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ABSTRACT. Due to rapid expansion in the field of robotics, policy issues have arisen in regard to developing human skills to deal with the new technology and to deal with the obsolescent human skills which are the inevitable result of this growth pattern. Industrialists, educators, union leaders, and government officials must work cooperatively to insure that the coming changes are made with minimum disruption. Improved training methods and courses have to be developed for the skills needed to control, manage and supervise the new machines. Some of the ways in which this can be accomplished are through offering financial incentives for investment in training and education; establishing more institutions to educate and train the workforce; cooperative public/private planning for future employment needs; and financial safety nets for workers who may be displaced by new technologies. The authors feel that these aims can only be accomplished through a massive national investment in education and skill-training across the whole spectrum of ages and social backgrounds—"an updated version of the GI Bill of Rights for the entire workforce."

The purpose of this paper is to call attention to some policy issues associated with the growing use of robotics technology. There has been little serious discussion to date of how to build the human capital to support the rapid development of robotics, on the one hand, and how to deal with people who have obsolescent skills, on the other. To ensure a smooth and successful transition to robotics, private industry, organized labor, government, and educational institutions must commit themselves to a cooperative effort to a) identify vulnerable categories of workers well in advance of actual job elimination; b) plan for future employment

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needs and new job skill requirements; c) provide effective education and training facilities to upgrade workers from skill categories that are no longer needed to skill categories that are scarce; and d) provide effective facilities to locate suitable jobs and place workers in them. Private industry, in particular, must assume a more active role in planning future employment needs. Robot users must ensure that the workforce gets an accurate preview of tomorrow's workplace and that the appropriate skills are sought and taught.

There is too much emphasis on education for white collar jobs as opposed to training people to control, maintain and supervise machines. As a result, there is a surplus of professionals in many areas and a shortage of people who "make things work." People who interact with machines do not have a favorable image in today's society, nor do the factories themselves. This problem has been a major barrier to developing a skilled factory workforce.

Unions and management need ways of interacting cooperatively—rather than as adversaries—in dealing with issues of displacement and changes in the workplace. If industry continues its uncommunicative policy on future automation plans, the unions will probably continue to emphasize the setting of precedents to ensure their survival. This type of "game-playing" inhibits the types of planning needed to solve real problems and achieve mutual benefits.

The government has five vital functions to perform in promoting a successful transition to robotics and other forms of "flexible" automation. These are:

1. To bring industry, labor, and educational institutions together, especially where these parties face each other in adversarial roles;
2. To provide financial incentives for investing in education and training;
3. To operate institutions to carry out education and training;
4. To gather data and disseminate information to assist in cooperative public/private planning for future employment needs;
5. To create a much more effective financial safety net for displaced workers in order to alleviate fears of, and resistance to, change.

Neither industry nor society at large can afford the consequences of having too many people steered into obsolescent occupations—or underemployed—while there are too few people with badly needed skills.

What is needed, in the view of the authors, is a massive national investment in both education and skill-training across the whole spectrum of ages and social backgrounds—an updated version of the GI Bill of Rights for the entire workforce.

Background

Robots are already a viable alternative to human operators in a few types of jobs today performed by semi-skilled operatives and unskilled material handlers who work in a batch production environment.[1] The next generation of sensor-based robots—with rudimentary sight and/or tactile sensing capabilities—will be able to perform a broader range of tasks, including some jobs now done by skilled workers in these same industries, in addition to becoming cheaper and easier to use. Eventually, many of the "hands on" tasks now performed by production workers on the factory floor will be done by robots in computer-controlled manufacturing systems.

Programmable automation is beginning to replace the current generation of manually operated machines. This transition will undoubtedly continue for several decades.

The increased use of robots forces society to confront the short-term prospects of technological displacement and the longer term prospects of basic structural shifts in the economy. But robots are only one of several change agents in the work environment. Concurrent advances in product design, metal cutting, metal forming, finishing, assembly, and inspection—under the control of computers—will also modify the mix of skills needed to work in "the factory of the future." Differential growth rates between different industries (*e.g.*, electronics versus steel) may also cause broad shifts in overall levels of employment, skill requirements, and the occupational composition of the workface. Shifts in the industry mix and changes in the composition of the labor force are indirectly influenced by trade and defense policies, too.

As a nation, the US is not confronting radical technological changes for the first time. Robots should not be given the credit (or blame) for initiating these changes. This does not make the potential problems associated with the phasing in of robots less important or less urgent. It does mean that the need to cope with technological change is continuing. Resistance to the use of robots would not affect the likelihood of having a surplus of people whose skills are not needed, while there is a simultaneous shortage of people with the skills required to develop and support the new technologies. Both mismatches are potentially troublesome.

Experiences from a long history of technological innovation in the United States economy suggest that the rate of robot introduction—as well as the social impacts of the use of robots—will depend upon factors beyond the control of individual firms. It is important to recognize that the adjustment issues that the US faces as a nation depend upon the complex interactions between technological progress and the worldwide economy. But the variable and uncontrollable elements of the economy should not be used as a smokescreen for ignoring the adverse possibilities of labor displacement, or for delaying the implementation of necessary programs for vocational training, retraining, and adjustment.

Transitional Problems

Most of the published literature on robots describes physical capabilities and particular applications, or deals with the narrowly defined economics of robot use, based primarily on the difference between amortized robot cost and the "all-included" cost of hourly labor. Discussions of human factors—if any—tend to be sweeping statements about the importance of gaining the acceptance of workers and top management support, limiting human factor concerns to bypassing or eliminating potential pockets of resistance to robotics. There has been little serious discussion to date about how to cope with the hard reality of developing needed new skills on the one hand and how to deal with people who have obsolescent skills on the other.

It is well documented that physical capital has been an important contributing factor to economic growth in the postwar era, but there is also a growing recognition that human capital—the skills, dexterity, and knowledge of the workforce—has come to play an increasingly important role. Unfortunately, experience to data suggests neither private industry, organized labor, or government is prepared to invest in the human capital needed to exploit robots or other new technologies. If the benefits of using robots are ever to be realized on a significant scale, the trained manpower must be available to step into the opportunities that are being created.

With a few exceptions, such as General Motors, robot users have been reluctant to discuss plans for robot use in the future, even though many manufacturers are testing applications. They argue that such information must be kept confidential for competitive reasons. One result of private industry's uncommunicative attitude about future plans is that very little is being done to warn or prepare those workers whose jobs may be eliminated, or substantially modified, as a direct or indirect result of introducing robots. In the absence of solid facts, or even informed speculations, as to what types of adjustments might occur and their time-phasing and magnitude, unions, media reporters, and government officials have started to suspect the worst, and ask: *How many people will lose their jobs as this new wave of automation sweeps through industry?*

Private industry undoubtedly has an interest in the public perception of the impacts of robots on the labor force. If the phasing-in of robots on a large scale is handled ineptly and insensitively (or if people even think that this is the case), unions and other factions of society might conceivably find enough common interest—based on a fear of technology—to organize a "neo-Luddite" political attack on robots and other forms of automation. Unions are already advocating various forms of protectionism to blunt the impact of foreign competition. In the most extreme scenario, widespread social dissension could occur, fed by distrust of business and dissatisfaction with the record of a capitalist society in dealing with a cluster of festering social problems.

The "Factory of the Future"

While industry, in general, has been silent about the impact of robots on the present and future workforce, some prominent industry spokespersons have promoted the view that the world is currently on the threshold of building a robotic "factory of the future." These optimists are perhaps trying to rally industrial management and the financial community to invest in the revitalization of aging and inefficient plants and equipment. The producers of robots and automated equipment are also understandably seeking financial support for further expansion. While the financial community and most large manufacturing firms have treated these enthusiastic claims about new technological capabilities with (proper) skepticism, the same claims have been heard and taken very seriously by unions and by individual workers who fear for their own security. Indeed, unions and workers in the present adversarial society tend to be skeptical of what they hear from management. Worried workers may occasionally interpret real conservatism as a Machiavellian attempt to placate the worker's concerns, while trying to undermine the union or eliminate jobs. The only antidote to this problem—where it exists—will be a quantum increase in the amount of communication between the parties.

To develop the necessary human capital at both the institutional and individual level, and to smooth the short-term transitory impacts on the labor force, all the major actors must commit themselves to a cooperative effort to prepare and assist the workers most likely to be affected by the changes to come. In the past, the "band-aid" approach to social welfare problems has not proved especially effective. The only realistic alternative to "band-aids," however, is some sort of preventive medicine. To effectively prevent social trauma due to rapid introduction of robotics, without impeding technological progress itself, requires:

- Identification of vulnerable categories of workers well in advance of actual job elimination.
- Long-range planning by industry and government for future employment needs and new job skill requirements.
- The provision of *effective* education and training facilities to upgrade workers from skill categories that are, or will be, in surplus supply to skill categories that are scarce.
- The provision of *effective* facilities for locating suitable jobs and placing workers in them, with relocation assistance, if necessary.

As part of a 1981 Carnegie-Mellon research project, all member firms of the Robot Institute of America were surveyed to determine the potential for robotization within various occupations. The RIA members were asked to estimate what percentage of jobs within a given occupational title could be done by a robot similar to those on the market today (Level I), and by the next generation of robots with rudimentary sensing capabilities (Level II).

Based on the responses of 16 firms, several occupational titles were singled out as having a high potential for robotization, as shown in Tables 1 and 2. The responses to the survey were quite varied, reflecting the different requirements of similar jobs in various industries. The response from each firm depended upon its products, the length of a typical production run, and the experience of management with robots. Despite obvious limitations on the comprehensiveness of the survey, several occupational categories still can be targeted as prime candidates for replacement by Level I and Level II robots, even though there are some specific tasks within these occupations that will not be automated for years to come.

Almost all the present membership of the RIA—and 90% of current robot users—fall within a group of industries commonly referred to as the *metalworking sector.*[2] In 1980 there were nearly 6.7 million production workers employed in the metalworking sector. Of these 6.7 million production workers, nearly 5 million worked within the three broad categories of job most amenable to robotization: metalworking craft workers, semi-skilled machine operators, and laborers (see Table 3).

Based on the results of the survey, it is estimated that Level I robots could theoretically replace 16% of the workers in these three groups and that Level II

TABLE 1. Prime Operative Task for Level I Robots

Occupation	Level I Robots		Level II Robots	
	Range of Responses	Average Weighted Response	Range of Responses	Average Weighted Response
Production Painter	30–100%	44%	50–100%	66%
Welder/Flamecutter	10–60%	27%	10–90%	49%
Machine Operator*		20%		50%
Machine Operators (NC)	10–90%	20%	30–90%	49%
Drill Press Operators	25–50%	30%	60–75%	65%
Grinding/Abrading Operators	10–20%	18%	20–100%	50%
Lath/Turning Operators	10–20%	18%	40–60%	50%
Milling/Planning Operators	10–20%	18%	40–60%	50%
Machine Operators (Non NC)	10–30%	15%	5–60%	30%

*Machine tool operators includes the separate types of machinists listed below. These estimates are used as an average to approximate the percentage of all categories of machinists listed below which could be robotized.
Source: CMU Robotics Survey: April 1981

robots could theoretically replace 40% of the same population of workers. Thus, if all the potential for job displacement of Level I robots were realized in metalworking, more than 800,000 could be eliminated. If Level II robots were available, and fully exploited, an additional 1.2 million jobs, making a total of nearly 2 million jobs, could theoretically be eliminated. Extrapolating the data for metalworking to similar tasks in other manufacturing sectors, it appears that Level I robots could theoretically replace about 1.5 million metalworking craft workers, semi-skilled machine operators, and laborers, and Level II robots could theoretically replace about 4 million out of the current total of 10.4 million of these workers. The time frame for this displacement is *at least* 20 years, however. In the course of the coming decades, the capabilities of robots can be expected to increase further, and with these changes their potential for displacing operatives will increase. On the other

TABLE 2. Prime Task for Level II Robots

Occupation	Level I Robots		Level II Robots	
	Range of Responses	Average Weighted Response	Range of Responses	Average Weighted Response
Electroplaters	5–40%	20%	5–60%	55%
Heat Treaters	5–50%	10%	5–90%	46%
Packagers	1–40%	16%	2–70%	41%
Inspector	5–25%	13%	5–60%	35%
Filers/Grinders/Buffers	5–35%	20%	5–75%	35%
Assemblers	3–20%	10%	20–50%	30%

Note: Results are based on 16 responses. All respondents did not give estimates for all occupations.
Source: CMU Robotics Survey: April 1981

TABLE 3. Employment of Production Workers, 1980: Metalworking and Total Manufacturing.

Occupation	Employment in Metalworking	Total Employment All Manufacturing	% Employment in Metalworking
	SIC (33–38)*		
Total, all occupations	9,964,878	20,361,568	48.9
Production workers, total: (craft workers, operatives, + laborers)	6,688,306	14,190,289	47.1
Craft and related workers, total	2,015,212	3,768,395	53.4
Metalworking craft workers	582,861	668,002	87.2
Other craft workers	1,432,351	3,100,393	46.1
Operatives, total	4,060,916	8,845,318	45.9
Nontransport operatives	3,880,876	8,134,123	47.7
Assemblers	1,311,870	1,661,150	78.9
Metalworking machine operatives	1,030,132	1,069,540	96.3
All other machine operatives	893,701	4,231,988	21.1
Welders and flame cutters	369,558	400,629	92.2
Production painters	79,594	106,178	74.9
Packing and inspection operatives	78,413	587,631	13.3
Sawyers	17,604	76,728	22.9
Transport operatives	180,040	711,195	25.4
Laborers, except farm	612,178	1,576,576	38.8
Nontransport operatives and laborers	4,493,054	9,710,699	46.2

*For explanation of SIC see Note 2 at the end of this article.
Source: Compiled from The National Occupational Employment Survey-Based Industry-Occupation Matrix for 1980, Bureau of Labor Statistics (1982).

hand, not all of the potential displacement will actually be realized, and if the economy grows—as anticipated—some of the job loss due to displacement of people by robots could be offset by increases in other manufacturing employment.

Redirecting the Future Workforce

By the year 2010 or so, it is conceivable that more sophisticated robots will replace almost all operative jobs in manufacturing (about 8% of today's workforce), as well as a number of skilled manufacturing jobs and routine nonmanufacturing jobs. Concerted efforts should be made by the public and the private sectors to redirect the *future* workforce in response to these changes. Even though several million jobs in the current manufacturing workforce are vulnerable to robotization, the transition seems hardly catastrophic on a national scale, provided new job entrants are properly trained and directed. In the view of the authors, the oncoming transition will probably be less dramatic than the impact of office automation over the same period. By the year 2010, most current operatives will have retired or left their jobs. The jobs would not disappear all at once, and robot manufacturing, programming, and maintenance itself will provide some new jobs, although it is probably true that most new jobs will *not* be in manufacturing despite the rapid growth of the robotics industry itself. New "growth" sectors in the economy — including undersea and space exploration — may also provide many new jobs.

The important conclusion is that *young people seeking jobs in the near future will have to learn marketable skills other than welding, machining, and other operative tasks that are now being robotized.* Even though the adjustment problems seem manageable, the potential for social unrest in specific locations cannot be dismissed quite so lightly.

Consider the following points:

- Nearly half of all the unskilled and semi-skilled "operative" workers — those in the types of jobs that could be replaced by robots — are concentrated in the four metal-working industries (SIC 34–37[2]). Almost one-half of all production workers in these four industries are geographically concentrated in the five Great Lakes states (Indiana, Illinois, Michigan, Ohio and Wisconsin), plus New York and California. Within these same states, the metalworking sector also accounts for a large percentage of the total statewide employment in manufacturing. Adjustments in response to the rapid diffusion of robotics may be intensified in these areas. The impacts of *not* improving the productivity and competitive standing of these very same industries will also be concentrated in these same few states.
- Older established workers will generally be protected by union seniority rules, except in cases where the whole plant closes. Unfortunately, this is happening with increasing frequency. Even in the newest, most efficient plants, some younger workers with less seniority may be "bumped." When either event occurs, the displaced worker starts again at the bottom of the ladder. Thus, re-employed "displacees" are also more vulnerable to subsequent layoffs. *A class of perpetually insecure, marginal workers could result.* This would be a source of social problems and political dissension.
- The states where jobs are most likely to be lost to robots are mainly in the North Central region where industry is also most unionized, plants are oldest, and wages are highest. The "Sunbelt" states, where many new jobs are being created, have newer plants and lower wages. Many displacees will have to migrate to other regions. Those unable to upgrade their skills sufficiently might have to accept lower-paying service jobs or join the

"underclass" of insecure marginal workers who never became established with a stable employer.

- There would likely be a disproportionate impact on racial minorities and on women. Non-whites account for only 11% of the national workforce, but comprise over 16% of total employment in semi-skilled and unskilled manufacturing jobs. Women employed in semi-skilled and unskilled manufacturing jobs are less likely to be represented by labor organizations than their male counterparts. *De facto* economic discrimination will accordingly increase.
- Unions representing the affected categorized workers will probably experience sharp declines in membership and political/economic clout.[3] *A policy of organized resistance to the introduction of labor-saving technologies might seem attractive to fearful workers and their unions, resulting in a severe drag on the productivity of the manufacturing sector.*

Consolidating Resources

Private industry, organized labor, educational institutions, and government must consolidate resources to anticipate and solve a related set of problems:

- Building the *human capital* that can support the rapid development of new technologies—including robotics.
- Preparing the current workers most likely to be affected for the changes to come.

Industry's Role

As industrial firms push forward with developing robotics and other forms of advanced automation, they should be more forthright in identifying the vulnerable categories of workers. Currently industry is reluctant to identify the categories of jobs that will eventually be phased out. In the short term there may even be shortages of workers in some of the "prime operative" candidates for robotization (*i.e.*, machine operators and welders), which gives industry a disincentive to warn workers of the inevitable changes to come.

Admittedly, planning of this kind may not be easy, since the rate at which robots will be phased in depends upon rapidly evolving technology, and on an uncertain economic climate. It is in industry's interest, however, to assume a more active role in planning future employment needs. It must ensure that the workforce gets an accurate preview of the requirements of tomorrow's workplace, and that the appropriate skills are sought and taught.

It is not enough for the business community to assert that educational and training institutions have not been responsive to real needs in preparing people for work life. Business has also contributed to the problem—for example, by viewing its participation with advisory councils of publicly funded training programs as perfunctory exercises in public relations without taking these responsibilities seriously.

Top management also creates the ground rules for how new technology should be evaluated. These ground rules determine which aspects of productivity improvement are emphasized, and play a very important role in shaping the attitudes of middle management, operations staff, and even production workers towards robots. As part of the 1981 Carnegie-Mellon University study, 19 robot users and 19 prospective robot users were asked to rank the factors influencing their decision to install robots. The survey results are shown in Table 4. Survey respondents *overwhelmingly* ranked efforts to reduce labor costs as their main motivation.

Users frequently pointed out that the return on investment (ROI) calculation would not be favorable unless there is a dramatic decrease in direct labor cost. Arguments for the benefits of expanding capabilities, such as improving product quality or increasing production flexibility, were often considered "nebulous" by the financial analyst. *If the elimination of direct labor cost is the only benefit of robots acknowledged by management, there will undoubtedly be a perceived conflict between "successful" robot applications and job security for workers.*

While productivity can be improved by reducing the cost of producing a given mix of goods, it can also be raised by increasing the value of the goods which are sold. This can be done by producing more, by improving the quality of existing goods, or by creating and selling altogether new goods and services. Undoubtedly, production cost reduction is important, but if all the emphasis is put on cost reducing *process innovation* as opposed to value increasing *product innovation,* management may inadvertantly create the conditions for an adversarial showdown with organized labor.

The Role of Educational Institutions

Three types of educational/training programs are needed to support the growth of robotics:

- Programs to train technicians to operate and program the new equipment;
- Programs to train workers to install and maintain automated machines; and
- Programs to train people to engineer innovative production systems, supporting both (1) applied engineering and applications work for immediate needs; and (2) basic research and long-term development work.

Colleges and universities in the United States do a reasonably good job of educating science and traditional engineering students. But, in general, the existing educational institutions do not have the capability, or even the inclination, to involve themselves in training unskilled or semi-skilled people for operational skills needed in industry. Classroom techniques used in general education may not be applicable for transferring these types of skills. Indeed, wholly different techniques may be necessary. Skill training institutions must be more verbal- and "hands-on"-oriented. Experience with publicly sponsored training programs suggests that—while they are reasonably capable of retraining skilled workers to do new jobs—they have seldom been successful at training the semi-literate "hardcore" unemployed to be productive.

TABLE 4. Motivations for Using Robots

Rank	Users	Prospective Users
1	Reduced Labor Cost	Reduced Labor Cost
2	Elimination of Dangerous Jobs	Improved Product Quality
3	Increased Output Rate	Elimination of Dangerous Jobs
4	Improved Product Quality	Increased Output Rate
5	Increased Product Flexibility	Increased Product Flexibility
6	Reduced Materials Waste	Reduced Materials Waste
7	Compliance With OSHA Regs	Compliance with OSHA Regs
8	Reduced Labor Turnover	Reduced Labor Turnover
9	Reduced Capital Cost	Reduced Capital Cost

Note: Other factors mentioned were (1) to give an image of innovativeness and (2) to keep up with the Japanese.
Source: CMU Robotics Survey: April, 1981

The educational establishment must face up to this problem, since some of the factory jobs which have historically employed the least-skilled workers—such as material handlers and machine loaders/unloaders—will eventually be replaced by automated equipment, robots. The same is true to many semi-skilled jobs, such as welding.

Much of the human resource development for robotics (in the narrow sense), particularly the training of operations and maintenance personnel, is now carried out by the robot manufacturers themselves. The major robot manufacturers are educating potential users about robot applications, and they are running special operation and maintenance training classes. As the demand for robot information increases, the robot manufacturers may not have the capacity to fulfill the necessary requests for information and training. At present, there are very few alternatives. Only a small number of schools and training institutes as yet have the equipment required to train people to use or repair robots (or microcomputers). It seems that the number of vocational and technical schools interested in providing this type of training is increasing, but that the financial resources needed to hire the trainers, develop the programs, and purchase the necessary equipment is actually shrinking. Also, some educational institutions are laying off people in the wake of general educational cutbacks despite a recognized need to train more people to use and service new technologies.

Education and training are also needed if displaced workers are to successfully transfer to alternative lines of employment. Although the factory workforce will need new skills, it is anticipated that a smaller percentage of the workforce will be working in factories as the decades pass. The frequency of occupational change may be as important a motivation for additional training and retraining as the upward trend in skill requirements. The least skilled workers, especially, will need better background training in order to enable them to enter the productive workforce in an environment where machines and robots do most of the "unskilled" tasks.

The educational establishment also needs to face up to other deficiencies, such as:

- There is too much emphasis on education for "white collar" jobs as opposed to training for people to work with (*i.e.*, supervise, maintain and repair) machines;
- Universities help to create a status hierarchy which puts theoreticians above practitioners, and professions and administrators above everybody else. Too much emphasis on "high prestige" occupations results in a surplus of professionals—such as lawyers and administrators—and a shortage of people who make things work; and
- Even when blue collar workers want to improve their skills, facilities and teachers are scarce.

One of the major barriers to developing a skilled factory worker is the difference in self-esteem between the college-educated and those in the skilled trades. Blue collar and skilled workers do not have a favorable image in this society, despite the fact that some of these jobs require more schooling and pay comparable wages. Trade school is often viewed as an alternative for students who flunk out of the academic track, or for delinquents. The more capable students are steered away from factory work.

The Union's Role

Unions and management need ways of interacting cooperatively—rather than as adversaries—for dealing with issues of displacement and changes in the workplace. Management wants to maintain a flexible posture for negotiating with the unions. This seems reasonable, from a narrow perspective, since impending technological changes (and their precise labor requirements) are not yet well defined. Some managers feel that unions are seeking to formalize policies regarding displacement and workrules as early as possible, *even before* the situation is well defined, in order to establish precedents and protect their institutional structures. In response to this, management often adopts a "tight-lipped" policy on future automation plans. It would seem that, if industry continues its uncommunicative policy, the unions will continue to emphasize setting precedents in order to ensure their survival in an uncertain environment. This type of "game-playing" obstructs the type of planning that both unions and management need to do in cooperation with each other to solve real problems and achieve mutual benefits. Yet neither side can reasonably be expected to change its position unless there is outside intervention on the part of government to change the climate for negotiations.

On a more positive note, unions could cooperate with government and industry to help set directions for retraining. They could also do much to encourage their members to take advantage of retraining opportunities. Organized labor might also actively campaign to enhance the image of workers and of the industrial workplace. Factories have too long a history of being depicted as "hell holes." This image seems to have contributed to the low image of the factory worker.

Government's Role

The government can carry out five vital functions to promote a successful transition to robotics and other forms of "flexible" automation:

- To act as an "honest broker" to bring industry, labor, and educational institutions together, especially when these parties face each other in traditional adversary roles;
- To provide financial incentives for investing in education and training, and to improve the effectiveness of skill training programs;
- To create institutions and implement training programs;
- To gather data and disseminate information to assist in planning for future employment needs; and
- To create a much more effective financial *safety net* for displaced workers in order to alleviate fears of, and resistance to, change.

It is not reasonable to expect firms to be more open with unions if such disclosures would constrain them in what type of technology they could develop or how they could use it. Neither is it reasonable to expect unions to be more cooperative with management, and more flexible in their bargaining positions, if such an attitude would threaten the security of their workers and the long-term viability of the unions themselves. The only way for both sides to break out of this bind is for government to change the conditions under which unions and industry talk to each other. In this context, the US may have much to learn from Japan, Germany, and other industrial countries.

An Awareness of Needs

Most managers realize that they must eventually do *something* to assist part of their workforces to acquire the skills required to operate computer terminals and to supervise, maintain and repair automated machines. There is also an awareness of the need to assist the remaining part of the workforce to acquire new skills appropriate for alternative employment. But there are substantial costs involved in education and training, and there is little incentive for firms to start addressing the problems today. This perception of lack of urgency must be overcome. One of the government's key roles should be to provide the incentives which would induce industry to take positive action on upgrading its human resources now. For example, the government could give tax incentives to partially reimburse industry for education and training investments in their employees. And, of course, it could provide inducements (financial and other) to educational institutions to influence them to redirect their efforts toward providing new skills necessary for workers in the factory of the future.

Education and training are established functions of all levels of government. It is vital that publicly funded education/training programs reflect the emerging—rather than the obsolete—needs of industry and society. Vocational education enrollments and completions in six metalworking occupational categories are shown in Table 5. These six categories accounted for just over three percent of all vocational educational enrollments for fiscal year 1978.[4] Several popular occupational categories for publicly funded training programs are precisely those which have been identified as prime candidates for robots.

It appears that public education institutions in the United States have not yet recognized the future employment skill needs of society. Training programs

TABLE 5. Enrollments and Completions in Public Vocational Education in Selected Metalworking Occupations: National Totals: Fiscal Year 1978

Occupations	Enrollments	Completions
Machine Shop Occupations	117,069	32,588
Machine Tool Operations	14,232	3,437
Sheet Metal	45,694	6,571
Welding/Cutting	205,486	51,722
Tool/Die Making	8,475	2,369
Other Metal Working Occupations	58,709	17,548
Totals	449,665	114,285

Source: Occupational Projections and Training Data, 1980 edition. U.S. Department of Labor, Bureau of Labor Statistics, Bulletin 2052

funded directly by government have an incentive to get people through a program quickly, and document their "success," even if they are providing people with obsolescent skills.

Passing money *from* the government *to* training institutes *through* industry would ensure that business plays a greater role in setting the directions for the skill requirements of the workforce. This type of indirect transfer provides a commercial incentive to educational institutions to develop curricula that better match the needs of industry. It would also force business to take more of an interest in the quality of training and retraining programs.

Potentially Serious Problems

On the other hand, there are potentially serious problems with giving business such a strong guiding hand in redirecting training needs, just as there are problems in insulating government and academic programs from the swiftly changing requirements of the "real world." Recently management and business administration programs themselves have come under fire for excessive shortsightedness in their planning. In the past, most firms have initiated their own retraining "on demand," only *after* a need is clearly recognized. The Federal government could do a better job of forecasting future societal needs and transmitting the information—in relevant form—to business and educational establishments.

The future outlook for employment in most factory occupations cannot be extrapolated from historical data. The basic technological relationships governing the mix of labor and capital required to satisfy a given level of output are changing in very fundamental ways. Yet government publications are still projecting employment requirements for many of the factory occupations with only a minor acknowledgement to the potential impact of emerging production technologies—including robotics. In fact, up until late 1982, when the Department of Labor published its first overview of the impact of robots on factory jobs,[6] government publications counselled workers about the skill requirements and long-term outlooks of various occupations with no mention of robots on the jobs where they are already in use.

The 1981 edition of the US Department of Labor's *Occupational Outlook Handbook* makes no mention of robots in its descriptions of production painters, welders, machine operators, inspectors or assemblers. The handbook predicts that the need for welders will increase "because of the greater use of welding." Welding was one of the earliest robot applications, and is one of the prime areas for future robot applications. Although the handbook acknowledges that new technologies may slow the growth of the need for machine operators, it still advises potential machinists to prepare themselves with "thorough backgrounds in machining operations, mathematics, blueprint reading, and a good working knowledge of the properties of metals." There is no mention of the need to have an exposure to programmable machine tools or robots.

It is obvious that the long-range planning of employment requirements and identification of vulnerable job categories cannot be carried out by government agencies, such as the Bureau of Labor Statistics, without input from industry. Neither industry nor society at large can afford the consequences of having too many people steered into obsolescent occupations while there are too few people with badly needed skills.

The Unemployment Insurance Program

The existing *safety net* for dislocated workers is the unemployment insurance (UI) program. Eligibility requirements may vary across states, but, as a rule, benefit payments are determined primarily on the worker's earnings within the previous four to six calendar quarters.[5] A lifetime's worth of work experience accumulated before the year to year-and-a-half "qualification period" is not considered in determining UI benefits. The established worker with many years on the job, children, and a mortgage is usually left high and dry if his plant closes—as has happened many times in the past year. In the authors' view, a program that provides approximately the same unemployment benefits to a worker with 1 year's experience as to a worker with 30 years' experience on the job is somewhat perverse.

This program also encourages abuse. After several months of working, a drifter can quit and live "free" on benefits for the next six months, and repeat this cycle indefinitely. Such a program gives no incentive to people with obsolete or unstable jobs to learn other skills.

What is needed, in the authors' view, is a system that provides transitional benefits for dislocated workers in proportion to length of service, and that provides strong incentives and financing for retraining and education. Some of the essential components are already part of experimental government programs currently operating on a small scale. For example, the Trade Adjustment Assistance program (TAA)—in operation since 1974—provides income support and training benefits for workers who have lost their jobs as a result of import competition. For the most part, the program serves manufacturing workers, many of whom are age 45 and older. Like the UI program, the income compensation given to eligible workers is independent of the length of service beyond the qualification period. In contrast to the UI program, income benefits are extended if the worker is enrolled in any type of job-related vocational training. In addition, the TAA program pays tuition for training programs, as well as job search and job relocation allowances. In 1981, nearly 80,000 workers applied for the job referral, placement, and counseling services offered by the program, but only 20,000 met the eligibility requirements. (To qualify, a worker must be certified as being adversely affected by import competition.)

Conclusion

The likely social consequences of major losses of industrial jobs—whether due to economic depression, migration of manufacturing to overseas export platforms, or robotization—are obviously very severe. A foretaste of these consequences has already been experienced in the older northeastern industrial heartland of the US. The worst scenario is a disappearance of the well-paid blue-collar middle class, resulting in a bifurcated society consisting of low-wage, unskilled service workers on the one hand, and high-wage, "elite," professional workers on the other. The authors feel that this kind of division sharply decreases social mobility in society, and has ominous long-range implications for the democratic system.

The only way to steer away from these grim prospects—in the opinion of the authors—is to undertake massive national investment in both education and skill-training across the whole spectrum of age and social background—an updated version of the GI Bill of Rights for the American workforce.

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Notes

1. A large fraction of all robots are used in the auto industry, which is noted for "mass production." However, robots in the auto industry work on tasks such as body welding and painting, which vary from model to model, so this is still considered as a batch production environment.
2. The definition of the metalworking sector used here is restricted to the following industries (followed by their Standard Industrial Classification Code): Primary Metals (SIC 33); Fabricated Metals (SIC 34); Machinery, except Electrical (SIC 35); Electrical and Electronic Equipment (SIC 36); Transportation Equipment (SIC 37), and Precision Instruments (SIC 38).
3. The major unions representing workers in the metalworking industries are the United Auto Workers, the United Steel Workers, the International Association of Machinists, the International Brotherhood of Electrical Workers, the International Union of Electrical, Radio and Machine Workers, and the United Electrical Workers.

4. Machinists and machine operatives and welders account for slightly less than four percent of the employed workforce.
5. The standard period of benefits is 26 weeks. If a share has a higher than average rate of unemployment, benefits may be extended by an additional 13 or 26 weeks.
6. See Gail M. Martin, "Industrial Robots Join the Workforce," *Occupational Outlook Quarterly*, 26:3 (Fall 1982), pp. 2-11.

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