouvelles technologies et automatisation dans l'industrie". (New technologies and automation in industry). Section for economic activity, employment, continuing education, January 1982.

C.G.T. : "L'automatisation de la production : premières réflexions". (Automation of production : first thoughts). Economic Note N° 184. May 1980.

The two trade unions recognize the need for controlling the production of automated equipment goods, thereby making possible a fair redistribution of productivity gains, which must translate itself into reality in the form of a significant reduction in working hours. For the C.G.T., "democratic action concerning the manner in which work is thought at before hand and organized is becoming a practical necessity if workers' claims are to be asserted effectively".[1]

It is in these terms that the problem is posed of scope for action concerning the content of design work. "For example, it is well known that studies on robotics are being pursued. It is even said that the CEA, which has acquired a considerable body of knowledge as a result of the remote handling of objects in a radioactive environment, and Renault are planning to conclude cooperation agreements in this field. However, is it not important that our trade union organization should be kept informed and should be able to take a hand concerning the content of these studies, in view of their likely impact on manufacturing work ?". Likewise, while the specific nature of training for work on a particular machine may be reduced, general training in skills to gain proper mastery of work and the content thereof on automated systems must be greatly widened and developed. Despite these proposals, there are two limits to the "democratization" of negotiations concerning automatic data processing.

- French trade unions do not possess, at the micro-economic level, the necessary competence to arrive at an informed opinion on the methods whereby computerization is to be implemented;
- French trade unions do not possess sufficient resources with which to negotiate concerning computerization.

---

[1] C.G.T. <u>op. cit.</u>

AUTOMATION AND EMPLOYMENT : FOR A REAL DEBATE ABOUT REAL PROBLEMS*

THE RELATIONSHIP BETWEEN AUTOMATION, EMPLOYMENT AND UNEMPLOYMENT : FROM FICTION TO FACT

With the advent of the economic crisis of the 70s, many macro-economic theories were found to be no longer relevant. However, one fact has emerged from the continuing economic debate, namely that a new relationship between technology and employment is emerging. The extraordinary development of automation processes has given new breadth to this debate (1). At the same time, the relationship between automation, employment and unemployment should not be seen as the only explanation of recent employment trends. For the last 30 years, analysis of the impact of automation on work and employment has had to deal with contrasting beneficial and adverse effects, which now need to be demystified and defined with greater precision. The introduction of micro-electronics in industry and the general use of robots is not the determinant factor in a strategy for overcoming the economic crisis, nor is it the explanation for unemployment. (2)

This analysis can be illustrated by theories of compensatory employment (3), even if somewhat sketchily. According to this approach, automation enables large increases in productivity to be made, and even if in the short term it is liable to increase pressure on employment, in the long term it has basically beneficial effects. The manufacture of automated machines creates new jobs, and most importantly, the resulting increased productivity enables prices to be reduced, makes industry more competitive, enables home markets to be recovered more easily, encourages exports and helps to generate new demand.

---

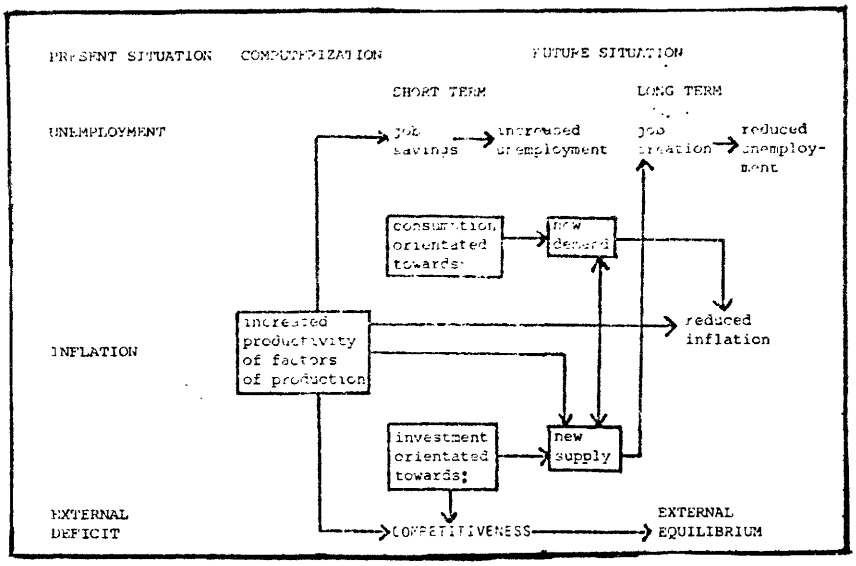
* This text was presented to the robotics industry mission in May 1982.

(1) J.L. MISSIKA, "Les débats sur informatique et emploi. Comparaison internationale". Ministère de l'Industrie, 1980.

(2) J.H. LORENZI, O. PASTRE, J. TOLEDANO, "La crise du XXème siècle".

(3) S. NORA and A. MINC, "L'informatisation de la Société". Ed. Seuil, 1978.

F. SAINT-GEOURS, "Information et macro-économie". Appendix N° 3 of report by S. NORA and A. MINC : La Documentation Françaises, 1978.



This outline analysis is, however, too mechanistic. The uncertainties and macro-economic constraints remain, namely the following :

- Will the electronic capital-goods industries really create jobs overall ?
- Given the structural rigidity of industry, will the increased productivity result in lower prices (1) ?
- Lastly, will the development of the international economic environment permit increased national competitiveness ?

The other extreme would be to put the main responsibility for unemployment on automation. However, the reality is different. On the one hand, it is necessary to distinguish between the total and net number of jobs lost, only the latter having a direct effect in terms of employment, and on the other hand, automation should be considered "an endogenous phenomenon which only has a variational effect on employment trends".

---

(1) B. MERIAUX and M. VIGEZZI, "Automatisation, structures et volumes d'emploi" in "Emploi et Système Productif". La Documentation Française, 1979.

"Automation does not determine the development of the labour market from outside, but rather it is a simple factor in the process of wealth accumulation, and only modulates this development".

"Even although automation is intrinsic to the logical evolution of developed economies, and as such should be associated with recent changes in the process of wealth accumulation, it nevertheless has certain specific characteristics which need to be understood in detail". (1)

From the standpoint of this logical development, priority must be given to analysing these specific characteristics in terms of changes in job qualifications, work content and working conditions, and then to considering the necessary steps to be taken. However, in order to understand the need for the general use of automation and how this is to come about, it is also necessary to arrive at a firm, quantitative understanding of the magnitude of the productivity increases brought about by the introduction of new robot equipment at micro-economic, sectoral and macro-economic levels. The starting point for this understanding is an analysis of the present crisis and the acknowledgement of the critical role of productivity increases.

REAL PRODUCTIVITY INCREASES : SOME SIGNIFICANT EXAMPLES

The spread of the new technologies has an impact in terms of productivity on all levels of the economy and on nearly all industrial activities. Rather than give endless instances, it is sufficient to quote a few figures which will serve as enduring examples.

Thus, at the micro-economic level, the use of automated production equipment in the manufacture of metal tubes and pipes enables productivity to be increased fourfold; the productivity of annealing operations in the manufacture of thin sheet metal is increased by 300%; the use of computer-assisted design in aerospace design departments multiplies productivity by a factor of ten for complex drawings and by three for simple drawings; certain stamping robots enable increases in productivity of 30% to be made, and soon (2).

---

(1) O. PASTRE, D. MEYER, J.L. TRUEL, R. ZARADER, "Les effets de l'informatisation sur le travail et l'emploi en France à l'horizon 85", in "Informatisation et emploi, menace ou mutation ? La Documentation Française, 1981.

(2) H. AUJAC and J. DE ROUVILLE, "Automatisation industrielle et emploi". BIPE 1980

At the sectoral level, the introduction of new, automated textile production equipment leads to productivity increases of the order of 30% on average,[1] and experts agree that in the motor-vehicle manufacturing sector, on the basis of the present rate of robotization, increases in productivity of 5 to 10% per year will be made in the course of the next decade.

At the macro-economic level, EEC estimates conclude that between now and the year 1990, increases in industrial productivity in France will be as much as 12% according to the low estimate and 18% according to the high estimate. This ties in with estimates made for the Netherlands, which forecast productivity increases of the order of 1% per year throughout the 80s. (2)

Even although the new robot technologies make for productivity increases greater than those achieved with most other forms of mechanization, "this equipment is often underestimated, which makes it impossible to regard the theoretical figures as approximations of reality. Since the utilisation factor is very often less than 30% of the theoretical capacity, it is important here not to confuse what can be achieved with what has already been achieved." (3)

Also, technological uncertainties such as functional reliability, risks, failure rates and learning times add to the uncertainty of all forecasts in this field.

This is not to deny the quantitative importance of those productivity increases in industry which are associated with the spread of automation.

However, this search for increased productivity everywhere is part of a wider process of substitution of capital for labour. Certain studies

---

(1) G. DONNADIEU, "Le devenir des industries du textile et de l'habillement". C.E.S. 1981.
(2) RATHENAU Report, "The social impact of microelectronics". La Haye 1980.
(3) O. PASTRE, "Informatisation et Emploi : de faux débats autour d'un vrai problème". B.I.T. Geneva 1980

clearly demonstrate a positive limit between the growth of capital and that of employment, and also an (imperfect) positive correlation between growth in production, accumulation of capital and creation of employment (1). The special interrelationship between industry, automation and employment in the automated industries is due to the specific way in which this correlation operates in these industries.

Even though these sectors have created employment in the recent past through large-scale substitution of capital for labour by the very act of introducing automation, they are nevertheless characterized by the fact that, for an identical rate of job creation in different sectors, the annual rate of capital growth seems to be greatest in the most highly automated sectors. Or to put it another way, for equal capital growth in different sectors, those sectors which are most highly automated create the fewest jobs, relatively speaking (2). This is also the basis of the specific nature of "automation investment", which is at one and the same time an investment both in productivity and in capacity (3).

In conclusion, it is in the context of this broad relationship between automation, productivity, economic activity and employment that the processes of job creation and job loss should be considered at all levels (micro-economic, sectoral and macro-economic).

---

(1) C. SAUTTER, "Investissement et emploi dans une hypothèse de croissance ralentie". Economie et Statistique N° 93. June 1975.
(2) O. PASTRE, D. MEYER, J.L. TRUEL, R. ZARADER, op. cit.
(3) A. SAGLIO, "Des programmes d'investissements d'entreprises aux fonctions de production macro-économiques". I.N.S.E.E. Year Book N° 10. May - August 1972.
In this respect, the relationship established by C. SAUTTER does not seem to take into account the growth and specificity of automation investment.

JOBS LOST, JOBS CREATED

It is far from easy to foresee what impact automation will have on employment, since various unknown quantities still play a determinant role, whether these be of a technological nature, such as developments in robot and industrial data-processing technology, or economic, such as the nature and level of investment in various sectors. In spite of these uncertainties the following few examples, most of them theoretical, are very significant indeed (1) :

- On a paintwork production line working in two 8-hour shifts, the present staff is made up of 60 semi-skilled workers (including 6 tool setters) per shift plus the supervisory staff (2 workshop foremen plus 2 x 4 group foremen). To automate this production line, 10 software specialists would have to be employed for 1 year in order to prepare the software. In normal operation, the production line personnel for each shift would be made up as follows : the supervisory staff (1 workshop foreman and 2 assistants), 6 repair technicians, 3 paintwork specialists (for setting up new ranges) and an increased maintenance staff. Two software specialists would be required to maintain and modify the software. All this would mean the loss of 2 x 60 semi-skilled jobs, as against the few new jobs created.
- In the case of a semi-automated sheet metal welding installation, 8 robots can replace 2 x 12 semi-skilled workers working in two 8-hour shifts. Supervision is then carried out by two charge hands (instead of one). In total, the number of semi-skilled workers employed decreases from 34 to 10.
- Lastly the use of a stamping robot means that a stamping job is lost. But as a factory manager testified when automating part of his production, "When we do away with a stamping job, we have to take on an electronics fitter". However, the job is still effectively

(1) D. BELLANGER, "Développement de l'automation en France, ses conséquences sociales et économiques". Industry Ministry Data-Processing Mission internal note (Mission à l'Informatique. Ministère de l'Industrie)

(2) "Usine Nouvelle ", N° 5 of 2 February 1978.

lost.

As another example, at the sectoral level, a recent study shows that the general use of automation in the textile industry (introduction of machine transfer, auxiliary automation, production line automation, etc) as part of a modernization plan for the 1980s could enable drastic reductions in employment to be made, as the following table very clearly shows. (1)

Activity	Total investment (10^6F at 1980 value)	Future employment	Present employment (1980)
Man-made textiles	6,000	7,000	11,000
Spinning	2,500	25,000	45,000
Weaving	8,000	45,000	75,000
Finishing	3,000	16,000	25,000
Knitting	5,500	38,000	76,000
Other activities	7,000	49,000	82,000
Total (textiles)	32,000	180,000	314,000
Clothing	9,000	160,000	259,000
Industry total	41,000	340,000	573,000

For their part, Japanese mechanical-engineering firms have set themselves the target of doubling production in 10 years (1975 - 1985) without any great increase in the workforce, by means of robots and industrial manipulators. They are well on the way to achieving this.

Still at the sectoral level, the motor-vehicle manufacturing industry also provides a good example. Here, the main American and Japanese firms are at present reducing and will reduce still further the number of assembly jobs. General Motors intends to shed 50% of its jobs by 1986 ! If it is borne in mind that in France at the moment 550,000 people are employed in assembly work and that at the same time various studies forecast that by 1990, worldwide, 20% of production will be carried out by automated assembly machines, the scale of the jobs losses will be obvious to everyone.

---

(1) G. DONNADIEU op. cit.

(2) Datamation December 1980

Over and above the micro-economic and sectoral levels, various studies of a more macro-economic charachter have considered the effects of automation on employment (see table on page 10).

A large number of jobs will in fact be lost (1) However, there are three propositions which enable this conclusion to be modified, or even in the long term invalidated, namely the following :

- These estimates are only valid all other things being equal. However, various options and initiatives are possible : thus working time can be reduced, or the number of shifts increased, and there is scope for training programmes and industrial relations initiatives, etc;
- These estimates concentrate on the impact of automation in user industries. However, there are possibilities for job creation in the electronic capital goods producer industries, and these are still difficult to quantify. If these possibilities are to be realized, it will certainly be necessary to work out a coherent development strategy for this sector, especially for the robotics industry; and in more general terms, a combined development strategy for the robotics, electronics and mechanical-engineering industries will have to be worked out;
  - a stimulating effect on employment in certain branches of the industry (including production of electronic capital goods);
  - a restructuring of the production system, which has the effect of externalizing a number of activities which are entrusted to service companies and various sub-contractors.
    As the pace of introduction of robot equipment accelerates, the new work content, the need for new qualifications and the obsolescence of old ones become determinant factors in this dialectic of job creation and job loss.

---

(1) J. LE QUEMENT, "Les robots enjeux économiques et sociaux". La Documentation Française. 1981.

RESULTS OF SOME STUDIES CARRIED OUT ABROAD ON THE EFFECT OF AUTOMATION ON EMPLOYMENT

COUNTRY	TYPE OF AUTOMATED EQUIPMENT STUDIED	SECTOR	TIME HORIZON	RESULTS	RESULTS
JAPAN	Industrial robots	Industry	1985	Doubling of production without increase in workforce	Industrial robot. December 1978
UK	Micro-electronics	All	1990	4 million unemployed, i.e. around 7% of the working population	I. BARRON and R. CURNOW, "The Future with Micro-electronics". 1979
JAPAN	Series production automated equipment	Foundry	1990	80% reduction in workforce	BIT, "Les répercussions du progres technique sur la structure du personnel dans les industries de la CECA". 75
FRG	Micro-electronics	All	1990	12% unemployment (compared with 4% without development of micro-electronics industry)	PROGNOS, "Développement économique et marché d'emploi en RFA et dans le Bade Wurtemberg". 1978
FRG	Micro-electronics	Machine tools Precision engineering	1990	5 - 6% job savings	Institut BATTELLE, "Les conséquences sur l'emploi du développement technologique." 1978
FRG	Micro-electronics	Watch-making	1985	26 to 55% fall in employment between 1977 and 1985, with low volume of production	Institut TOPPER, "Conséquences des développements de la technologie sur l'emploi et les entreprises". 1978
UK	Micro-electronics	All	1985	15% unemployment	B. SHERMAN and C. JENKINS, "The Collapse of Work". 1979
FRANCE	Micro-electronics	All	1985	Loss of 210,000 jobs	O. PASTRE, D. MEYER, J.L. TRUEL, R. ZARADER, "Automation, travail et emploi".1979
FRANCE	NCMT	All small-series production industries	1985	Loss of 4000 jobs	idem
FRANCE	Robots, programmable automated equipment, large-series production mini-computers	Motor-vehicle manufacture General engineering Electronic components Metal foundry	1985	Loss of 50,000 jobs	idem
FRANCE	Automated process equipment	Industries using continuous processes	1985	Loss of 50,000 jobs	idem
FRANCE	Computer-assisted design	Electrical and electronic engineering, motor-vehicle manufacture, Aerospace, Shipbuilding, Mechanical engineering	1985	Loss of between 2000 and 3000 jobs	idem

THE BIRTH AND DEATH OF QUALIFICATIONS

Before examining the basic changes brought about by automation, we must first consider how qualifications will change in the future. This we can do by looking at the considerable changes which they have already undergone. A brief survey shows that since 1968 the following changes have occurred :

- the number of people employed in production has decreased in comparison with the number of people employed in services;
- the increase in the number of people employed in services is part of a process of compensation for the relative decrease in the number of the most highly qualified workers employed (skilled workers);
- there has been a slight increase in the number of managerial staff employed, relative to non-managerial staff. This tendency is partly reflected in the increased number of technicians and supervisory staff.

These are the sort of changes which automation will bring about. Numerous studies have shown the effect of automation on qualification structures. Most of these studies have come to the same conclusions, namely that :

- there is an appreciable increase in employment for semi-skilled and unskilled workers in a very wide range of jobs;
- in the majority of cases, automation does not lead to changes in the system of personnel categories and classifications, hence quantification is sometimes difficult, if not impossible;
- there is a considerable and rapid rise in the proportion of managerial staff;

- Lastly, the proportion of maintenance staff increases as more jobs become automated.

The general introduction of the new electronic capital equipment would seem to reinforce these already widely established tendencies.

Thus, as old qualifications disappear, new qualifications appear (1).

EFFECTS OF COMPUTERIZATION ON QUALIFICATIONS STRUCTURES : TRADES REQUIRED

ESE Code	Qualifications
384	Maintenance mechanics
387	Skilled machine operators
388	Highly qualified, skilled machine operators
389	Automatic machine tool setters
390	Control panel operators
270	Technical surpervisory staff (shift foremen)
20-21-22	Engineers (especially electronics specialists)
24	Specialist test, monitoring and laboratory technicians
25	Work study and methods specialists

THREATENED TRADES

Type of automated equipment	ESE Code	Qualifications
Large-series production Process	471	Semi-skilled workers
	472	Unskilled workers
	502	Non-qualified warehouse and stock-handling staff
	503	Lifting equipment operators
	500	Warehouse and stock-handling staff
	274	Supervisory staff
Process	400	Qualified chemical workers
	401	Qualified glass workers
	402	Qualified glass manufacturing workers
	405	Qualified paper and paper board manufacturing workers
	454	Qualified leather workers
	468	Qualified plastics workers
	301	Qualified furnace workers
Large-series production	341	Qualified industrial painters
	350	Qualified foundry workers
	351	Hot- and cold-rolling workers and allied trades
	360	Hot-metal workers
	361	Qualified welders
Numerically controlled machine tools	387	Skilled machine tool operators
Large-series production and Process (jobs mainly indirectly affected)	260	Production management technical staff
	261	Production management services supervisory staff

(1) O. PASTRE, D. MEYER, J.L. TRUEL, R. ZARADER : op. cit.

Some conclusions can be drawn from these tables. It can be seen that the number of people employed in some jobs, supervisory jobs in particular, increases or decreases in different cases.

On the other hand, there seems to be a considerable increase in the number of technicians of all kinds in electronics, mechanical engineering, automation, hydraulics, etc...

Automation also causes a change in the composition of the workforce. There is an increase in the number of less well qualified workers, and in this category a new grade appears which is directly concerned with automation, namely machine minders/operators. These now represent 65% of "qualified" workers in the petroleum industry, 33% of those in the chemical industry and 23% of those in the food and agriculture industries. As against this, there would seem to be a spectacular increase in the number of maintenance workers. In actual fact, these would seem to be the only workers who can really be said to be qualified, since where other jobs are concerned, the effect of automation is to take tradesmens' qualifications obsolete.

However - and this applies primarily to the initial stage in the introduction of robot equipment-the jobs which are automated are the unskilled jobs; thus we read :

"If we look at the tasks performed by the first 200 robots installed in France, we find the following distribution :

- spot welding : 55
- stock handling : 80
- painting : 50
- arc welding : 15" (1)

---

(1) Y. LASFARGUES, "L'utilisation de la robotique dans la production et ses perspectives d'avenir". C.E.S. 1982

More generally, it is the jobs which are performed in a hostile environment and the basic, unskilled jobs, such as keeping machines supplied, identification, assembly and integration, that are concerned after the introduction of advanced automated equipment.

Apart from these particular observations, there are more general conclusions to be drawn.

The similarity of the new jobs required, and, by contrast, the specific natures of the jobs threatened, are part of the same tendency for the differences between jobs to become blurred owing to an increasing homogenization of jobs and qualifications. Differences between jobs are already disappearing as a new, uniform job category becomes predominant, namely machine control and supervision.

The disappearance of specific trades also accelerates the process of job generalization (merging of different jobs). This then becomes one of the basic characteristics of the new pattern of production organization, which is marked by a devaluation of former trades (2).

However, the disappearance of differences in jobs also leads to an increase in the number of semi -skilled and unskilled jobs.

Various jobs are thus deskilled and this adds to the homogenization of work. Also, increasing specialization of automated equipment and the simplification of machine languages help to bring about the "age of computerization without computer specialists", and also facilitate switching to deskilled jobs within the same organization. This reduces quantitative pressures on employment, to the detriment of qualification levels. However, at the same time, where technicians' jobs and job requirements are concerned, a process of over-qualification (3)

---

(1) Groupe pour l'aménagement des conditions de travail, pour l'informatique et l'automatique, Ministère du Travail, de l'Emploi et de la Population. Délégation à l'informatique. 1974.

(2) B. CORIAT, "Robots et automates dans les industries de série". C.R.E.S.T.

(3) M. FREYSSENET, "La division capitaliste du travail". ed. Savelli. 1977

and the emergence of new areas of specialization (1) can be observed.

In actual fact, this process of over-qualification and deskilling a vigorous continuation of the process of work reorganization foreshadowed by Taylorism and Fordism.

But besides the changes in qualification structures, the extent of the accompanying organizational changes should also be noted. These contribute to increased insecurity of employment. One example is the development of group working methods in order to make cost-effective use of the new automated equipment. Another is the externalization of certain sections of the workforce, whether qualified (repair and maintenance, design, engineering, etc), or deskilled (stores and stock handling). This is achieved by resorting to sub-contracting or temporary labour. The following table summarizes the trends which have been mentioned so far (2).

---

(1) R. ZARADER, U. MULDUR, "L'adéquation formation-emploi. Nouvelle technologie, nouveaux métiers, nouvelles formation". Le Nouvel Automatisme. June 1981.

(2) F. GEZE, F. GINSBURGER, "L'automatisation dans l'industrie". Impact sur le niveau d'emploi à moyen terme. A.C.T. 1980.

OUTLINE (AND INCOMPLETE) TABLE OF THE EXPECTED EFFECTS OF AUTOMATION ON EMPLOYMENT

	Continuous and batch processes		Sequential processes	
	continuous processes	semi-continuous processes	Assembly Installation Store-keeping	Machining welding Painting
industries mainly affected effects on employment	*petrochemicals *refining *mineral chemistry *steel *non-ferrous metals *glass *wood pulp	*food and agriculture *pharmaceuticals *fine chemicals *construction materials *plastics *etc	*motor-vehicle manufacture *construction *electrical and electronic engineering *packing industries (food and agriculture, pharmaceuticals, etc)	*motor-vehicle manufacture *construction *mechanical engineering *aerospace *shipbuilding *etc
Job loss (1)	low	high	low	medium
Deskilling (1)	medium	medium	low	high
Skilled sub-contracting (maintenance)	↗	↗	→	↗
Non-skilled sub-contracting - production. - maintenance	↘ ↗	→ ↗	→ ↗	↗ ↗

(1) For each of these categories, it is necessary to distinguish the effects on the different types of work affected, i.e.,
- direct productive work
- stock management and handling
- repair and maintenance
- management and supervision
- design and work organization

TOWARDS A NEW WORK CONTENT

Automation can prove to be one of the surest ways of freeing people from unpleasant work.

Automation, by accentuating the separation between the worker and the product, puts an end to certain kinds of arduous work. Thus it helps to do away with work which formerly demanded great physical effort in a hostile environment.

This is true in particular of many robots, such as welding, painting and assembly robots. But automation also does away with work which is fatiguing because of its repetitive and fragmented nature.

However, the reality is more complex and the effects of automation can take many forms.

The adverse effects which automation has on work content are already discernible in the homogenization of work, the emergence of control/ supervision functions and the generalization or deskilling of jobs.

Often, instead of physical stress, mental stress occurs as an accompaniment to the following :

- deskilling;
- the nervous tension associated with many control/supervision tasks;
- the impossibility of personal contacts during work;
- the increased work rate due to automated pacing of the work.

New illness thus arise.

Furthermore, automation can lead to new forms of control over workers, since if a worker supervises a machine, the machine also supervises the worker.

However, to consider the evalution of work content solely from the stand point of improvement or worsening of working conditions is too simplistic.

The evalution of work content is still an economic issue : if working conditions are improved, so too is productivity. Automation may constitute an effective solution to the contradictions that stem from Taylorism or Fordism. At present, accidents at work cost more than 24 thousand million francs per year (1980), and the labour crisis brought about by Taylorism (personnel turnover, abseteeism, etc) still costs the economy 15 thousand million francs.

A new economic, social and organizational deal is now necessary, and automation can be one of the means of achieving this.

IN VIEW OF THE FOREGOING, WHAT ACTION SHOULD BE TAKEN ?

First of all, a new philosophy of action must be determined by defining a new relationship between industrial policy and social policy. (1)
Our analysis shows that industrial strategies based on automation have a fundamental social impact. Hitherto, the division of responsibility seemed to be well established : "It is up to industrial policy to define the actions necessary to achieve a central aim, namely international competitiveness and it is then up to social policy to deal with the consequences of these actions afterwards. However, it is industrial policy decisions which very largely determine changes in work. It therefore follows that certain social policy guidelines should be worked out in advance as part of the process of defining industrial options". (2)

All actions aimed at reducing both quantitatively and qualitatively the pressures that automation exerts on work and employment must be worked out with this in mind.

Besides affirmation of the necessity of tripartite industrial-relations negotiating procedures (which should take place in accordance with legally and institutionally defined rules concerning the venue, the powers of the negotiating parties, etc), there are a number of concrete proposals which already offer scope for effective action.

---

(1) The Swedish example is significant in this regards :
R. ZARADER, P. MANCHION, J.C. MIGETTE and U. MULDUR, "Développement de la robotique et politique sociale en Suède." Report to the "Ministère des Relations Extérieurs" 1982

(2) O. PASTRE, D. MEYER, R. ZARADER, "32 propositions pour une politique sociale de l'informatisation à moyen terme". C.R.E.I.

Reducing the number of hours worked reduces not only the quantitative but also the qualitative pressure on employment. Negotiations aimed at reducing the number of hours worked in various industries should take account of the degree of automation, both present and future, in industries such as motor-vehicle manufacture and the agri-food industry, since this is one of the determinant factors.

Increasing the number of shifts confers an extra degree of freedom and offers considerable opportunities for creating new jobs in the industries most directly concerned with automation, for instance, by :

- changing from a discontinuous, two-shift system to a semi-continuous, three-shift system and shutting down at weekends only, or by

- changing to a five-shift system in continuous-process industries, e.g. the glass, chemicals, oil and man-made fibre industries.

Drawing up new training policies (initial training and job training) is also a means of adapting a plentiful labour market to new employment. It is expected that, because of computerization, 900,000 people will have to be retrained by 1985.

However, such programmes aimed at reducing quantitative pressure should also be accompanied by qualitative programmes. Design of new equipment should take much more account of ergonomics and health and safety standards. This also applies to software (software ergonomics). This will necessitate large-scale public- and private- sector research programmes which will require the cooperation of manufacturers, trade unions and public authorities.

ACCORDINGLY, THERE ARE THREE THINGS TO BE DONE AS A MATTER OF PRIORITY, namely :

- as regards design and manufacture of new electronic capital goods, to develop coordinated, national research projects to deal with ergonomics and health and safety (hardware and software);

- to promote new job training programmes for the new technologies, with special emphasis on small and medium-sized businessess;

- to facilitate the flow of information and to promote coordination, by organizing regional discussions between manufacturers, users, trade unions and public authorities on the problems posed by the introduction of robots, and by enabling works councils to appoint and pay for technical experts to advise them (information, participation) in design projects, etc...).

Report on the social impact of robots in germany

Prof. Dr. Willi POHLER
Landesinstitut der Sozialforschungsstelle
Rheinlandamm 199

D - 4600 DORTMUND

SUMMARY

The following report surveys the state of development and use of industrial robots , the social effects and what government , trade unions and employers are doing in this field.
With some 2 300 robots now in operation it can be seen that things have not developed as rapidly in this field as was expected in the mid-seventies. This is no doubt partly due to the present economic situation in the Federal Republic.
The use of industrial robots can result in substantial redundancies. It is a fair assumption that the some 2 300 robots now in use have displaced some 8 000 - 9 000 workers, most of them in semi-skilled jobs in the bottom to medium range, though less skilled jobs can be created. The use of robots can eliminate adverse workloads, but successful results in this area depend on the proper selection of applications.
The Federal Government is providing substantial resources for the development, testing and use of robots, with the dual aim of boosting the competitiveness of the economy and relieving the worker of adverse working conditions. As shown by a study on the effects of the humanization programme it has not been possible to attain these humane objectives completely. Both sides of industry are discussing measures for shortening working hours and cushioning the social effects within companies of the new technologies. Here the existing laws and regulations play an important role.

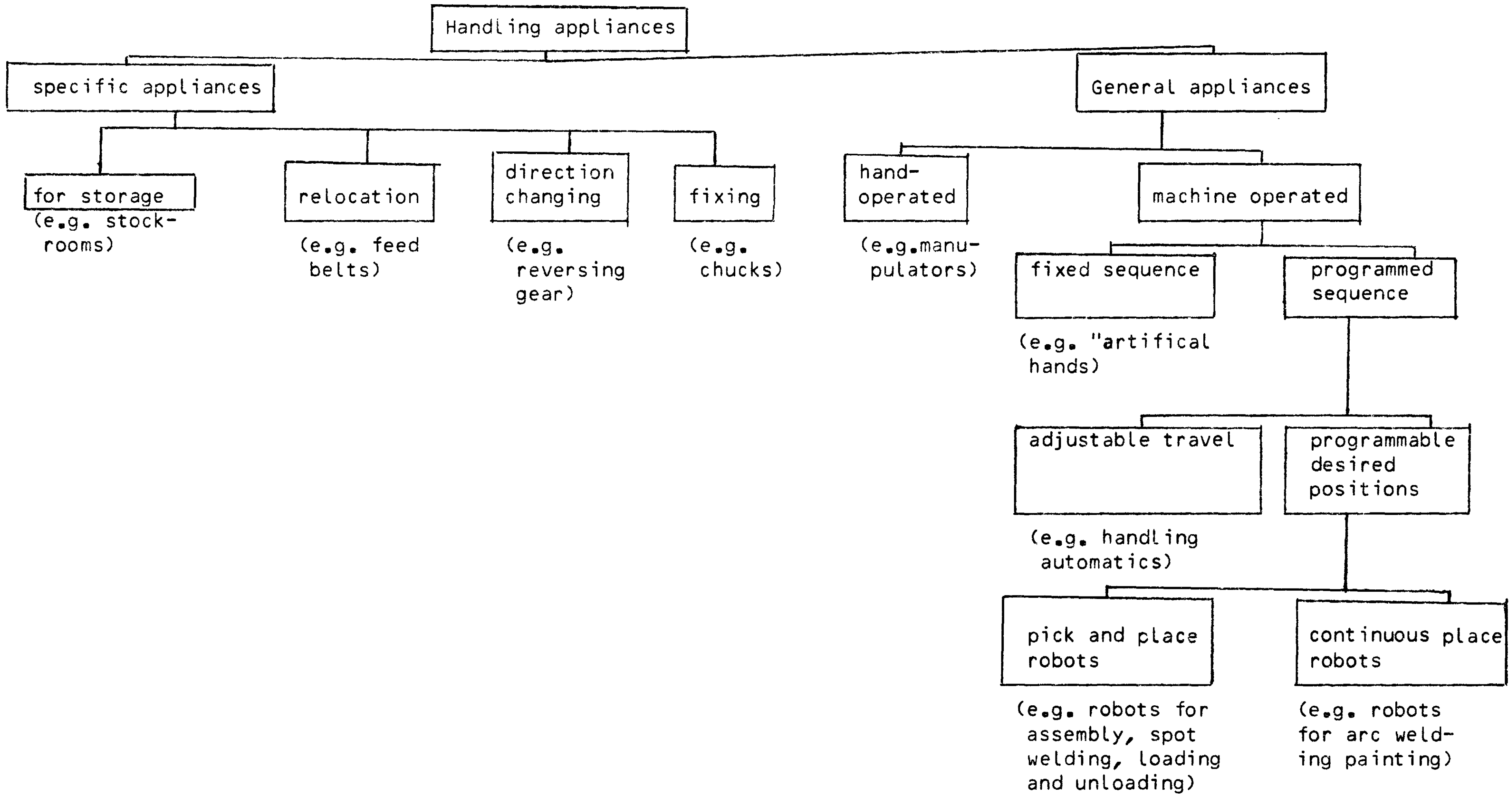
1. State of technical development and its application

As tools for the flexible automation of production industrial robots are gaining more and more ground, even though the pace of their development and application is not as fast as was initially expected. From the technical angle their general application to handling and assembly techniques depends on the development fully operational optical and tactile sensors. Though robots were initailly put to work as single handling tools, the tendency is now to use them as integrated elements of production systems. A typical example is their function in handling parts, tools and measuring instruments in flexibly sequential manufacturing systems (FMS) or as flexible tool operators in sequential welding lines.

1.1. Typical operations

For a clearer understanding of the possibilities of robots and exactly what they can do let us first consider some typical operations. Chart 1 on the next page already shows that robots are only one of many tools for handling. Their specific features are that they can be used anywhere, are mechanically controlled and can be programmed. This report therefore takes no account of hand-operated manipulators and fixed sequence appliances like "artificial hands" such as for example for mechanical feeding of presses.
A further limitation concerns control : in the Federal Republic, as in the USA, handling appliances with at least three degrees of freedom that can be programmed in respect of path or position and control data are designated as industrial robots.

Chart 1 : Classification of handling equipment



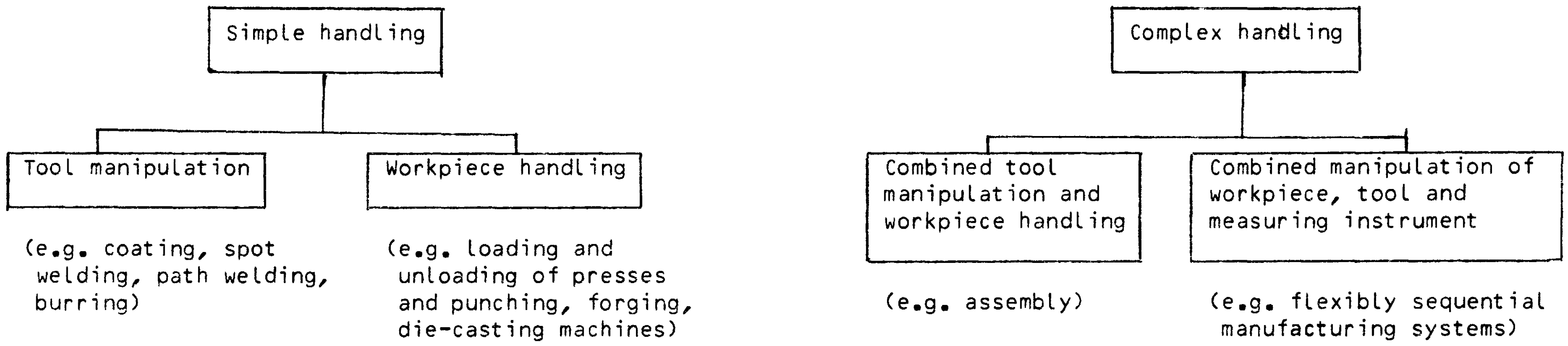
(Source : Spur, Auer, Sinnig - Industrierrobotier, p. 17)

Unless otherwise stated, all figures refer to this type (see, among others, H.J. Warnecke, Handhabungstechnik und Industrieroboter).
Robots can be used in a number of different fields (see chart overleaf), where, in practice, the emphasis varies widely. (see next paragraph). In the motor industry, for example, robots are now prominent as tool manipulators, particularly in welding. The widespread use of robots for assembly processes will have considerable technical and social repercussions, though this will only be possible when sensors, essential to such complex manipulative processes, have been fully developed.

Next to Japan the Federal Republic is leading in the development of "flexible manufacturing systems" (FMS), which consist of the following components :

- Processing system for automated processing of various parts in optional sequence, with automated part and tool change (e.g. NC or CNC tool machines, tool stores, butter stock)
- Material flow systems (e.g. storage, conveyors)
- Manipulation systems as the interface between processing and material flow systems (industrial robots)
- Data system for process control and supervision.

Chart 2 : Applications of industrial robots



Jobs performed by robots include : workpiece handling (loading and unloading), tool manipulation (tool change and toolboxing), measurement manipulation (instrument change, instrument case), clamping and chucking (work accommodation, clamp changing), auxiliary manipulation (sensor control).

In FMS robots are considerably more effective than when used as tool or material manipulators. FMS are technical alternatives to single machines and processing complexes as well as to transfer lines.

1.2. State of the art

As the use of robots is constantly developing and new applications are continually being found, quantitative data must be considered in relation to earlier and forecast developments. The following use figures may be cited for the Federal Republic :

Table 1	Number of industrial robots in use					
Year	1974	1975	1977	1978	1980	1982
N° of IR	133	243	541	620	1255	2300

(Source IPA (International Press Agency) and VDA (Verband der Automobile-Industrie).

The most concentrated application is, as it always has been in the motor industry, which has some 1 200 robots. Concentration in specific applications is as follows (the figure in brackets indicates the number of robots) :

Spot welding (800)
Machine loading and unloading (355)
Path welding (230)
Coating (230)
Die-casting and injection moulding (130)

On the assembly side about 100 appliances are currently in use for simple assembling procedures.
Twenty-two FMS are currently in operation, mainly in machine tool, gearbox/transmission and aircraft production.
Ten of these have between 5 - 10 integrated machining stations and five of them have more than 10. The emphasis is unmistakeably on drilling and milling machines (32 %).

1.3. Forecasts for further development and application

Forecasts by producers and users indicate that by 1985 between 4 000 and 5 000 robots will be in use. This means that the number of applications will be twice that of today. Spot welding and coating, areas in which the use of robots is at present most concentrated, will continue to expand. One new technically viable application will be arc welding.

Workpiece handling, particularly the loading and unloading of NC machines including the operation of other machines, in terms of use,is still in its infancy.
The broad breakthrough of robotics into manual assembly is not expected for about another ten years. The main problems lie in developing sensors to identify the location of workpieces and control assembly paths and assembly forces.

Development of FMS has reached high technical standards. The pace of their expansion is largely determined by the high capital costs, so that in our present uncertain economic situation it is extremely difficult to make quantitative forecasts. A market study (Steinmüller, p. 36) suggests that about 100 FMS will be in use by 1990, the main branches involved being the electrotechnical (20%), the motor (20%) and the machine tool industries (15%).

2. Social effects

The use of robots is not without effect on employment, both quantitatively in terms of redundancy and qualitatively in terms of new skills required of workers. Working conditions also change and with them the pressures and strains on the work force.
The social impact is not the same in all areas. It depends mainly on the technical and organizational setting in which robots are used and on the effects of general economic and social conditions.
After comparing and relating the various effects the conclusion is that labour is made redundant by the use of robots.
The redundancy effect is most severely felt when robots are used as part of a manufacturing system (e.g. in sequential welding lines or in FMS).

The new skills required of workers vary according to the type of application. In FMS, for example, higher value jobs are created in servicing and supervision.
Robots can be used on jobs performed under extremely arduous working conditions (heat, dangerous materials, noise, strenuous manual labour). They can help to humanize work. This was, for example, one of the reasons why the Federal Government is promoting the development and use of robots as part of its "Humanization of working life" programme (see sec. 3.1.).
But tests have also shown that working with robots has its own stresses of imposed tempos and boredom.
It is precisely this lack of uniformity as regards impact which makes it obvious that the strategic elements of future development are vitally important, meaning the strategies of companies, trade unions and the Government. (see sec.3).
The following breakdown of social effects under the headings "Employment", "Skills" and "Working conditions" is made for analytical reasons. The complexity of the effects is illustrated by examples so that the contexts can be more clearly identified.

2.1. Employment

The acceleration of technical progress through the development of microelectronics and standardization of development in various branches (production, management) and economic sectors is bringing serious social problems in its train. The ensuing redundancies may vary from one technology and one branch or sector to another, but, overall are extremely serious.
In view of the worldwide recession and the high level of unemployment in the Federal Republic job and income security are of major importance.
Two studies on the social impact of robots - one by the Sofi Institut (Mickler et al. - "Bedingungen und soziale Folgen des Einsatzes von Industrierobotern) and the other by the Batelle Institut (Soziale Implikationen der Einführung von Industrierobotern) arrive at the following conclusion :

Table 2

Savings in manpower by using robots in two-shift operations

	Number of operatives saved for each robot in use			
	Total		Less new requirements	
	Batelle	Sofi	Batelle	Sofi
All individual cases studied	5.5	4.0	4.0	3.7
Workpiece handling	7.3	5.6	6.2	5.4
Tool manipulation	3.6	2.6	1.7	2.3

Workpiece handling involves the loading and unloading of presses, processing machines and transfer lines. Tool manipulation covers processes such as arc welding, spot welding, coating and tacking.

Investigation of threatened jobs, taking into account the present state of the art, yields the following results : some 30 % of production processing activity (technically tool manipulation) are affected by the use of robots, and that, after all, represents 16 % of the total labour force.

The activities first and foremost affected are machine operation, spot welding, arc welding, varnishing, hand grinding and tacking. The result of a study by Prognos AG (Soziale Auswirkungen des technischen Wandels in der hessischen Automobilindustrie) is that a real 3.5 % a year growth in productivity can be expected.

The estimates show a decline in employment in the motor industry from 746 000 in 1982 to 683 000 in 1990. This is largely attributable to the growth in productivity resulting from the use of new technologies.

2.2. Skills/ training

The use of robots in workpiece handling is currently replacing mainly simple repetitive tasks (e.g. machine operation, conveyance to work stations). In tool manipulation, however, many higher value jobs are also involved (fusion welding, spot welding, arc welding, varnishing).

The increase in the proportion of servicing activities - an area in which new higher-value jobs are being created - is relatively slight (0.3 %). In general terms and taking account of the work force as a whole, the less skilled categories of workers can be said to be more affected.

New needs arise when robots are used in FMS. New all-round technical skills in supervision and control are required, which calls for new training courses.

The worker can suffer adverse effects when :

- in tool manipulation some residual manual activity remains which involves little actual work, a faster imposed tempo and social insolation;
- in workpiece handling job steps are not automated and are even more limited than his previous work (e.g. positioning and aligning workpieces, manual loading at the first station of a sequential press line), the worker is not only bored but may often suffer from muscular strain on one side of the body.

To counter these tendencies care must be taken in planning the overall system to ensure optimal lay out and minimum strain on the operative. The main consideration is for overall planning to cover both the technical and organizational requirements and what the work entails. A further problem in this context has proved to be separating the man from the machine. This must be achieved if minimal requirements in job content are to be satisfied.

2.3. Working conditions

In using robots it is hoped that they will free people from stresses and hazards, such as :

- industrial accidents (e.g. in handling explosive materials);
- stressful environment (heat, gases, humidity, noise and vibration, dust, poor ventilation);
- physical strain (heavy manual work, work in which the body is allowed no movement, unbalanced strains on the bones);
- psychic and social strain (boredom, social isolation, concentration).

The majority of robots are in fact used to perform jobs which impose a heavy strain. Tests also confirm that using robots can limit adverse effects of environment and physical workloads but new strains have since appeared :

- faster tempos imposed by the technical system;
- monotonous work in "residual jobs";
  (i.e. jobs not mechanized and now having a low work content and working tempos involving only short cycles of operations).

The realization that the use of robots does not *ipso facto* diminish stress and can even bring new stresses in its train has considerably influenced discussion on this topic (see, *inter alia*, the humanization of working life project : "Das Programm Forschung zur Humanisierung des Arbeitslebens", p. 194). One result has been that as part of the Government's programme for humanizing working life a study was made on possible uses of robots from the humanization standpoint and that more attention is being paid to the connection between robots and other factors in working life.

3. What the Government, the unions and the employers are doing

Robotics must be considered in the context of other technologies (e.g. production data technology, design and operations planning of a company). This is particularly true with respect to the effects on labour and employment.

It is therefore appropriate that the strategies and measures of the Government and of the parties to collective agreement be based on developments in overlapping fields.

3.1. State support

The Federal Government is currently promoting robots in two of its programmes : production technique and humanization of working life. While in production technique programmes the use of robots in being promoted in connection with other sophisticated technologies (perhaps as components of FMS), the humanization programme involves the use of robots at high-stress workplaces. The table below shows the context of State support for robots, which is concentrated in programme areas 5 and 10 (X).

Federal Ministry for Research and Technology - 1982 Budget Objectives and programme coverage

Objective	Programme	Expenditure in mill. DM	% Share
Security of material resources	1. Energy - Research and technology	2618.7	40.1
	2. R&D for raw material and materials, inc. water research	242.5	3.7
	3. Marine research and technology Polar research	213.8	3.3
Maintaining and boosting industrial competitiveness	4. Innovation promotion	28.4	0.4
	5. Physical and manufacturing technology	78.0	1.2 (X)
	6. Electronics	140.0	2.1
	7. Data processing	52.0	0.8
	8. Aero-space research and technology	915.1	14.0
Improving living conditions	9. Technology for health, nutrition and the environment	470.0	7.2
	10. Humanization of working life	118.0	1.8 (X)
Modernizing and improving public infrastructures and services	11. Transport technology, building research	253.0	3.9
	12. Technical communications Information technology	131.0	2.0
	13. Information and documentation	85.3	1.3
Basic research	14. General scientific research	564.6	8.6
	15. Basic physical and chemical research	578.1	8.8
	Administration	48.0	0.7
	Total	6536.4	100.0

(X) Further basic research is included in the other programme.

Studies on the development and use of robots were commissioned by the Research Ministry as early as 1973. By 1974 the preliminiary work had made such progress that, when the humanization programme was launched, an association of institutes, producers and users could be subsidized. The aim was to develop and test industrial robots in order to catch up with the United States and Japan.
The use of robots held out a promise of rationalization and deliverance from strenuous and one-sided manual labour. Robots were to be used everywhere where people had to work with dangerous materials. In 1976 the association added a social science auxiliary project to study the effects of robots on the work force. These investigations found that the use of robots not only involved substan redu dancies but also new stresses such as, for exemple, uneven stresses in socalled residual jobs. (See sec. 2.3.). From this and many other experiences with industrial robots conslusions were drawn regarding future promotion. A study on areas of use is to ensure that possible areas of use are identified in good time and that, above all, account is taken of high-stress jobs. Furthermore, development and testing is not to be restricted to robots alone but is to devote itself likewise to changing the manufacturing system in question. For experience with "residual jobs" has shown that only planning and redesigning the whole system - in which robots are simply one technical factor - can ensure their appropriate application.

Starting from a purely engineering view of the matter, a more complex approach was developed by social organizational and production viewpoints.

In contrast to the practice of promoting key technologies not only the technological development of prototypes but also their testing under complex general conditions was encouraged. Only on that scale can the manifold effects of government assistance policy be evaluated and given their due place in development strategies.

3.2. Parties to collective agreements

In view of the large number of unemployed and the fact that more are expected, the quantitative effects on employment figure prominently in the discussions between parties to collective agreements.

While employers associations point to greater productivity as the prerequisite for preserving and creating jobs (competitiveness on the world market), the trade unions are more concerned with the problem of apportioning existing jobs and thus with the shortenting of working hours.

The following measures for shortening working hours are being discussed by the unions;

- a shorter working week (35 hours);
- shorter working life by lowering the flexible retirement age;
- compensatory time off in stressful jobs (recovery time).

On the other hand, the employers' associations have compiled what is called a "list of taboos", one of which is that in matters relating to shorter working hours their members should make no concessions. The discussions have also lately focused on the question of whether shorter working hours are to be with or without compensatory wage adjustments. As regards a shorter working life there have been proposals to enlist pension insurance and/or unemployment insurance in financing the costs. All information to hand points to the fact that disputes over collective agreements in the years ahead are a distinct possibility.

In respect of the direct effect of the introduction of new technologies there are a number of arrangements in the form of collective wage agreements, internal wage and salary agreements and laws to alleviate social handships. In nearly all branches we have agreements to safeguard employees against the consequences of rationalization or equivalent internal wage agreements to protect the individual worker from any adverse effects.

These include :

- The offer of another equivalent job (before other applicants) in the company;
- The offer of retraining;
- Security limited in time for the present wage category.

Though such arrangements only alleviate hardships without solving structural problems, they have their effects in practice.

Thus, for example, no workers have been dismissed in cases so far know where robots have been introduced. In this connection it should be noted that the unions and works councils can fall back on a body of legislation aimed at protecting the labour force. Articles 90 and 91 of the amended law on labour relations at the workplace (Betriebsverfassungsgesetz) (1972) figure prominently in efforts to reach internal and collective agreements. Article 90 lays down that employers and works councils must discuss the introduction of new technical installations, their effects on the nature of the work and the demands made on the worker. In so doing the employer and the works council are required to take into account established scientific knowledge regarding the organization of work in a manner commensurate with human needs and capabilities.

Article 91 stipulates that the works council can demand appropriate measures of the employer to obviate, alleviate or offset stress which may result if workers are particularly affected by changes in the workplace, cycle or the working environment.

(19

Bibliography

- Autorenkollektiv : Neue Handhabungssysteme als Hilfe für den Arbeitsprozeß (8 Bände), Fachinformationssystem Karlsruhe

- Batelle-Institut e.V. : Soziale Implikationen der Einführung von Industrierobotern im Fertigungsbereich (4 Bände), Frankfurt 1978

- Benz-Overhage, K. et al : Neue Technologien und alternative Arbeitsgestaltung, Frankfurt/New York 1982

- Brodbeck et al: Handhabungssysteme, Düsseldorf 1981

- Brödner et al : Die Bedeutung fertigungstechnischer Innovationen für die Humanisierung des Arbeitslebens, Zeitschrift für wirtschaftliche Fertigung, Nr. 9, 1977, S. 471 - 475

- ERNO et al : Studie zur Ermittlung neuer Einsatzbereiche für Handhabungssysteme, Schlußbericht April 1979

- Hermann, G. : Arbeitsplatzanalysen zur Ermittlung der Einsatzmöglichkeiten und Anforderungen an Industrieroboter (Schriftenreihe des IPA), Stuttgart 1978

- Mickler, O., et al (Sofi Göttingen, Universität Bremen) : Bedingungen und soziale Folgen des Einsatzes von Industrierobotern, Göttingen 1980

- Pöhler, Willi (Hrsg.) : ... damit die Arbeitmenschlicher wird - Fünf Jahre Aktionsprogramm Humanisierung des Arbeitslebens, Bonn 1979

- Prognos A.G. : Soziale Auswirkungen des technischen Wandels in der hessischen Automobilindustrie - Untersuchungen des Hessischen Sozialministers zu den Folgen des technischen Fortschritts, Bd. 5

- Projektträger Humanisierung des Arbeitslebens Das Programm zur Humanisierung des Arbeitslebens. Ergebnisse und Erfahrungen arbeitsorientierter Forschung 1974 - 1980 (Schriftenreihe Humanisierung des Arbeitslebens, Bd. 1), Frankfurt/New York 1981

(20

(20

Schulte, Bernd (Hrsg.) : Handbuch technischer Arbeitshilfen, Düsseldorf 1980

Sorge, A. et al : Mikroelektronik und Arbeit in der Industrie, Frankfurt/New York 1982

Spur, G. (Hrsg.) : Leistungsvermögen moderner Produktionstechnik, Produktionstechnisches Kolloquium, Berlin 1979

Spur, G. et al : Industrieroboter, Steuerung, Programmierung und Daten von flexiblen Handhabungseinrichtungen, München, Wien, 1979

Steinmüller, P.H. : Flexible Fertigungssysteme und ihr künftiger Einsatz in der Industrie, Industriekurier, Nr. 104, 30.10.[illegible], S. 35-37

Warnecke, H.J. et al : Industrieroboter, München 1979

Warnecke, H.J. : Handhabungstechnik und Industrieroboter, Industriekurier, Nr. 49, 18.6.1982, S. 95-97

Wissenschaftszentrum Berlin et al : Ein Programm und seine Wirkungen. Analyse zu ausgewählten Zielen und Aspekten des Humanisierungsprogramms, Frankfurt/New York 1982

Zentralsparkasse und Kommerzialbank Wien : Roboter im Einsatz. Ergebnisse eines Symposions, Dezember 1980