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Robotics: Human Resource Implications for Michigan: A Research Summary

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ROBOTICS

Human Resource Implications for Michigan

A Research Summary
by
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Foreword

The Michigan Occupational Information Coordinating Committee (MOICC) is an interagency program responsible for coordinating state agency resources in the design of an Occupational Information System(OIS). The OIS is aimed at providing occupational information to assist in career guidance, job search, and the planning for occupational training programs. Presently, our emphasis is on the development of occupational supply and demand information. Analysis of this type of data is an attempt to determine whether too many or too few workers are being trained for specific occupations.

Robotics is currently the subject of much interest and considerable concern, particularly in Michigan. This is the case because the use of robots in the workplace has implications for economic development and job creation, job displacement, and worker training and retraining. Significant attention by the media as well as high levels of unemployment have heightened interest and concerns. Additionally, questions on current and future labor market trends cannot always be answered through the use of standard sources of information. Consequently, a research study of the potential labor market impact of robotics was designed and funded by MOICC. The W. E. Upjohn Institute for Employment Research was selected to conduct the research.

The following is a summary of the complete research report, "Robotics: Human Resource Implications for Michigan." The reader should note that definitive conclusions on the subject of robotics are not always possible because robot production and the use of robots are not yet significant in magnitude. Thus, much looking into the future based on a limited amount of information was required. Although this was recognized as a possible limitation when the research study was first contemplated, a compelling need for independent judgment and thorough investigation seemed apparent. We feel this need has been met and encourage Michigan training institutions and career information deliverers to use this research to meet the challenges, and to avoid the problems, associated with the employment and training opportunities afforded by the use of robots in the workplace.

MOICC

Michigan Occupational Information Coordinating Committee

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Summary

Introduction

This monograph explores one aspect of the evolution of technology, the application of industrial robots to the manufacturing process in Michigan. The robotics "revolution" is important to Michigan for two major reasons. First, Michigan has traditionally relied on the "metal-bending" business for a large share of its manufacturing exports. In particular, the dependence of the Michigan economy on auto and auto related manufacturing is well documented. This focus has led to a major concentration on manufacturing process technology as well. Thus Michigan already has a very substantial commitment to manufacturing and to manufacturing process technology.

Second, Governor Milliken has designated robotics technology as the highest priority in the drive to rebuild the Michigan economy with a high technology base. Of course, the established stake in manufacturing process technology had a role in that selection. So did the circumstance that the auto industry, upon which Michigan has depended for so long, is the leader in the application of industrial robots to the manufacturing process. It was fairly obvious that industrial robots constituted a threat against the Michigan economic base. It was also obvious that the domestic auto industry has been facing intense competitive pressure from the Japanese, and that part of the Japanese cost advantage was emanating from their superior productivity. This in turn could be attributed to the Japanese use of industrial robots, among other factors.

In the face of this situation, the Governor's High Technology Task Force elected to try to make Michigan a world class center of excellence in manufacturing process technology, including but not limited to robotics technology. The centerpiece of this effort has become the development of the Industrial Technology Institute as an independent nonprofit corporation designed (1) to foster basic and applied research in manufacturing process technology, including the social and economic implications thereof, and (2) to provide practical assistance to Michigan manufacturers in both adopting and producing new manufacturing process technology.

This study is focused on the human resource implications of the robotics "revolution," but before proceeding it is necessary to put the "revolution" into some perspective. There are precious little hard data about industrial robots today. Most of the public awareness of robots has been shaped by the hyperbole in the popular press in the last year or so. For example, a recent issue of *Newsweek,* which highlighted the jobs of the future, included an estimate of employment in industrial robot production in 1990 of 800,000 workers, a figure which would surpass current U.S. employment in the motor vehicle industry. We believe the intense media attention on robotics in the past year or so may have seriously confused the issues.

First, we submit that the very use of the word "revolution" is inappropriate when dealing with *any* manufacturing process technology. Capital goods for production have long lives and are not scrapped immediately when something better comes along. Numerically controlled machine tools, usually regarded as the most closely related capital equipment to robots, expanded at a growth rate of only 12 percent for the most recent ten-year period. After 25 years, only 3 to 4 percent of all metalcutting machine tools are numerically controlled. Even digital computers, widely heralded as the most significant technological innovation of the 1960s and 1970s, expanded at a growth rate of only 25 percent, yet many are implicitly assuming much higher growth rates for industrial robots. In terms of actual application, all process technology changes are evolutionary rather than revolutionary because there are physical, financial and human constraints on the rate of change of process technology.

Second, the fear of massive unemployment caused by the introduction of industrial machinery appears to be unfounded. Such fears began with the dawn of the industrial era in the 1700s. They are particularly acute during major recessions. For example, the "automation" problem was of urgent national concern in the early 1960s after a halting recovery from the sharp recession of 1958-59. There were grim predictions that automation was causing permanent unemployment in the auto industry and other industries. A national commission was appointed to study the problem and in 1966, with the economy near full employment, the commission rendered its final report. To no one's surprise, they concluded that a sluggish economy was the major cause of unemployment rather than automation.

Third, there appears to be a fundamental lack of understanding that the association of technological change, economic growth, and job displacement is not just a coincidence; they are intertwined and inseparable. That is not to imply that adoption of new technologies necessarily insures economic growth, or that displaced workers will always find new jobs. However, it does mean that we all have a vital stake in productivity gains (i.e., in displacing jobs) because that is what allows the *possibility* of economic growth. The price of a growing, dynamic economy that makes more goods and services available to all of us is job displacement, or the elimination of jobs through technological change.

Basics of Robots

A robot is a reprogrammable,multifunctional manipulator. A robot can perform the same task on identical workpieces repetitively; it can perform multiple tasks on the same workpiece; or it can be reprogrammed to perform entirely new tasks.

The Robot Institute of America (RIA), the trade association of robot manufacturers and corporate users, reports that there were approximately 4,700 robots in the U.S. in 1981. By the end of 1982 we estimate that 6,800 to 7,000 robots will be operating in U.S. factories. We estimate that employment in U.S. robot manufacturing is roughly 2,000 workers nationwide today. This should make it clear that most of the employment impacts to be discussed are in the future. The growth in application of industrial robots and the employment implications of that growth both have to be projected because of the very limited empirical base to date.

Unlike R2D2 and C3PO of the move *Star Wars,* robots of today are essentially "dumb machines." They are generally immobile, they usually lack any visual or tactile sensory perception, and therefore cannot adapt to their environment in any way. Generally they are no faster than human workers, but they are tireless. In layman's terms that means a robot can reproduce a specific range of motions for which it has been programmed, but it does not know if it is really holding the part is is supposed to be or if the work was done correctly. Although the trade literature makes much of the reprogrammability of robots, relatively few robots today are truly reprogrammed.

The proven applications of robots today are welding, painting, and various pick-and-place operations. Assembly robots are viewed as the number one growth application of the future, but presently robots cannot perform most assembly tasks with consistency in an industrial environment at a reasonable cost. Given all of the media attention to robots, it is surprising that there are so few actually in operation. Part of the reason is to be found in the limited industrial applications so far developed.

Virtually all robots can be found in manufacturing firms, and the bulk are located in what is sometimes referred to as the metalworking sector. The auto industry is the primary user of robots today with approximately 25 percent of all robot installations. Again, the surprise is that so few industries are actually using robots, but it is also true that these heavy industries are particularly concentrated in the traditional industrial heartland of the five Great Lakes States.

Robots should be viewed as a capital investment in automated equipment. In terms of cost, flexibility, and capability, robots are actually a compromise between the extremes of custom production and dedicated automation. Set-up time for a robot far exceeds that of a human operator in custom production, yet the speed of a robot is no match for dedicated automated equipment. Likewise, robots are no match for the flexible skills of a precision machinist, nor can a robot repeat a single task as perfectly as highly specialized automated equipment. In view of these facts, robots today are being applied in semi-automated batch or mass production facilities where the human worker or the type of work itself already limits the speed of the overall facility. The robot, once installed, appears to be just one more piece of dedicated automated equipment.

In the future such production facilities may be computer controlled with robots moving the workpiece from machine to machine. If an entire "production cell" is computer controlled, then human workers will not be needed except for maintenance, provision of the necessary material inputs, and transportation for the final output. If off-line reprogramming capability becomes available, then human operators will not even be needed to switch to the next batch. Such "flexible automated systems" will ultimately be linked together and lead to the completely automated factory of the future. However, off-line programming of robots has not yet been perfected, and computer memory systems today are quickly exhausted in controlling even a small manufacturing cell, let alone an entire factory.

Our study is focused on the development and introduction of industrial robots in Michigan manufacturing by 1990. Flexible manufacturing systems, the automated factory, etc., are beyond the scope of the study because their impacts lie beyond 1990 in our judgment. We simply do not find that this technology is sufficiently close to routine implementation to make accurate predictions of its extent or its impact at this time.

Robot Population in 1990

The projections of occupational impact in this study are the result of first forecasting the U.S. robot population by industry and application areas within those industries. This approach constrains the employment impacts to reflect the actual expected sales of robots. In this way a consistent economic framework is established within which it is possible to estimate not only the population of robots and job displacement but also the job creation resulting therefrom. This consistency is also very helpful in avoiding unrealistic or exaggerated conclusions.

Our data were gathered from published sources and through interviews with robot manufacturers, corporate users of robots, and other experts. While some judgment was undeniably necessary, we attempted to maintain objectivity throughout our efforts. In the full study, all judgments and assumptions are explicitly stated and, thus, are available for review. However, due to the space limitations of this summary, emphasis is on concusions rather than methodology.

We expect strong growth in the utilization of industrial robots in the decade of the 1980s. By 1990 the total robot population in the U.S. will range from a minimum of 50,000 to a maximum of 100,000 units. Given our estimate of the year-end 1982 population of approximately 6,800 units, that implies an average annual growth rate of between 30 and 40 percent for the eight years of the forecast period, or roughly a seven- to fourteen-fold increase in the total population of robots.

This range is intended to contain the actual robot population with a high probability level, and allows for variation in interest rates, capital investment climate, auto industry recovery, and rate of economic growth. We are confident this range will contain the 1990 robot population. That means we do not expect the total collapse of the automobile industry, a major renaissance in U.S. capital investment, the early development of nonmanufacturing robot applications, or the widespread adoption of robotics technology by small firms.

The U.S. population of robots is developed separately for the auto industry and all other manufacturing. This is partly to take advantage of the fact that the auto producers have announced goals for robot installations which could be factored into our robot population forecast. It also reflects the fact that the major impact of robots in the State of Michigan will be in the auto industry. Our forecast of the robot population sees 15,000 to 25,000 robots employed in the U.S. auto industry by 1990.

The Michigan robot population in 1990 is derived from the U.S. total by assigning the robots in proportion to production worker employment, both in the auto industry and in all other manufacturing. The result is a forecast of roughly 7,000 to 12,000 robots in Michigan in 1990. Somewhere between 5,000 and 9,000 of these will be employed in the auto industry, roughly three-fourths of the total. Consequently we conclude that, outside the auto industry, robots will have only a minor impact in the State of Michigan during the forecast period.

Gross Cumulative Displacement Effects by 1990

Before discussing the displacement effects of robots, it is important to insure that the meaning of the term ''displacement'' is clear. We use displacement to refer to the elimination of particular jobs, not to the layoff of individual workers. It clearly is possible that the displacement of a particular job by a robot might lead to the layoff of the occupant of that job, but it is not necessary. Layoff refers to the involuntary separation of the worker from the firm; displacement refers to the elimination of the job itself without any assumption as to whether the worker in that job is separated from the firm, either voluntarily or involuntarily.

Utilizing the Michigan robot forecast by industry, and the assumption of a gross displacement rate of two jobs per robot which was strongly supported in our interviews, estimates of gross job displacement are derived. We estimate that robots in Michigan will eliminate between 13,500 and 24,000 jobs by 1990. Between 10,500 and 18,000 of these will be in the auto industry, while 3,000 to 6,000 non-auto jobs will also be eliminated. In relative terms, over 75 percent of the job losses in Michigan are expected to be in the auto industry.

In addition to the assignment of robots by location and industry, it was necessary to forecast the applications for which they will be used. This is required if the robot population forecast is to be useful in predicting occupational displacement. Otherwise there is no way to connect the robots with the work content of specific jobs. The application areas used in this study are welding, assembly, painting, machine loading and unloading, and other.

When the robot forecast by application area and industry is matched against an occupational data base similarly organized, specific occupational displacement rates can be derived, as illustrated in table 1. Although the overall job displacement rate of 1.1 to 2.0 percent through 1990 is not particularly problematical, specific industry and occupation displacement rates are very significant, even dramatic.

To begin with, the displacement rate derived for the auto industry in Michigan ranged from 2.6 to 4.3 percent of all employment. But when displacement was calculated only against the operatives and laborers in the auto industry, the magnitude of displacement was from 5.1 to 8.6 percent. Even when considered to be over a period of a decade, these rates of job displacement *are* significant.

When specific occupational displacement rates are calculated, even more striking results emerge. Our results suggest that between 15 and 20 percent of the welders in the auto industry will be displaced by robots by 1990. Even more dramatically, between 30 and 40 percent of the production painter jobs in the auto industry will be eliminated by 1990. While displacement results are generally less significant for specific occupations in all other manufacturing, it is still projected that 6 to 10 percent of the production painter jobs will be lost here in the same time frame.

The conclusion of the job displacement estimates is that while job displacement due to robots will not be a general problem before 1990, there will clearly be particular areas that will be significantly affected. Chief among these will be the painting and welding jobs for which today's robots are so well adapted. Lesser impacts will be apparent on metalworking machine operatives and assemblers.

Table 1
Displacement Impact of Robots in Michigan by Application, Cumulative 1978 to 1990

	Autos		All other manufacturing		Total	
Application	1978 employment level	Displacement range (percent)	1978 employment level	Displacement range (percent)	1978 employment level	Displacement range (percent)
Welding	14,910	15.2 - 19.5	22,694	2.0 - 3.6	37,604	7.2 - 9.9
Assembly	65,764	4.5 - 9.5	50,678	0.8 - 2.4	116,442	2.9 - 6.4
Painting	4,378	29.2 - 40.6	4,387	6.0 - 10.3	8,765	17.6 - 25.4
Machine loading/ unloading	42,149	8.4 - 13.5	86,906	1.7 - 3.2	129,055	3.9 - 6.6
All operatives and laborers	206,927	5.1 - 8.6	397,598	0.7 - 1.5	604,525	2.2 - 4.0
All employment	409,506	2.6 - 4.3	769,841	0.4 - 0.8	1,179,347	1.1 - 2.0

We do not believe that this job displacement will lead to significant job loss among the currently employed, however. Even in the auto industry, voluntary turnover rates historically have been sufficient to handle the reduction in force that might be required. In addition, the new General Motors-United Auto Workers contract seems to provide adequate job security assurances, and the retraining commitment necessary to back them up. Thus we do not expect any substantial number of auto workers to be thrown out of work due to the application of robots. Any unemployment impact is likely to be felt by the labor market entrants who will find more and more factory gates closed to the new employee. Therefore, if there is an increase in unemployment as a result of the spread of robotics technology, we fear the burden will fall on the less experienced, less well educated part of our labor force.

Job Creation in Michigan by 1990

Turning our attention to the job creation issue, it is interesting to first consider the current occupational profile of U.S. robot manufacturers, as presented in table 2. For comparative purposes, the occupational structure of the motor vehicle and equipment industry, all manufacturing, and all industries are also presented. The occupational profiles have been aggregated into broad occupational groupings primarily to facilitate comparison and to highlight the technical labor input component.

Unquestionably, the most surprising finding is that slightly over two-thirds of the workers in robot manufacturing are in the traditional "white collar" areas of professional, technical, administrative, sales and clerical workers; while only one-third are in the traditional "blue collar" areas of skilled craft workers, production operatives,and laborers. To some extent that is simply a reflection of a young high technology industry with low sales, where the firms tend to be assemblers with little fabrication of parts. However, it is also indicative of a product that cannot be sold like a loaf of bread; there are significant requirements for engineering design, programming and installation for *each* specific application.

Table 2
Current U.S. Occupational Profiles
Robot Manufacturing, Motor Vehicles and Equipment, All Manufacturing, and All Industries

Occupation	Employment distribution (percent)			
	Robot manufacturing	Motor vehicles & equipment	All manufacturing	All industries
Engineers	23.7	2.3	2.8	1.2
Engineering technicians	15.7	1.2	2.2	1.4
All other professional and technical workers	4.2	2.4	4.0	13.5
Managers, officials, proprietors	6.8	3.3	5.9	8.1
Sales workers	3.4	0.5	2.2	6.3
Clerical workers	13.9	6.2	11.3	19.9
Skilled craft and related workers	8.4	20.8	18.5	11.8
Semi-skilled metalworking operatives	4.2	15.8	7.2	1.7
Assemblers and all other operatives	19.0	38.6	36.2	13.1
Service workers	—	2.8	2.0	15.8
Laborers	0.7	6.1	7.7	6.0
Farmers and farm workers	—	—	—	1.0
Total	100.0	100.0	100.0	100.0

Columns may not add to total due to rounding.

By 1990 we foresee the direct creation of from 5,000 to 18,000 jobs in Michigan in four broad areas: robot manufacturing, direct suppliers to robot manufacturers, robot systems engineering, and corporate robot users (autos and all other manufacturing), as illustrated in table 3. The jobs in corporate robot users identify maintenance requirements for robots, while the jobs in robot systems engineering identify the applications engineering requirements for robot systems, without regard to industry of employment.

The range of uncertainty is wide in the case of job creation because, in addition to the question of the robot sales level, there is also a question of Michigan's share in robot production in 1990. We attempted to bracket that figure as we did earlier with the robot population. In the case of robot production, our projected Michigan range is from 20 to 40 percent of U.S. production. In 1981 robot manufacturers with Michigan production facilities accounted for nearly one-fifth of the approximately $150 million in U.S. sales of robots.

There is no guarantee that Michigan producers will maintain their share of the U.S., or worldwide, market. This threat is especially menacing because of Japanese and European expertise in robotics technology. There is also no guarantee that Michigan will increase its share of that market, but that is a goal of various initiatives of the State of Michigan, including the Industrial Technology Institute, the target marketing efforts of the Department of Commerce, and the efforts of the Governor's High Technology Task Force. While a market share of 20 to 40 percent for Michigan is optimistic, it is not unreasonable.

Table 3
Potential Cumulative Direct Job Creation in Michigan Due to Robotics, 1990

	Employment range of estimate	
Area or industry	Low	High
Robot manufacturing	1,740	6,960
Direct suppliers to robot manufacturers	974	3,898
Robot systems engineering	1,059	4,238
Autos	1,065	1,776
All other manufacturing	287	865
Total	5,125	17,737

The projections of robot-related job creation by occupation are presented in table 4. They are very speculative because of the limited experience to date with robots and the uncertainties involved in predicting the future occupational profiles of firms that do not yet exist. However, the high technical component of labor demand is quite startling. Well over half of the jobs created will require two or more years of college training.

The largest single occupational group of jobs created by robotics will be robotics technicians. This is a term which is just coming into general usage; it refers to an individual with the training or experience to test, program, install, troubleshoot, or maintain industrial robots. We anticipate that most of these individuals will be trained in community college programs of two years duration. We expect that jobs for 750 to 2,700 robotics technicians outside the auto industry will be created in Michigan by 1990. We do not anticipate a supply problem for robotics technicians, as the Michigan community college system gives every indication that they will be ready and willing to train whatever numbers are needed. In fact, our current concern is that they may, in some instances, be increasing the supply too rapidly.

In the auto industry, we expect the robot maintenance requirement will continue to be met by the members of the UAW Skilled Trades Council. General Motors already has agreed to a retraining effort approximating $120 million annually. We believe the strong implication of the contractual arrangements is that auto industry employers will not be required to hire from the outside to meet their robotics technician needs.

Given that the robotics technicians will be one of the keys to the spread of robotics technology, it is important that the Michigan community colleges ensure that their product is what employers need. It is also important that the keen student interest not be dissipated in premature offerings. We strongly endorse the Robotics Technology Clearinghouse, sponsored by the Michigan Department of Education, for those community colleges interested in offering robotics technician curricula. This will help to ensure the *quality* of supply, and also to keep supply in some balance with foreseeable demand.

Table 4
Potential Cumulative Direct Job Creation in Michigan by Occupation Due to Robotics, 1990

Occupation	Employment range of estimate	
	Low	High
Engineers	884	3,537
Robotics technicians	1,810	4,469
Other engineering technicians	91	360
All other professional and technical workers	159	637
Managers, officials, proprietors	241	966
Sales workers	108	433
Clerical workers	472	1,888
Skilled craft and related workers	354	1,418
Semi-skilled metalworking operatives	211	843
Assemblers and all other operatives	677	2,709
Service workers	27	110
Laborers	91	367
Total	5,125	17,737

There also will be a relatively large number of graduate engineers needed to implement the expansion of robotics technology in Michigan industry. We estimate the requirement from about 900 to over 3,500 new engineers. These will be mostly electrical, mechanical, and industrial engineers. When these numbers are compared to the production of graduate engineers in Michigan in recent years, it is found that this represents approximatly one graduating class at the baccalaureate level.

While it would be feasible to increase the supply of engineers by this amount, there is already a clear shortage of electrical engineers and a possible current shortage of industrial engineers. So we start from a deficit position. In addition, we face the challenge of other likely engineering demand increases, as well as the historical instability of engineering enrollments. Thus it is quite likely that a shortage of engineers could compromise the expansion of robotics technology. It is especially disturbing, therefore, that Michigan's share of the production of engineering graduates has been declining over the last two decades.

In summary, industrial robots are simply one more piece of automated industrial equipment, part of the long history of automation of production. Robots will displace workers in the same way that technological change has always displaced workers. There is a possibility that this job displacement will be a significant problem, particularly in a given occupation or industry or geographical area. There is also the certainty that robots will create new jobs.

The most remarkable thing about the job displacement and job creation impacts of industrial robots is the skill-twist that emerges so clearly when the jobs eliminated are compared to the jobs created. The jobs eliminated are semi-skilled or unskilled, while the jobs created require significant technical background. We submit that this is the true meaning of the so-called robotics revolution. The ability of the State of Michigan to meet the human resource demands of robotics technology will play a critical role in determining the success in making Michigan a world class center of excellence in robotics.

Selected Sources of Additional Information on Robotics

Industrial Development Division
Institute of Science and Technology
University of Michigan
2200 Bonisteel Blvd.
Ann Arbor, Michigan 48109
(313) 764-5260

Among various other economic development and applied research activities, the Industrial Development Division has a continuing interest in robotics. One of their major ongoing projects is the Delphi forecast of industrial robots.

Industrial Technology Institute
2901 Baxter Road
Ann Arbor, Michigan 48109
(313) 763-9273

The Industrial Technology Institute (ITI) is an independent, nonprofit corporation designed (1) to foster basic and applied research in manufacturing process technology, including the social and economic implications thereof, and (2) to provide practical assistance to Michigan manufacturers in both adopting and producing new manufacturing process technology. Robotics is one element within the broad scope of ITI's planned activities.

Robot Institute of America
One SME Drive
P.O. Box 930
Dearborn, Michigan 48128
(313) 271-1500

The Robot Institute of America (RIA) is the U.S. trade association of robot manufacturers and corporate robot users. Among various activities, RIA conducts an annual worldwide robotics survey.

Robotics International of SME
One SME Drive
P.O. Box 930
Dearborn, Michigan 48128
(313) 271-1500

Robotics International is an educational and scientific society for robotics professionals. It is both applications and research oriented. Its interests include all phases of robot research, design, installation, operation, and maintenance, as well as the associated human factors.

Robotics Technology Clearinghouse
Washtenaw Community College
Ann Arbor, Michigan 48106
(313) 973-3441

The purpose of the Robotics Technology Clearinghouse is to develop and disseminate educational definitions and curriculum in the automated manufacturing systems/robotics technology area. One of the current projects is a survey of robot users to help determine the needs of employers.