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Elaine A. Adams for the degree of Master of Science in Foods and Nutrition presented on April 23, 1984.

Title: An Assessment of Potential Uses for Robots in Food Systems

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Ann M. Messersmith, Ph.D.

The purpose of this research was to determine potential job functions in the food systems industry for implementation with robots. The research objectives included (1) to isolate job functions in food systems that should be implemented with robots, (2) to identify job functions that robot manufacturers believe robots are technologically capable of performing in the food industry, (3) to compare job functions that are most desired by food systems with those that are technologically possible from robot manufacturers and (4) to identify characteristics of professionals who are evaluating job functions for robots in food systems.

Data collection was accomplished through the use of a survey questionnaire. The survey, consisting of two parts, was mailed nationwide to target populations in the food industry and robot manufacturing. Part one of the survey consisted of sixty-four job functions categorized into the major categories of receiving and storage, sanitation, food production, food service, food

distribution, related job functions, education and entertainment. Part two of the survey consisted of ten demographic data questions, involving age, job title, work experience, educational background, sex and computer usage.

The sample population to receive the survey was divided into three groups. These were (1) foodservice industries, including hospitals, universities and primary/secondary schools, (2) food processors and (3) robot manufacturers. Management personnel in foodservice and food processing were asked to provide an assessment of job functions feasible for robotics implementation. Robot manufacturers received questionnaires to provide an assessment of robot capabilities with regard to food industry needs. Each population group was stratified, based on a predetermined cut-off point, to include only large volume producers. Individual participants in each population group were selected through a systematic sample with a random start.

Of six hundred sixty-seven surveys mailed, forty-one percent provided valid responses and were analyzed using frequencies and chi square test of significance. Using a seventy-five percent or greater yes response rate and significance greater than .05, sixteen of the sixty-four job functions were identified for further analysis with the demographic data. This identification process was used to determine job functions which the food industry and robot manufacturers did not disagree on feasibility for robotics implementation. Looking at seventy-five percent or greater no responses where significance is greater than .05, only five of the sixty-four job functions were identified as not feasible for robots at this time. Analysis of demographic data with the sixteen identified job functions resulted in no significant difference in responses in relation to age, years of work experience, sex, computer usage or level of education.

There were several conclusions to be drawn from this research. First, the overall positive response to robots in the food industry suggest further research with actual robotics implementation would be indicated. It appears that robots aas reprogrammable, multi-functional manipulators are not currently in use in the food industry. Second, persons in the food industry need education on robots and robotics applications in the form of workshops, continuing education and academia for students. Robot manufacturers need to be educated, through publications and personal contact, in all areas of the food industry to enable the development of applications to occur. Third, further research is needed to determine appropriate job skills and training needed for food industry employees replaced by robots.

An Assessment of Potential Uses for Robots in Food Systems

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APPROVED:

Ann M. Messersmith, Ph.D., R.D., Associate Professor and Head, Institution Management in charge of major

Margy J. Woodburn, Ph.D., Head, Foods and Nutrition

Dean of Graduate School

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INTRODUCTION

ROBOT, from the Czechoslovakian word, robota, meaning forced labor (1), brings visions of complex machines that look and perform like human beings (2). The definition of robot includes a mechanical person constructed to perform in the place of human beings, one who works mechanically, and any mechanism or device that operates automatically or is remotely controlled (1). These definitions represent the typical minds-eye picture seen by most people when the term, robot, is mentioned. In reality, to date, the majority of robots consist of a mechanical arm that has the ability to be programmed to perform several different tasks. Just recently are companies developing and beginning to market the "mechanical person" that fits the general physiology of human beings (3).

As a result of the confusion as to what constitutes a robot, the Robot Institute of America (4) has defined a robot as being a reprogrammable, multifunctional manipulator, designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks. The key words here are reprogrammable and multifunctional. This allows a single robot to be used for a variety of tasks or jobs without requiring any major retooling of the machinery. In addition, a robot must be able to function automatically, on its own, by means of inbuilt intelligence or a programmable memory (5). In contrast, automated machines or hard automation, which may be mistakenly identified as robots, are designed exclusively for a specialized function (6). That is, if they are no longer required to perform the function for which they were designed, the automated equipment is simply outdated. A true robot, on the other hand, could be reprogrammed to perform an entirely different function. To differentiate between a robot and hard automation, one must look at flexibility and reprogrammability. While hard automation can do a variety of things, it cannot be changed to a dramatically different use as a programmable robot can (7).

Devices that are similar to robots but do not qualify as robots include prostheses, exoskeletons, telecherics and locomotive devices (5). Protheses are artificial replacements for parts of a human body, while exoskeletons are frames which surround human limbs and amplify the available power of the particular muscle. Telecherics are remote manipulators that are used to add distance to the motions of a human limb, allowing an operator to work outside the environment in which the work is to be done. Locomotive devices imitate men or animals by walking on legs instead of using wheels. All of these devices have some technology in common with robots but lack the ability to work independently, in some cases a more desirable trait, without constant direction from human operators. For the purpose of this study, the Robot Institute of America (RIA) definition of robot as being a reprogrammable, multifunctional manipulator will be the recognized and accepted one. However, the review of literature reports several robotic applications that do not meet the RIA definition but have been included as a point of interest to the reader.

The term, 'robot', first came into popular use in 1923 with Karl Capek's play intitled R.U.R. (Rossum's Universal Robots) (5,8). Rossum is a slightly eccentric scientist who creates biological robots to serve mankind as slave and perform all the nasty work of the world. Though the robots look and act like zombies, they have enough good sense and organizing ability to revolt and take over the world. Fortunately for mankind, they become humanized when they discover love and eventually return control fo the world back to the humans.

In 1939, Isaac Asimov began writing and publishing stories about robots, though a much more complex, versatile and intelligent robot than those in actual use today (5). Unlike Capek's robots, Asimov's robots were benevolent, containing an inviolable control circuitry to insure that they always kept their place (5). Three laws of robotics, worthy to be considered as design standards, evolved out of Asimov's work: (1) a robot must not harm a human being, nor through inaction allow one to come to harm, (2) a robot must always obey human beings, unless that conflicts with the first law and (3) a robot must protect itself from harm, unless that conflicts with the first or second law (5).

The first to actually begin working toward the functional robot was George C. Devol, who patented the robotics concept in the early 1950's. His first work was the application of digital control, pertaining to the use of digits for processing information, to a multi-axis manipulator which could be "taught" on the job (9). By 1954, he was involved in more than forty patents that described a Programmed Article Transfer System and its tooling, this nomenclature later dropped for robot. In 1958, Devol entered into license agreement with Consolidated Controls Corporation, a subsidiary of Condec Corporation, which led to the formation of Unimation, Inc. of Danbury, Connecticut (6, 10). Unimation, now the world's largest robot manufacturer (2), developed and installed its first "Unimate" robot, a huge mechanical arm used for die casting purposes, in a General Motors plant by 1961.

In the early 1970's, predictions of industrial use of robots called for massive implementation by 1980. This did not happen in the United States for several reasons pertaining to the state of the art, expense, and management and employee receptiveness (2, 11). Though the United States was the first to start robotic technology and has kept abreast of it, Japan is the world leader in robotics use, manufacture, and export (6, 8, 10, 12). Data in 1981 showed Japan's use of robots at 10,000, United States at 3,200 and Western Europe at 2,800 (12). A study by W.E. Upjohn Institute for Employment Research (Kalamazoo, Michigan) estimated the United States robot population in 1982 to be between 6800 to 7000 (13).

There are several explanations for the difference in usage between Japan and the United States. First, the government of Japan demonstrates an active interest in robotics because robots increase productivity and thus, enhance the Japanese economy (6). Management in the United States has not been supportive of robotics implementation and use for several reasons. Focused more on short-term profit than on long-term planning (6), Unites States management also places an unreasonable demand on return on investments. Training costs in the use of robotics usually are not provided, or are misued, while spare parts or special tools are not considered during project funding. In addition, management support for production and maintenance personnel is simply not available (11). A second factor influencing Japanese use of robotics is a shortage of labor, which results in Japanese workers being less resistant to robots (6). In the United States, there has been an abundance of labor which has resulted in postponement of the robotics revolution until 1980 (14). Finally, the seemingly large number of robots in use in Japan may be an inflated figure that includes automated machinery not meeting the RIA definition of robot (10).

A turnaround in United State philosophy regarding robots is beginning to occur due to an increased emphasis on productivity and quality in manufacturing (12). United States automakers lost 40,000 jobs to foreign competition by lagging behind in the implementation of robots (14). There is a definite need to identify the emerging, rather than the obsolete, requirements for industry and society. An example of this can be seen in many programs that still train unemployed workers for factory jobs that robots are beginning to occupy (14). This brings up the issue of the impact of robotics implementation will have on unemployment. Historically, however, the introduction of new technology has expanded economic opportunity for the total society (4). Since people have gained from the mechanization and automation of work, it seems reasonable to believe that they can gain from the robotization of work also (15).

The future of the food systems industry appears destined to become involved in the new technologies of robotization. Lower production and service costs can be achieved through the economical and technological advantages robots provide (4), particularly in an industry where many job functions are highly repetitive and tedious. Direct labor costs alone can drop from $15.00 per hour for humans to less than $5.00 per hour for robots (4), along with the elimination of fringe benefits. Robots are fast learners, speedy, untiring and accurate workers that don't "mind" tedious repetitive work (10). Soon robots will be able to see, talk, listen and adjust to varying conditions (14).

One purpose of this study was to determine how food systems managers in many areas of the industry perceive robotics use in their facilities. In an assessment of the future of health-care foodservice by Gullickson (16), the need to control health care costs has been emphasized with the federal government's legislation that will eliminate subsidizing patient bills on a cost-plus basis. This resulted in Diagnosis Related Groups (DRG's) which incorporate standard fees for specific procedures, to be in effect by October 1, 1986. As a result, administrators are looking hard at dietary costs and means of improving productivity. With similar situations occurring in other areas of the food industry and robots having been shown to improve productivity by up to sixty percent in given areas (17), this study was engaged to determine which job functions in the food industry are most suited to robotics implementation. The desires and requirements of food systems management for robots need to be ascertained to provide robot manufacturers guidelines in their development of robotics for use in the foodservice industry. In addition, robot manufacturers need to be consulted to aid in the identification of the capabilities of robots as they relate to food systems requirements.

REVIEW OF LITERATURE

A more precise definition of robots and a look at their physiology and capabilities is needed before robotics can be applied to food systems or any other industry. To be useful, a robot must have several attributes: (1) a hand to grip or release a workpiece, (2) an arm to move the hand in three planes, (3) a wrist for the arm with two or three articulations, (4) sufficient power to move the limb and workpiece around, (5) manual controls so an operator can control limb motions, (6) memory to store a sequence of instructions, (7) automatic means that allow instructions stored in memory to control operations in absence of a human, (8) ability to function at speeds equal to or greater than a human and (9) reliability of at least 400 Mean Time Between Failure in actual working environments (5, 6). Any human attributes not essential to production, such as legs, sense of taste or smell, should be eliminated (5). Engelburger (5) expands the list of attributes to include (1) sufficient strength to lift a five hundred pound workpiece, (2) positioning repeatability to 0.3 mm, (3) a library of programs which can be selected at will and allows the robot to switch back to operations it has been taught in the past, (4) facilities for safety and process interlocks (switches or other sensors that are mounted on associated machines to insure that the robot keeps in step and causes no damage), (5) computer-compatible interface and (6) configuration which allows easy maintenance with quick access and interchangeability of parts in the event of breakdown, aided by self-diagnosis routines.

Robot Classification

The identification of specific classifications for robots is not an easy assignment. The capabilities of robots can range from very simple, repetitive point-to-point motions to extremely versatile movements that are controlled and sequenced by a computer (5). The progress in robot design development has caused overlap between once clearly distinguishable robot types (5), resulting in different classifying methods by various scientists. Whaley (4) bases classification upon resemblence to humans in appearance and function, which results in two classes: anthropomorphic and nonanthropomorphic. Anthropomorphic robots have an approximate appearance to and many functions of humans. These include more recent personal robots aimed at hobbyists, such as the Hero I by Heath Company, the Genes 1 by Robotic International Corporation, and BOB (Brains on Board) by Atari, Inc. (3). Nonanthropomorphic robots, according to Whaley (4), do not resemble humans and perform only limited human functions. These include the majority of industrial robots in use which consist of a mechanical arm able to perform several functions of the human arm.

Robots classified by the level of technological sophistication, according to Callahan (6), results in three catagories: low technology, medium technology and high technology. The low technology robots are not "servo" controlled, meaning that their movements are directly powered with no feedback or self-correction. They have a limited number of program steps and usually demonstrate good repeatability. The medium technology robot utilizes the servo mechanism for accurate position and velocity control and contains microprocessors or mini-computers as a basic control element. It can be easily reprogrammed because of the flexibility associated with the digital computer. The majority of robots in use today fall into this classification. In the experimental stage are the high technology robots of the future. These robots have all the features of the medium technology robot in addition to external sensors that provide information about the external environment. This will allow robots to "see", "feel", and navigate in their surroundings.

Edson (8) approaches the classification problem by defining varying sophistication levels of machinery, not all of which can be labeled robot. He defines robots as mechanical simulators of rudimentary human functions as picking, grasping, and lifting. His first category is a simple machine, an extension and amplification of muscle power. These include the lever, the screw, the wheel, the wedge and the pulley, which form the basis of all machinery. The second category by Edson includes programmable or instructable machine that can do a sequence of tasks using a set of instructions that has previously been given it by a human operator. A typical programmable machine is the assembly-line bottle capper. It continues capping bottles in the same way until it is stopped by an operator or a programmed stop point. The third category, the industrial robot, differs from programmed machinery in a very important way. The robot is programmed to do a sequence of actions required to perform a specific job, can be reprogrammed with a new series of actions to do an entirely different job, and can change its behavior when it receives a signal to do so. In contrast, a programmable machine, such as the bottle-capper, is unable to change its sequence of actions to perform a new job function. Once bottle capping is complete or no longer required, the bottle-capper sits idle.

Another scientist classifying robots according to the technological sophistication is Engelburger (5), which results in three categories: (1) limited sequence robot, (2) playback robot with point-to-point movement (3) and playback robot with continuous path control. The limited sequence robot, sometimes referred to as 'pick and place' or bang-bang machine, uses a system of mechanical stops and limit switches to control movements, with memory consisting of a set of complex and interdependent limit switches, interlocks, end stops, and electrical connections. The controls switch the drives on and off at the ends of travel, with the path in between undefined, but providing good position accuracy with repeatability at greater than plus or minus 0.5 mm. Though difficult to reprogram, these robots have been successfully used in die-casting, press loading, plastics molding, and as part of special-purpose automation.

The second classification by Engelberger (5) is the playback robot with point-to-point movement, which uses servo mechanisms to achieve positional control of each limb. Having unlimited memory, the memory unit is used to stimulate all the servo systems, programmed by manually driving the robot through all stages of an operation and recording the sequences in memory, thus the term "playback". Safety and control interlocks still must be incorporated between the robot control unit and the machinery being operated to prevent collisions and other problems. The control is point-to-point with no definition of paths that limbs follow to complete an operation unless intermittent points are recorded by the operator in the process of programming a sequence.

Engelberger's (5) third category is the playback robot with continuous path contol, which has the ability to control and trace the path of a robot limb as it travels between start and finish points of an operation. The robot is taught by literally moving the limb by hand through the desired operation. The speed of playback operation can then be increased or decreased to fit the needs of the operation.

Robot Physiology

The physiology of a robot is composed of two major component systems. The power/drive component, such as the arm, wrist and end effector, or the hand, and the control system component, such as the digital computer and feedback sensors (6). The purpose of the power/drive component is to position a tool or other end effector anywhere in the sphere of influence of the robot. To accomplish this, the robot must have at least three degrees of freedom, or articulations. A more general-purpose robot will have six degrees of freedom (6). There are two primary methods to move the elements of a robot. A hydraulic drive is used for large robots where heavy loads (450 pounds minimum) are to be manipulated. An electric drive is used for smaller robots where position accuracy is essential (6). The hydraulic is popular because it is compact, provides high power and force and, with proper feedback, can offer good position and velocity control (6).

The end effectors, or hands, are one of the major reasons that robots are so versatile (6). Though the end effector must be chosen or designed specially for a specific application, it is easy to retool a general-purpose robot to do another job simply by changing the hand (5). The requirements for grippers are numerous and there are many methods that can be utilized. Some of these include mechanical grippers, hooking on to a part, lifting and transferring parts on a thin platform or spatula, scooping or ladling, electromagnets, vacuum cups, sticky fingers using adhesives, and quick disconnect bayonet sockets (5). The industrial robotics research program at Clarkson College of Technology (18) has recently developed an end effector to simulate the human hand. About twice the size of the human hand, the end effector has five fingers designed to emulate the function of the human hand. Another end effector simulating the human hand, developed at the University of

Pennsylvania (19), consists of three two-jointed fingers, one of which can move about the base to oppose the other two fingers similar in action to the thumb. This hand is capable of a variety of grasps, including spherical, cylindrical, tip, hook, palmar and lateral. Speciality tools may also be utilized as end effectors, such as spray guns, welding torches, routers, sanders, grinders, and drills, with the use of a quick disconnect mechanism to allow for a selection of tools (5).

The control system, the second major component required of robots, functions to direct the motion of all the robots elements. Along with the entrance and execution of a series of instructions, the control system must allow for human intervention with manual controls as well as automatic operation (6). Two methods are available to program robot movement. In the first method, a human operator moves the robot through a series of required motions using manual controls. The control system then "remembers" the sequence and can play it back at a later date, providing a very easy means of programming. The second method of programming uses explicit instructions. The motions of the robot are controlled by a sequence of commands that the robot understands. These commands are then interpreted and generate a control signal that performs the required movement (6).

Though some experts believe that vision is too advanced for robotics (7), on-going research has already led to the development and, in some cases, the implementation of vision and tactile systems in robots. Of all the senses, it is generally agreed that vision has the greatest potential, with predictions of twenty-five percent of the robot population in 1990 being equipped with vision (20). The ability to identify different parts or shapes at random, reach out and grasp each part and place it at the proper spot for the next operation are some of the goals of robotics vision research (8).

The driving force behind the vision market is higher productivity and improved product quality. In one application, a robot is able to inspect and sort as many diamonds in two hours as it takes six humans to sort in one day (21). Vision systems in robots eliminate the problems of human fatigue and boredom and free individuals from work in hazardous environments. Robot vision can also do things human vision can't, such as see in small or restricted areas or perform precise measurements (20).

According to Schreiber (20), vision systems can be categorized depending on how they process images. Binary systems, which are easier to use and understand, translate each point of image into one of two colors, black or white. Gray scale systems, on the other hand, allow numerous different shades of gray to be assigned to image points, which permits this type of system to gather more information. Whichever system is used, it needs to be simple, accurate, fast and three-dimensional to meet the needs of most real world problems.

The application possibilities for artificial vision range from industrial manufacturing to uses with a more human touch.

Artificial vision can be a powerful aid to people with visual handicaps in addition to actually providing optical navigation and recognition for the blind (22). Systems to see and report intrusions in the front and rear blind spots of buses would add a tremendous safety factor in the transportation of school children as well as the public. About ten percent of total labor cost in manufacturing goods is accounted for by visual inspection (20). Robotic vision inspection will result in improvements in both quality and cost of products. Tremendous cost savings just in raw materials can result by implementing quality control inspection early in the production cycle (20).

An infrared vision system from Eltec Instruments Inc. in Daytona Beach, Florida, is designed to precisely detect an object by sensing the thermal contrast between a moving object and its background (23). This type of system will be useful when visual inspection is difficult or impossible, as in hot glue application, tamper-proof packaging, soldering and coating. It would also be adaptable to continuous control of manufacturing processes for container filling, labeling, protective shrink wrapping, drilling and extruding (23).

Parts identification with robot vision can be implemented for parts sorting, palletizing/depalletizing, character recognition, inventory monitoring and conveyor and bin picking. A 1983 report by Trans Tech Corporation of Naperville, Illinois estimates that thirty percent of the vision systems applications will be in parts recognition (20). DataMan vision system by Cognex Corporation of

Boston, Massachusetts is already capable of reading codes which are printed, etched, stamped or inscribed directly on product surfaces, including cardboard, for inventory routing and tracking purposes (20). Ford Motor Company plans to use Cytocomputer vision system from Synthetic Vision Systems Inc. of Ann Arbor, Michigan to verify precision circuitry, which is a basic building block of electronic control modules in Ford cars and trucks (24). Many defects that can be detected by this system are not detected by traditional electrical tests currently in use.

Guidance and control is another general application for robotics vision. These systems can direct the action on a production line based on what it sees and how it is interpreted. Applications with needs for guidance and control include seam weld tracking, parts positioning, processing and machining, fastening and assembly, bin picking and collision avoidance (20).

High speed vision (25), operated at the touch of a button, is capable of complex measurements at high speeds. Used for multi-cavity plastics, stamping, castings, molds and precision machined parts, these systems can measure radii, diameters, centers, centroids of any irregular shape, distances, angles and intersections.

Progress is also being made in the area of tactile sensors, though only a few systems for tactile sensing are currently available for implementation. Research and development in the area could lead to robotic systems that duplicate humans in their ability to manipulate objects (26). Electrotopograph Corporation of Eldred, Pennsylvania has a line of tactile sensors capable of detecting a whole range of defects in metal products (27). A new gripper from Object Recognition Systems, Inc. in Princeton, New Jersey incorporates both optical and tactile sensors (28). The interruption of a beam directed between the tips of the gripper signal the robot control system that an object is present. Pressure sensors in the new gripper prevent fragile objects from being damaged or crushed.

Advantages in the Use of Robots

There are several advantages in the use of robots for any application. The greatest advantages are productivity improvements (reducing labor and increasing output) and cost reduction (5, 11, 14, 29, 30, 31). Robots are fast learners, speedy and accurate workers who never tire of tedious, repetitive work and always do a job in the exact same way (10, 14). Along with working multiple shifts, robots will never strike or ask for raises, never have to eat or take vacation, have no family responsibilities and require no social interaction (5, 10, 14). Requiring a minimum of supervision, robots are capable of working in hostile environments where noise, vibration, smells, or danger adversely affect the human counterpart (5). A report by the Society of Manufacturing Engineers/University of Michigan (SME/Mich) estimates that productivity gains from robot use in 1982 range from twenty to thirty percent with an expected rise to thirty to forty percent by 1990 (32). The hydraulic or electric power of their limbs gives more strength than human muscle power, enabling them to lift objects too heavy for humans to grasp. They are better able to deal with sharp or corrosive-covered objects and red-hot parts than humans. In comparison with automated equipment, robots have additional advantages. Along with being economical, robots have a fast reaction time, that is, they can be up and operating quickly and rapidly reprogrammed as needed. Debugging for robots occurs at the manufacturing plant, prior to delivery, where automated equipment must be debugged on the production floor after delivery. Robots are resistant to obsolescence, in that when one job is completed, reprogramming enables the robot to perform any new appropriate job as necessary. They are neither product nor operations nor industry limited (5). As the robotics technology is rapidly developing, in addition to vision, robots will soon be able to "talk", "listen" and adjust to varying conditions in the environment (14).

Disadvantages in the Use of Robots

Though the robot can provide numerous advantages to a production unit, it is not without drawbacks. Major problems encountered in robot applications result from a combination of various human, social or organizational factors that are not anticipated during development and implementation. Management tends to devote ninety-nine percent of their efforts on machine hardware and computer software, with only one percent on the "people" factor of attitudes, job satisfaction, training/retraining, and related fears of robotic utilization with respect to impact on employment (11). As a piece of machinery, robots must be cost-justified along with being correctly used and properly maintained (14). Robots can be inflexible and can cause bottlenecks in production if skilled labor to handle programming is unavailable. They also will never do more than they are told to do and will not contribute innovative ideas (14).

Guidelines for Robot Implementation

In consideration of their advantages and drawbacks, there are factors and guidelines to consider in deciding to implement robotics applications. As a general rule, if only one robot is needed, then there probably is not a need for any robots (14). The cost of training, maintenance, and parts inventory would offset any productivity improvement. When purchasing robots, Price (33) recommends buying a more complex, more flexible machine that could be programmed for many jobs, rather than a more simplistic one. Robotic applications should be aimed at areas to increase productivity and should be used for the right kinds of tasks (11, 14). If a simpler, cheaper machine can do a task effectively, then a robot may be inappropriate.

The cost of a robot depends on the attributes and accessories with which it is equipped. Some of these attributes include arm reach, accuracy, rotating ability, repeatibility accuracy, number of axes, load capacity, computer program capacity and type of drive (10).

Due to the large number of robot systems available, there is a lot of flexibility in choosing a system. Callahan (6) suggests the following performance measurements as useful in comparing robots: position, repeatability, number of degrees of freedom, power requirements, maximum lifting capacity, number of control options and cost. Invest or don't invest equations need to be rewritten for robots to take into consideration factors that are ignored with human-operated automated equipment. Along with direct labor savings, some of these factors include changes in health and safety rules where robots are doing hazardous work, improved product quality, reduced maintenance costs for all machinery due to operation under consistent conditions, and savings in materials due to less waste (7, 12, 14, 31). The practical utilization of robots has evolved due to the breakdown of job processes into very small parts in an effort to increase the ratio of output to labor cost using low-cost unskilled labor (5). This resulted in dull, repetitive jobs and worker dissatisfaction with a resulting high rate of turnover, absenteeism, and continued demands for increased wages. Engelburger (5) illustrates how robots have helped ease this situation and improve cost benefits to employers. With an initial investment of $55,000 for a robot and its accessories, $3,000 for robot maintenance, and $24,000 for one replaced employee, the payback period for this robot is only 2.62 years, three years considered the cut-off point by most accountants. If the robot is utilized around the clock, thus replacing three employees, the cost benefits are even more impressive.

Implications for Labor

As the impact of robotics on productivity is being evaluated, it is important to consider the effect robotics will have on employment and the labor force. Job displacement refers to the elimination of specific jobs; not necessarily to the layoff the individual workers (13). Though opinions vary, it appears that the majority believe that robotics will create more jobs than it replaces (11, 15, 32). The SME/Michigan report (32) expects that about six percent of the human workers replaced by robots will be laid off in the 1980's. The majority of these workers will be retrained and reemployed as robot manufacturers and distributors create new jobs in the form of secretaries, salespersons, managers, persons for robot installation and repair, mechanical and electronic engineers and computer programmers and technicians. The report continues to say that by 1995 human worker injury in factories will have decreased as much as forty-one percent because of robotic replacement creating safer, cleaner work environments for humans and improving job quality. Obrzat (11) makes a few suggestions for dealing with job displacement before it occurs. By identifying volatile categories of workers well in advance of job elimination, plans for future employment needs can be made and new job skills requirements determined. Providing effective education and training will upgrade employees to skilled categories of employment where help is needed.

Possibly greater than job displacement is the problem of employee acceptance of robots at all levels of employment.

The transition to robots has not been easy in the United States, where as in Japan it has gone fairly smoothly (10). The United States worker fears robots while the Japanese see them as "friends" to perform dehumanizing tasks, allowing humans to do more rewarding jobs. The Japanese worker is also guaranteed job security for life while the United States worker is not (10). Ironically, employee resistance to robotics poses a threat to employment levels in that, if foreign competition automates and takes the market through cheaper products, resistance to robotics use then results in the creation of an unemployment problem (14). If robots are used appropriately, they can turn money-losing operations into ones that make economic sense and thus, actually preserve jobs (15). This theory was proven valid at the Albina shop of Union Pacific Railroad where freight cars are built and repaired (34). The spread of cost between a car built by Union Pacific and a car built by a contract builder was getting continuously smaller. By the time the difference reaches zero, it is no longer economically feasible to build freight cars in-house. After research, "Milly" the robot was purchased and implemented to manufacture a number of types of car parts to be used in building the freight cars. With the increased productivity that resulted from Milly's implementation, many jobs were kept viable as a result of Union Pacific being able to cost justify building its own cars.

The key to gaining employee acceptance for successful robotics application and implementation is to involve workers in planning the introduction of robotics (4, 15, 33). It is the responsibility of top management to create an awareness of the potential for robots. Middle management is responsible for showing what automation can do and how it can be integrated with the present system (35). Lower level management then is responsible for production and maintenance. The use of participative management techniques to counsel, advise, and get input from employees results in the understanding that a robot can be a "friend" in the workforce and results in better employee acceptance (15, 35). In selecting a project or area for the introduction of robots into a facility, there are several factors to consider. Most important is to select an area where there is a high probability of success (11, 35) and likely to have good payback (11). An area should be selected where there is good supervisory support of robot usage, good morale of employees and adequate service support (11). Communication with personnel and union representatives with regard to what will and will not happen with the introduction of robots is important, before rumors start (11). Lack of knowledge and understanding leads to fear and can result in employee sabatoge of the project (15). Obrzat (11) uses the 80-20 rule in selecting a site for robotics use, where eighty percent of the costs are in twenty percent of the operations. He suggests that a robotics project begin in an area where costs are high and that ranking areas by cost identifies those areas that may be best suited for an initial application of robots. A backup plan is also important in case the robot fails.

Impact on Human Resource Management

The impact of robotics on human resource management is wide ranging. There will be a new challenge in keeping employees satisfied due to the development of a different value system with the introduction of robots in the workforce (4). Factors involved in this new ethic might include entitlement of choice, multiple choices, participation and immediate gratification (4). Different skills will be required of personnel at all levels of employment. Jobs need to be upgraded and people need more education and training for the new manufacturing environment where robots perform the labor and humans do robot research and engineering, technical maintenance and programming (8, 33, 35). Human resource skills are still critical, even in an automated factory, in the areas of management and maintenance (35).

Policy or attitude changes are needed in five areas of human resource management, identified by Whaley (4) as organization, evaluation, rewards, development and maintenance. In the area of organization, more technical background is required with robotics use, resulting in changes in job descriptions, specifications and analyses. The selection of workers will be in competition with robot counterparts and will require a redefinition in job requirements and selection criteria. Job safety will be improved with the use of robots to perform dangerous tasks, while, at the same time, another hazard has been introduced. Since robots do not have eyes, as yet, humans entering into the sphere of the robot's work area could be injured, being mistaken by the robot as part of the job routine (34). Methods of handling this problem, until vision technology has developed to the point of human recognition, include fencing the robot work space off and/or moving the job functions of humans, such as materials loading and unloading, outside the range of the robot (34).

In the area of evaluation, Whaley (4) indicates a need to change the performance standards of robots in relation to those of humans. The use of robots serves to eliminate human-related problems and costs, such as absenteeism, turnover, training, personality conflicts, demotivation, high stress level, and alcoholism. A failure in a robot system is a failure of management (4). Human rewards, the third area to be affected by robotics, is not an issue in robotics use. Robots do not require fringe benefits, recognition, or work incentives. Humans, on the other hand, due to greater work alienation and decreased human interaction, will need compensation for these factors through more economic incentives, more time away from the job, and/or structural changes in the job. Job enrichment will be achieved through autonomy, responsibility and self-control in person-machine interface (4).

Due to newly developed performance standards, increasing real or potential performance for employee development will need to be in relation to these new standards. For robots, this is simply a function of improving engineering hardware and programming. To retrain a robot, simple reprogramming is all that is required (4).

For humans, the problem of employee development and training is more difficult, involving psychological, sociological and emotional factors. Maintenance of employee relations, the final factor Whaley (4) identifies for human resource management, consists of communication, leadership and motivational networks required to connect together other subsystems.

Industrial Robotics Applications

Robots have been successfully implemented in many industrial manufacturing applications, with new uses continually being developed. One of the earliest applications of robotics was in the automotive field in the process of die casting (5). This process involves the high-pressure injection of molten zinc, aluminum or their associated alloys into a steel die. Prior to injection of the molten metal, the die, which separates into two halves, must be cleaned of residue and lubricated. Molten material is pressure injected into the die until it is filled, resulting in metal seepage through the mating die surfaces and the presence of thin fins of metal, or flash, on the cooled pieces. After complete water cooling, the castings are removed and the flash trimmed. The nature of the work, tedium, heat, noxious fumes, physical danger and other problems, makes die casting an unpleasant task (5). Along with human factors involved, the die casting process involves many operational variables, such as the chemical and physical state of the hot metal, mold treatment, machine adjustment and cycle timing (5). Through the use of a single-arm robot with teaching controls, memory and logic links between the robot and the die casting machinery, a single human operator can instruct the robot in the process of die casting and then be removed from the hazards involved in the process (5). In addition to relieving the human from the actual task of die casting, robot users have reported significant reduction in scrap and reject rates, increased utilization of die casting machinery (robots can work twenty-four hours a day), reduced needs of safety equipment for humans, and cost savings (5).

Several other applications of robotics have been applied, or are in the process of implementation, in the automobile industry. Spot welding, the process of joining metals by fusing them together (5), is currently used in body construction at Chrysler's Windsor, Ontario, Canada assembly plant (36). By 1985, the management responsible for this plant plans to use robots in the application of adhesive sealer, in the installation of windshields and back lights, and in mounting wheels (36). According to their plans for robotics application, robots were to have started fusion welding, parts handling, and application of sealer and paint by June, 1983. In Chrysler's experience with robots, they have found a need to change facility design, operating methods and quality control techniques (36).

General Motors found that a robot programmed as a numerically controlled paint sprayer can provide many advantages in that application. Not only is the quality of paint improved, but savings in the cost of paint, one million dollars per year, has resulted simply because the robot cuts off the spray at just the right moment (30). Pollution abatement costs have been reduced due to the need for minimal ventilation while energy costs have dropped with robots working at lower temperatures than humans (30). General Motors estimates robot usage at 5,000 by 1985 and at 14,000 by 1990 (12).

Ford Motor Company (37) uses an extended reach robot for carrying instrument panels for assembly-line installation, at the same time removing and disposing of plastic packaging materials from the panel storage bin with a multifunctional end effector. This robot arm selects one of four panels, through a computer system, from storage and automatically moves it to the production line. Nissan Motors in Japan (38) has a newly developed robot to install tires on new passenger cars. Mobot Corporation robots are used for spot welding automobile bodies through an innovative implementation approach (39). The robot travels on an overhead bridge designed to use less floor space, permit more freedom to access work in process and allow more flexibility in process layout.

In the plastics industry, Tupperware reports a cycle time savings of ten to thirty percent through the implementation of robots for parts handling at the mold machine (40). By robotizing part removal, molding costs have been reduced, machine productivity increased, scrap reduced and operator safety improved. Along the same line, Hoover Company has installed robots to load and unload injection molding machines (41). The goal of the robotic implementation was to remove human operators from the hot, boring and highly fatiguing jobs and to produce more uniform parts. To fill in time between loading cycles, the robots were put to work broaching out the center sprue from parts, trimming and drilling holes.

In textiles, robots have been implemented in the production of denim at Burlington (42) and for the transportation of large bolts of fabric, with the capability of distinguishing colors (43). The Japanese have drastically reduced the amount of human labor required during the coating of wood furniture (38). In addition, the quality of the paint coating has been standardized, paint loss reduced and the need for organic solvents eliminated.

Steel pipe fabrication has been revolutionized with the implementation of a portable oxyfuel pipecutting robot (44). Weighing only thirty-five pounds, the robotic pipecutter is less expensive and easier to move than the twenty to forty foot pipes weighing several tons. This feature permits pipe cutting to be accomplished either in the factory or in the field.

Recently, high pressure water spray and robots have been implemented for two separate applications. Flow Systems Inc. has spent three years developing the hardware for waterjet cutting, trimming and cleaning (45). With the ability to cut at high speed with excellent edge quality, industrial robots integrated with high pressure waterjets are being used to cut automobile interior components made of cloth or plastic. In the second application, the Ford

Motor Company has implemented a robotic waterspray system for cleaning the deep narrow channels in transmission cases (46). With dedicated parts washers and manual operations unable to complete the job satisfactorily for several reasons, three robots with fan sprays and pin-point nozzles have succeeded in improving quality of the cleaning and reducing warranty work as a result.

Another loading/unloading function implemented with robotics is in the General Electric aircraft engine manufacturing facility in Evensale, Ohio (47). The areospace industry has been slow to accept and utilize robots in production due to small lot sizes, big part tolerances and complex geometries which call for long and exotic process cycles. As in any industry or application, when the operation requires only minimum utilization of the robot timewise, it is difficult to justify its implementation. Management must then start to look at giving mobility to the robot so it can move to various work stations to increase the level of utilization (47). To accomplish this, General Electric placed a Unimate 4000 robot on a special-built sled to allow it to move between four workstations, thus relieving human workers from the seventeen thousand degree heat and monotony of the hot form press operations.

The University of Western Australia is testing a sheep-shearing robot (48). Microcomputer software was developed specifically for the shearing operation with electrical sensing devices used to detect the sheep's skin. Robotic arms are utilized to hold and manipulate animals into different positions for shearing. With over one-hundred and fifty trials on live animals completed, results show that ninety percent of the wool can be removed with the system in two minutes, with the remaining ten percent removed in another minute.

In another innovative application, a simple load/unload robotic system is used at Philip Morris Research Center for cigarette tar testing operations (49). Weighing filters before and after machine smoking, a robot arm loads and unloads testing samples from two electronic balances, cutting weighing time in half and increasing operator efficiency by one-hundred percent. Another load/unload operation which has resulted in significant savings is at Grand Rapids Manufacturing Company in the stamping process of oven liners (50). Producing twelve to eighteen hundred kitchen ranges per day, the robotic system was added to manufacturing operations to aid the company in remaining competitive in product cost.

Applications with a more human touch are in development at Tokyo University, Stanford University and NASA (51). Tokyo has developed a "hospital aide" robot, which is a computerized machine that will open bottles, pour drinks and carry them to bedridden and disabled patients. At Stanford University, graduate students are working on robotics projects that will be of service to quadriplegics. A PUMA robotic arm integrated with interactive voice command programs can lift, pour, feed and do other useful tasks. Programmed to respond only to one master, a synthetic voice will repeat the commands to provide fail-safe control of the robotic arm.

A mobile cart carries the arm to wherever one chooses and is able to plug and unplug itself for energy recharging (51).

NASA (51) is workig on a voice-controlled wheelchair, using a microcomputer to translate commands into the appropriate desired motions. Stanford University (51) has made use of head motions to indicate the direction of travel for a wheelchair. Development of a combination of the voice-controlled arm and the wheelchair are promising research areas, according to NASA. By developing a mental picture of robots as human helpers, greater acceptance for the entire field of robotics may be fostered.

Robotics Applications in the Food Industry

Though applications of industrial robots are extensive and constantly increasing in many industries in the United States, the food industry has been slow to even look at potential applications. Just recently are experts in the food industry beginning to realize the potential of robots or robotic systems for foodservice and production applications. Palmer (52) has proposed a hypothetical automated food preparation and service (AFPAS) system that will utilize valves, plastic tubes and hydraulic mechanisms in offering freshly cooked entrees through a vending machine-type system. With choices of condiments and toppings, foodservice operations would be fully automated for both the sales transaction and for the final heating and serving of the selected food item.

Wegener (53) predicts the use of robots in food plants by the 21st century to keep labor costs down and improve productivity and sanitation. Additional advantages of robotics include reduced energy needs due to reduced lighting needs, except for quality control inspection, and reduced heating/air conditioning needs, except as needed to preserve product quality. Lasers and waterjet cutters, he predicts, will be utilized for dicing, slicing, chopping, cutting and peeling. For the last three years, Cedars-Sinai Medical Center frozen food factory in Los Angeles, California has filled containers with the use of robotics (16). According to foodservice director Jerome Berkman, it has resulted in reduced waste and a twenty-five percent cut in labor costs.

Robotic cranes are in use at two facilities in the United States. At Giant Foods new storage facility in Jessup, Maryland, four automatic stacker cranes, working in a minus-ten degree environment, pick up frozen food pallets, take them to storage locations and retrieve the items when needed (54). Hiram Walker's blending and bottling plant in Fort Smith, Arkansas uses computerized stacker cranes and Robo-Carriers (an unmanned, self-propelled and self-directed pallet carrier) to sort, retrieve and transport one-hundred forty-five different products for distribution across the country (55).

Rose (56) discusses a wide range of potential robotic applications for foodservice facilities and hospitals. Accuracy and speed of trayline functions could be improved with robots taking over checker and reject stations in addition to programming with data regarding food substitutes for therapeutic diets should first choice items run out. In storage and receiving, Rose suggests that robots equipped with visual or code-reading capabilities receive goods, enter data into inventory records and transport and rotate products into the proper storage locations. Robotic sanitation and dishroom activities might include dish sorting, mopping, wall cleaning, and, for stationary robots, sorting and stacking dishes, discarding paper and soil, putting dishes on a conveyor and cleaning work areas. Other applications proposed by Rose include diet, histories, therapeutic diet menu selection assistance, standard education module administration, cooking class demonstrations, individualized nutrition care in the form of behavior modification, equipment repair, job applicant screening and orientation sessions for new employees.

Outside the United States, other countries are already making limited progress in the implementation of robots in the food industry. In Cambridge, England, vision-equipped robots with piping nozzles are decorating chocolates, a task very similar to applying ribbons of adhesives or sealant to workpieces (48, 53). Capable of adapting to the exact position and orientation of each chocolate on a conveyor belt, robotic vision is able to recognize pieces that vary in shape and size and must be discarded.

In the United Kingdom, an automated boning system, built by Proman of Klippan, Sweden, acts as an aide to the skilled meat cutter (57). By providing the "muscle" to pull one-hundred fifty to two-hundred pounds of beef, most of the manhandling of large carcasses is eliminated, allowing the meat cutter to use both hands for boning and drastically speeding up the boning process. Using this system, two people can bone out a beef hindquarter in one minute and a forequarter in two minutes. At $75,000, the first U.S. installation was planned for in November, 1983, at Hillshire Farms, Wisconsin.

Other than media reports on the use of robots in kitchens and restaurants, the literature has few additional references on the use of robots in the food industry. Foreign articles in German and Italian (58, 59, 60) refer to studies done to determine potential applications for industrial robots in the food industry. Some of the areas considered include handling of multiple packs of margarine, tea, coffee, wines, spirits and beers; loading and unloading of bakery ovens; handling of raw materials; and loading of vehicles and inplant transportation devices (49).

Light Assembly and Minirobots

A new area of research and development for robotics is mini-robots, table-top versions of both the industrial mechanical arm and the mobile personal robot (61, 62, 63). Assembly minirobots (GPA Corp.) are designed for high speed assembly operations and feature precise position accuracy and flexibility (62). With two models available, options include horizontal or vertical·orientation and four or five axes. The minirobots are capable of loads up to 4.4 pounds and weigh between ninety-nine and one-hundred ten pounds. Mobile minirobots (Feedback Inc.) are designed for teaching and training in robotics technology (63). Models are equipped with touch sensors, arms and grippers and are free to explore the environment and calculate evasive or exploratory action.

With forty percent of robot growth in the next ten years forecast to be in light assembly robots (64), Intelledex of Corvallis, Oregon, has released two light assembly robots aimed at improving productivity in high technology manufacturing. With unusual flexibility and accuracy, the new light assembly robots have an optional fully integrated vision system that supports up to one-hundred different object definitions. It has the capability of recognizing randomly placed objects on a work table, of determining which to pick up, move or manipulate and of following software-determined assembly routines (65). Adept at manipulating irregularly shaped components, applications in electronics manufacturing include application of surface-mounted devices to circuit boards, final inspection of assembled circuit boards, final assembly of Winchester disk heads on disk drive mechanisms and fabrication of microwave cavity component devices (66).

Mobile Robots

Most robots in use in industrial applications have consisted of a large mechanical arm, an end effector and a control system.

Mobile robots have only been available in the form of personal robots for hobbyists or for use in robotics education. Portia Isaacson, a Dallas consultant who predicted the boom in personal computers, believes that the personal robot industry is now in the same state that the personal computer industry was in 1975 (67). With personal robots now available for the development of programs by hobbyists, real applications for personal robots, including vacuum cleaners, lawn mowers, security dogs and mail carriers in buildings, may become a reality in the next ten to fifteen years.

Several mobile robots are currently in use with a wide range of applications. FUBAR, which stands for futuristic uranium bio-automatic robot, is a mobile human-like philanthropist robot used for entertainment and the uplifting of human spirit (68). BOB, meaning brains on board, is used for home security, one of the most probable uses seen for personal robots. With the use of special sensors, mobile robots could also act as smoke, heat and fire alarms (68).

Hubot from Hubotics Inc. (69) is a mobile robot currently used for entertainment in the form of flashing red collar lights, a synthesizd voice with a twelve-hundred word vocabulary and a face that moves as it talks. Planned for introduction in late 1984, additions may include a fire and burglar alarm, vacuuming capabilities, an arm and hand, a drink tray and the ability to program the robot to navigate around obstacles.

Mobile robots have also found applications in schools. NUTRO was created by Hoffman-LaRoche Inc. in response to a growing demand for accurate nutrition information (68). This robot presents nutrition information in an interesting way and generates excitement in the classroom. Another classroom robot, LEACHIM, acts as a teacher's aide (68). Along with having a complete history of each student in memory, the robot asks students questions for which they are expected to provide an answer through fact-finding and research. The advantage of using personal robots in schools is two-fold: (1) interest is stimulated in a particular subject area through robotic presentation and (2) students are kept occupied in an interesting and educational activity, leaving the teacher free to work with individual students (68).

A more serious application of the mobile robot is "Denny", a four-foot, four-hundred pound robot from Denning Mobile Robotics Inc. (70). With the ability to feel its way along hallways and detect the presence of humans with infrared and ultrasonic sensors and ammonia "sniffers", "Denny" is planned for use as a roving guard robot in prisions, replacing the functions of human guards that are boring and dangerous. Waterproof, bulletproof and able to withstand hard knocks, the guard robot is designed to get verbal response, by asking a question or stating a warning, to verify the presence of intruders. This information will then be relayed to human security personnel in a control room for appropriate action.

A remote-controlled mobile robotic device has been used by G.P.U. Nuclear Corporation to decontaminate Three Mile Island (71). Walls and floors of the contaminated areas are sprayed with one-hundred fifty degree water at pressures of up to four thousand pounds per square inch. Another smaller vehicle was used in 1982 to inspect photographically and radiologically the contaminated areas.

Though the list goes on of personal robots on the market, Odetics Inc. of Anaheim, California, has just released Odex I, an experimental mobile robot designed for industrial applications (72, 73). Not a wheeled or track vehicle, Odex I walks on six legs and weighs three-hundred seventy pounds, with each leg capable of lifting up to four hundred pounds. Built without specific customer requirements or applications, Odex I was designed to be a multi-functional unit that could literally walk away from the factory floor and perform anywhere (72). In the development of Odex I, the company identified six highly desirable characteristics to be incorporated in the robot's design: (1) mobility/walking, (2) profile changing, (3) agility/maneuverability, (4) strength, (5) stability and (6) self-contained power. Plans for future models include (1) the ability to be autonomous, receiving only very general orders, (2) vital mechanisms and electronics sealed against environmental elements, (3) the ability to proceed to an ordered position by picking and navigating its own route, (4) accurate vision systems and (5) tactile sensors (72). With a goal of identifying and penetrating a large market for mobile robots, application possibilities for Odex I exist in forestry; agriculture; construction; land, sea and space exploration; security; surveillance; material handling; military and others (73).

According to two studies by SRI International (74), nearly one hundred thousand mobile robots could be used in today's marketplace. Up to now, the use of mobile robots has been limited to private security surveillance, bomb disposal for law enforcement and hose transportation for fire fighting. Other industries with potential applicaions include mining, oil exploration and production, cargo handling and storage, commercial nuclear, medicine, fire fighting and prevention, commercial surveillance, law enforcement and utilities (74). Agriculture alone could use in excess of twenty thousand mobile robots for irrigation, harvesting, cultivating, planting, spraying and field inspection.

The list could continue endlessly with industries and their potential applications for robots. With significant labor and materials cost savings and improved quality control repeatedly proven with the implementation of robotics, it is time for the food industry to take a serious look at applications within the field.

METHODOLOGY

The food systems industry is one partially composed of highly repetitive and tedious job functions. Robots built and specifically suited for this type of job, are being successfully utilized in many manufacturing settings. It was appropriate, therefore, to investigate the feasibility and desirability of implementing robots in food industries.

The purpose of this study was to determine potential job functions that could be implemented with robots in the food systems industry. The research objectives include (1) to isolate job functions in food systems that should be implemented with robots, (2) to identify job functions that robot manufacturers believe robots are technologically capable of performing in the food industry, (3) to compare job functions that are most desired by food systems with those that are technologically available from robot manufacturers and (4) to identify characteristics of professionals who are evaluating job functions of robots in food systems. An additional outcome of the study was to stimulate professionals into thinking about the use of robots in food systems.

Survey Design

The data collection was accomplished through the use of a survey questionaire, Appendix A, page 112. The survey, formatted using the methods of Dillman (75), was developed and mailed nationwide to the target population of directors and managers of large hospitals, primary/secondary school and university food-service, and food processing and robot manufacturing facilities. It consisted of two parts; (1) job function applications for robots and (2) demographic data. In part I, job functions were categorized into general areas of application with further specification of job functions in each category. These categories were developed based on personal experience and knowledge of the field and through consultation with other experts in the food and robot industries. The major job function categories included receiving and storage, sanitation, food production, food service, food distribution, related job functions, education and entertainment. Additional space was allocated at the end of each category to provide respondents an opportunity to identify other applications not already listed.

Part II of the survey consisted of demographic data and a section for comments. Personal information regarding age, sex, job title, work experience, educational background and computer usage in the facility was collected to compare responses with selected demographic data. Provisions were made for comments and requesting of results after completion of the questionnaire.

In addition to the survey, cover letters, Appendix A, pages 117, 118, 119, utilizing the construction methods of Dillman (75), were included to introduce the purpose and importance of the research. A brief description of robot terminology and directions for filling out the survey were provided and confidentiality of responses was assured.

Population Description

The sample population to receive the survey was divided into three groups. These were (1) foodservice industry, including hospitals, schools and universities, (2) food processors and (3) robot manufacturers. Due to financial limitations and the belief that larger institutions may have greater need for robotic applications, each population group was stratified, based on a predetermined cut-off point, to include only large volume producers. Because there was no prior estimate of the population variance, consultation with Oregon State University statistical staff determined that a population size of two-hundred fifty for each group was necessary.

Individual participants in each population group were selected through a systematic sample with a random start (76). Due to the large population from which each of the sample populations had to be drawn, the total population was estimated in the following manner. Each entry that met the predetermined stratification cut-off point was counted on a randomly selected ten percent of the total available pages from each population references source. After calculating the average number of qualified entries per page counted, the total estimated population meeting the stratification requirements was determined by multiplying this average by the total number of pages in the reference source.

The two-hundred fifty participants of the foodservice sector included hospitals, universities and primary/secondary schools. Therefore, eight-four hospitals, eight-three universities and eight-three primary/secondary schools were selected. Hospitals were stratified to include only those institutions of six hundred or more beds and were sampled from the American Hospital Association Guide to Health Care Field (77). Universities were stratified to include institutions with enrollments of fifteen thousand or more and were sampled from Barron's Profiles of American Colleges (78). Primary/secondary schools were stratified to include school districts with county population of sixty thousand or more and were sampled from Patterson's American Education (79).

The individual participants for hospitals, universities and primary/secondary schools were selected by dividing the total estimated population of each by eighty-four, eight-three and eighty-three, respectively, resulting in a variable value of X. Two random numbers were obtained to determine the page number of the population reference source and the entry number on that page with which to begin the systematic sample. Thereafter, every Xth qualifying entry was selected as a recipient for the survey questionaire. In the case where a second pass through the reference source listing was required, the next qualifying entry was chosen when the Xth entry had already been included in the sample population.

The sample population from the food processing industry included two-hundred and fifty facilities selected, using the same method as described for the foodservice sector, from the Thomas Register of American Manufacturers (80). The sample population was stratified to include only those industries with five million dollars or more in net tangible assets. An estimate of the total population of robot manufacturers from the Thomas Register of American Manufacturers (81) resulted in only two hundred and fifty facilities. Therefore, any industry with greater than one million dollars in net tangible assets was included in the sample population for robot manufacturers. This resulted in an actual population of one-hundred sixty-seven.

Pilot Study

A pilot study was conducted to determine whether the survey questionnaire was clear in format and content, quick and easy to complete and accurate in its information. The survey questionnaire and an accompanying cover letter, Appendix A, page 116, were mailed to participants performing a management role in their facility. Two each of hospitals, universities, primary/secondary schools, food processors and robot manufacturers were involved. The pilot study participants were not included in the results for the actual study. Response from the pilot study indicated that the survey was adequate in its current form with minor editing modifications.

Provisions were made to allow for requests for survey results and clarifications made in directions for completing the survey.

Instrument Administration

Three separate mailings of the survey questionnaire and accompanying cover letters were conducted in an effort to achieve the greatest possible return rate. The first mailing was sent on February 2, 1984. With an initial low rate of return, the second mailing was sent to all non-respondents on February 21, 1984. The third and final mailing was sent on March 8, 1984. In an effort to determine the reasons behind a continuing low return rate, the accompanying cover letter requested explanations for difficulties experienced in completing the survey if the respondent was unable to complete the survey in its entirety.

Statistical Analysis

Several comparisons were made with results derived from the survey questionnaire with regard to job functions desired for robotic applications. As the survey results will be in the form of frequencies, the chi square test for significance ($P \leq .05$) was used throughout the analysis of survey results.

A total of sixty-four job function applications questions were included in the survey. To identify the more likely applications for further analysis, the frequency of yes responses of both the food industry (hospitals, universities, primary/secondary schools and food processors) and robot manufacturers was used. The chi square test of significance was used for comparison of responses on the identified applications between the food industry and the robot manufacturers. Similar analyses was done between foodservice and food processors. Analysis of the affect of age, sex, work experience, computer use and level of education on responses to the identified job function applications was done. Using frequencies and chi square test of significance, comparisons were made between the food industry and robot manufacturers and between foodservice and food processors.

RESULTS AND DISCUSSION

The purpose of this study was to determine potential job functions in the food industry that should be implemented with robots. A survey questionnaire listing job functions in the food industry was mailed nationwide to management personnel in hospitals, universities, primary/secondary schools, food processors and robot manufacturers for their assessment. In addition, demographic data was collected to ascertain their effect on a manager's evaluation of potential robotics applications for the food industry.

Of six-hundred sixty-seven surveys mailed, three-hundred twenty-five were returned. With two follow-up mailings, this resulted in forty-nine percent response rate of the survey. Of the three-hundred twenty-five returned surveys, two hundred seventy-five were valid for use in data analysis, resulting in a usable response rate of forty-one percent. Figure 1 (page 50) illustrates the number of respondents from each population group and the percent return rate within each group. For example two-hundred fifty surveys were mailed to foodservice management personnel. One-hundred fifty-seven responded, representing sixty-three percent of the two-hundred fifty mailed. Statistical calculations were done using the computerized Statistical Package for the Social Services (SPSS)(82).

There were sixty-four specific job function application questions. The goal was to analyze in-depth only those job functions that showed the lowest level of disagreement as to potential

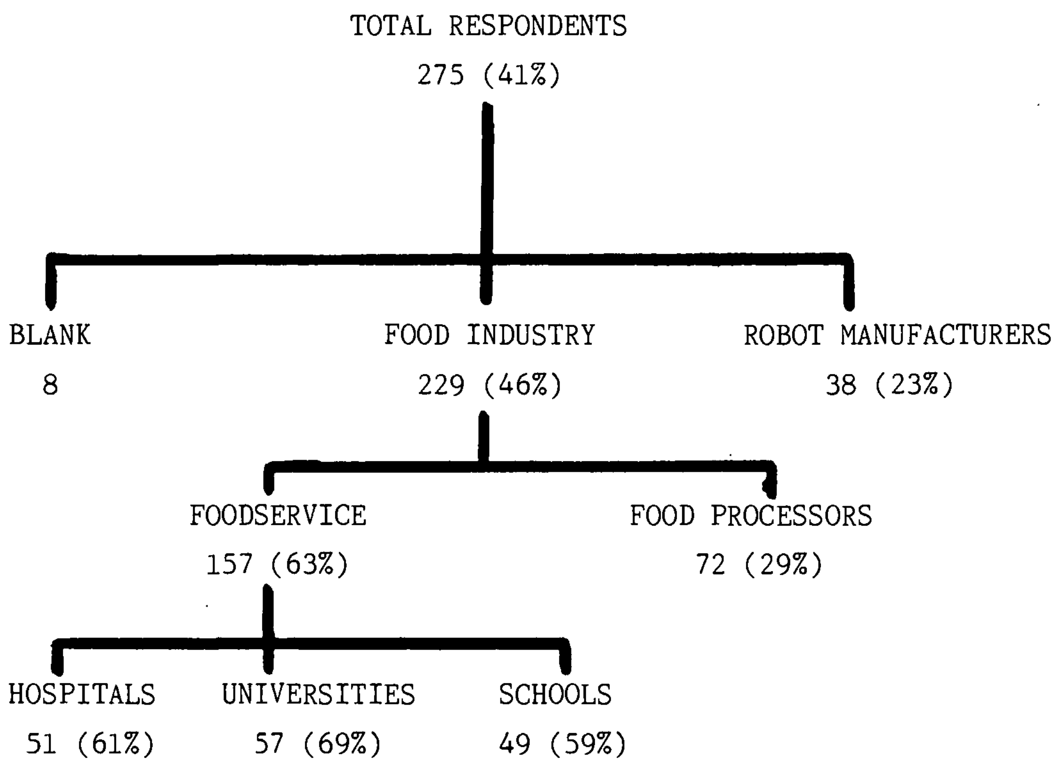

Figure 1

Distribution of Survey Respondents;
Total Returns and Respective Percentage
per Population Group

robotics implementation between the food industry and the robot manufacturers. Therefore, initial analysis was done on all questions to select the top job functions indicated for robotics application. This analysis was done through the use of chi square $(P > .05)$ and frequencies for the entire food industry and the robot manufacturers. The chi square calculations were statistically corrected on any job function resulting in a two by two table. Available response choices to the job functions were yes, no or don't know. As don't know answers or non-response provide no useful information, these responses were omitted from the statistical analyses. This resulted in chi squares and frequencies representing only yes or no responses. The total percentage of yes responses from all respondents for the sixty-four job functions are listed, in addition to the significance value calculated using chi square, in Appendix B, Table 1, page 121. Job functions marked with an asterisk are those identified as feasible for robotics application in the food industry.

Two decision rules were used to identify job functions with the least difference in opinion between the food industry and the robot manufacturers. The first rule was to look at job functions with a total of seventy-five percent or greater yes responses. Since the goal of the study was to determine job functions that both industries did not disagree upon, the second decision rule was to look at job functions with $P > .05$. The higher the significance value, the more the two groups did not disagree. This process resulted in the identification of sixteen job functions which had seventy-five or greater percent yes responses and $P > .05$ (Table 1, page 52).

Table 1

SIXTEEN JOB FUNCTIONS IDENTIFIED FOR ROBOTICS APPLICATION
BY FOOD INDUSTRY AND ROBOT MANUFACTURERS;
PERCENT YES RESPONSES, SIGNIFICANCE

Job Function	Yes Responses (%)	Significance
Loading/unloading (receiving & storage)	79.0	.26
Lifting and stocking shelves	77.9	.93
Steam clean carts, shelves, racks	80.8	.06
Loading/unloading glass racks (dishmachine)	77.0	.61
Loading/unloading dishes (dishmachine)	76.6	.20
Chopping/dicing with equipment	76.4	.38
Slicing with equipment	77.6	.96
Stirring functions	79.9	1.00
Filling operations (individual cartons)	89.3	1.00
Filling cases	90.1	.55
Sorting/picking operations	77.0	.97
Feeding equipment	88.4	1.00
Metering of ingredients	75.9	.42
Loading delivery cart (trayline)	77.2	1.00
Delivery of supplies from inventory to production	86.9	.80
Delivery of prepared products to storage or service area	83.7	.68

Results Between Food Industry and Robot Manufacturers

Response of the food industry (hospitals, universities, primary/secondary schools and food processors) for the sixteen identified job function applications were compared with the robot manufacturers (Table 2, page 54). Responses were recorded in categories of yes, no, don't know or blank for no response. The total number of respondents in each category was listed in addition to the percent frequency per category and significance levels. Seven job functions, showed very little disagreement ($P = .93$ to 1.00) between the two industries. These seven job functions were (1) filling operations for individual cartons, (2) stirring functions, (3) loading food delivery cart, (4) sorting and picking operations, (5) slicing with equipment, (6) lifting/stocking shelves in receiving and storage and (7) feeding equipment.

The decision on which job function is the most desirable for robotics implementation is simply a matter of the criteria used. More importance could be placed on the significance level to select job functions or more importance could be placed on the total percent of yes responses with $P > .05$. The greater the percentage of yes responses, the more desirable the job function for implementation with robots. The difference between the two methods would be in the level of agreement between food industry and robot manufacturing. For example, filling operations for individual cartons had 89.4 percent yes responses and $P = 1.00$ while filling cases had 89.4 percent yes responses and $P = .55$. In this case,

Table 2

SIXTEEN IDENTIFIED JOB FUNCTIONS FOR ROBOTIC APPLICATION BY FOOD INDUSTRY AND ROBOT MANUFACTURERS; OBSERVATIONS AND PERCENT RESPONSES FOR YES, NO, DON'T KNOW AND BLANK, SIGNIFICANCE

		Food Industry N = 229				Robot Manufacturers N = 38			
Job Function Significance		Yes	No	Don't Know	Blank	Yes	No	Don't Know	Blank
Loading/unloading (receiving & storage) P = .26	Obs.	160	45	17	7	30	4	3	1
	%	78.0	22.0			88.2	11.8		
Lifting and stocking shelves P = .93	Obs.	151	42	28	8	25	8	4	1
	%	78.2	21.8			75.8	24.2		
Steam clean carts, shelves, racks P = .06	Obs.	170	35	20	4	23	11	3	1
	%	82.9	17.1			67.6	32.4		
Loading/unloading glass racks (dishmachine) P = .61	Obs.	151	43	29	6	23	9	5	1
	%	77.8	22.2			71.9	28.1		
Loading/unloading dishes (dishmachine) P = .20	Obs.	148	41	28	12	19	10	5	4
	%	78.3	21.7			65.5	34.5		
Chopping/dicing with equipment P = .38	Obs.	146	42	31	10	22	10	6	0
	%	77.7	22.3			68.8	31.3		

Table 2 Continued

Job Function Significance		Food Industry N = 229				Robot Manufacturers N = 38			
		Yes	No	Don't Know	Blank	Yes	No	Don't Know	Blank
Slicing with equipment	Obs.	152	43	24	10	25	8	4	1
P = .96	%	77.9	22.1			75.8	24.2		
Stirring functions	Obs.	161	40	18	10	26	7	7	1
P = 1.00	%	80.1	19.9			78.8	21.2		
Filling operations (individual cartons)	Obs.	185	22	13	9	31	4	2	1
P = 1.00	%	89.4	10.6			88.6	11.4		
Filling cases	Obs.	185	22	14	8	33	2	2	1
P = .55	%	89.4	10.6			94.3	5.7		
Sorting/picking operations	Obs.	148	45	25	11	26	7	5	0
P = .97	%	76.7	23.3			78.8	21.2		
Feeding equipment	Obs.	176	23	21	9	29	4	5	0
P = 1.00	%	88.4	11.6			87.9	12.1		
Metering of ingredients	Obs.	145	43	26	15	22	10	6	0
P = .42	%	77.1	22.9			68.8	31.3		
Loading delivery cart (trayline)	Obs.	136	40	41	12	23	7	7	1
P = 1.00	%	77.3	22.7			76.7	23.3		

Table 2 Continued

Job Function Significance		Food Industry N = 229 Yes	No	Don't Know	Blank	Robot Manufacturers N = 38 Yes	No	Don't Know	Blank
Delivery of supplies from inventory to production P = .80	Obs.	173	25	22	9	26	5	6	1
	%	87.4	12.6			83.9	16.1		
Delivery of prepared products to storage or service area P = .68	Obs.	162	30	28	9	23	6	8	1
	%	84.4	15.6			79.3	20.7		

it appears obvious that filling operations for individual cartons represented a greater degree of agreement between industries and is the better choice. However, in comparing filling cases (89.4 percent yes responses, P = .55) with slicing equipment (77.9 percent yes responses, P = .96), it is not as apparent as to which job function is the most favored. Therefore, the decision as to which job function to implement must be based on individual needs and desires of the facility. The survey results simply reduce the number of choices and act to guide the direction of those choices toward areas of feasibility with regard to robot capabilities.

In looking at don't know and blank responses (which indicate a don't know reaction), ten to twenty-three percent of the total number of respondents in food industry answered in one of these two categories for the various job functions. In comparison, results ranged from ten to twenty-six percent for don't know or blank responses of the total number of respondents in robot manufacturing. This may lead to the conclusion that many individuals were not familiar with either food industry or robots and, therefore, were unable to make a decision regarding the feasibility of robots for the specific job functions.

The second purpose of the research was to look at various demographic data of respondents. Personal information on age, years of work experience, sex, computer usage and level of education was collected for purposes of identifying characteristics of survey respondents.

Age

There was no significant difference (P = .45) in the ages of respondents between the food industry and robot manufacturers (Figure 2, page 59). In the food industry, 22.1 percent of the respondents were in the twenty-five to thirty-four age category, 27.9 percent in the thirty-five to forty-four age category and 31.9 percent in the forty-five to fifty-four age category. This resulted in a total of 81.9 percent of the respondents falling between the ages of twenty-five and fifty-four years. The data showed the number of respondents from food industry increased as the age level increased, to age fifty-four. In contrast, the robot manufacturers had 34.2 percent of the respondents in the twenty-five to thirty-four age category, 31.6 percent in the thirty-five to forty-four age category and 21.1 percent in the forty-five to fifty-four age category. This resulted in a total of 87.7 percent of the respondents from robot manufacturing between the ages of twenty-five and fifty-four. The number of respondents in robot manufacturing declined as the age level increased. Less than three percent of the respondents in both industries were under twenty-five years of age, with the robot manufacturers having twice as many respondents in that age category (2.6 percent) than the food industry (1.3 percent). From age fifty-five to sixty-four, the number of respondents fell to 15.9 and 10.5 for food industry and robot

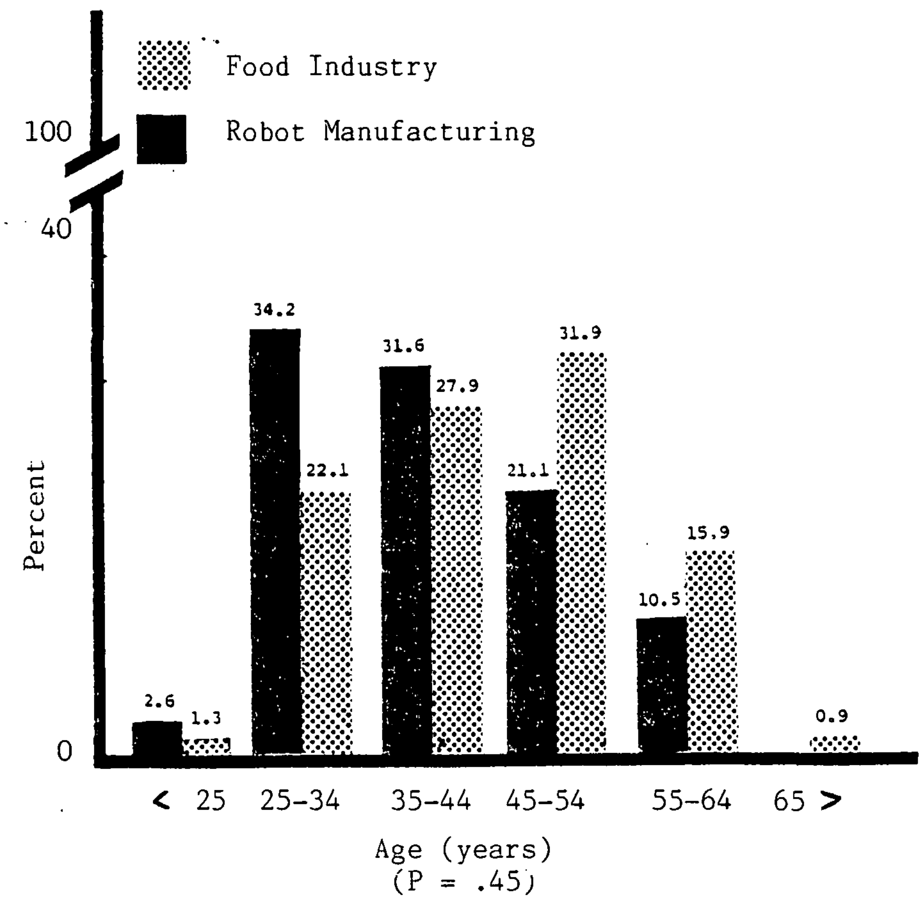

Figure 2

Age of Respondents in Food Industry and Robot Manufacturing; Percent Distribution, Significance manufacturers, respectively. Only the food industry had respondents in the over sixty-five age catetory at 0.9 percent.

Years in Managerial Experience

In assessing years of managerial experience, there was a significant difference (P = .00) between the food industry and robot manufacturers (Figure 3, page 61). Managerial experience in the food industry showed 0.4 percent of the respondents with less than one year of experience, 1.3 percent with one to three years of experience and 9.3 percent with four to six years of experience. This resulted in only eleven percent of the respondents in the food industry having less than seven years experience. In comparison, 7.9 percent of the respondents in robot manufacturing had less than one year of experience, 13.2 percent with one to three years of experience and 26.3 percent with four to six years of experience. This resulted 47.4 percent of the robot manufacturers with less than seven years experience. Both the food industry and robot manufacturers showed a decrease in the number of respondents in the seven to ten year category to 13.7 and 5.3 percent respectively.

In the eleven to twenty years of experience category, the food industry had 33.0 percent of the respondents with 42.3 percent having greater than twenty years experience. In the same two categories, the robot manufacturers had 26.3 percent and 21.1 percent, respectively. Combining these two categories, 75.3 percent of food industry respondents had over eleven years of work experience while 47.4 percent of the robot manufacturers were in the

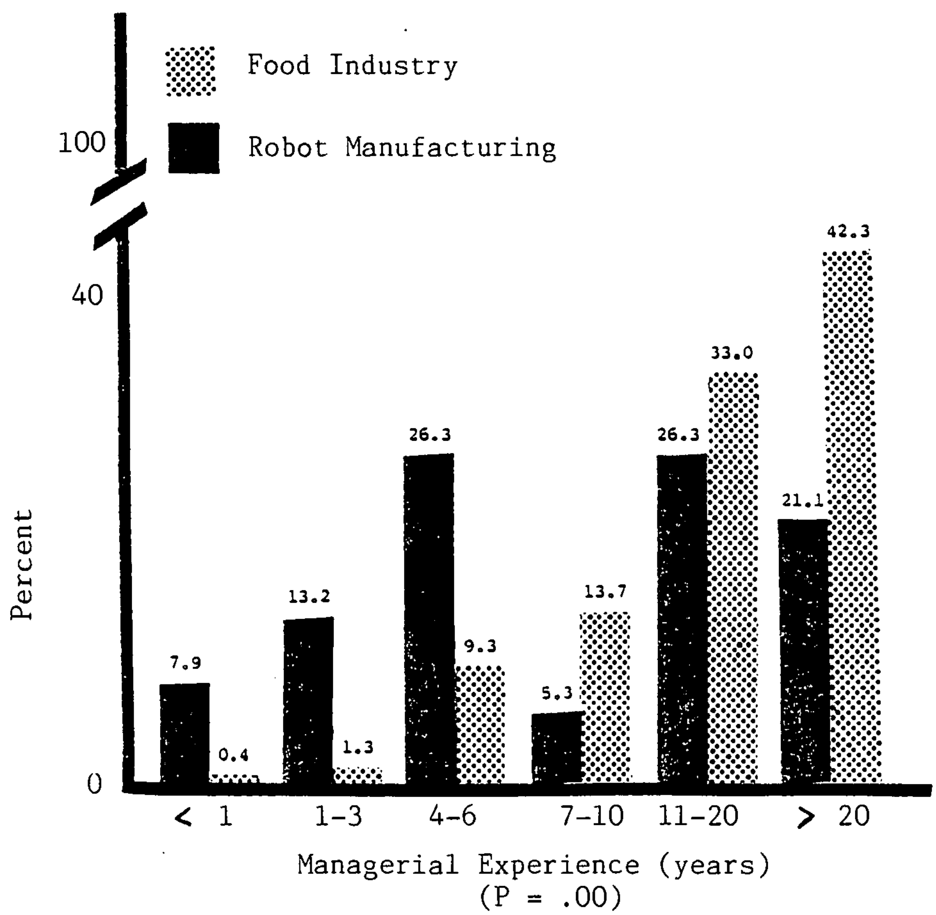

Figure 3

Years of Managerial Experience of Respondents in Food Industry and Robot Manufacturing; Percent Distribution, Significance upper two categories. The robot industry was more evenly split with 47.4 percent having eleven years of experience or more and 52.7 percent having less than eleven years of experience.

Sex

In analyzing the ratio of males to females (Figure 4, page 63), there was a significant difference (P = .00) between the food industry and robot manufacturers. In the food industry, 64.3 percent of the respondents were male while 94.7 percent of the robot manufacturers were male.

Computer Usage

In the food industry, usage of computers in facilities was 69.4 percent (Figure 5, page 64). However, less than half that many (31.7 percent) of the respondents utilized computers for personal use. In contrast, 85.7 percent of the robot manufacturers utilized computers in facilities, with 78.9 percent also using computers for personal applications. In comparing the two industries, there was no significant difference (P = .07) in usage of computers in facilities. In personal usage of computers by survey respondents, however, there was a significant difference (P = .00). Robot manufacturers utilized personal computers almost two and one-half times more than food industry.

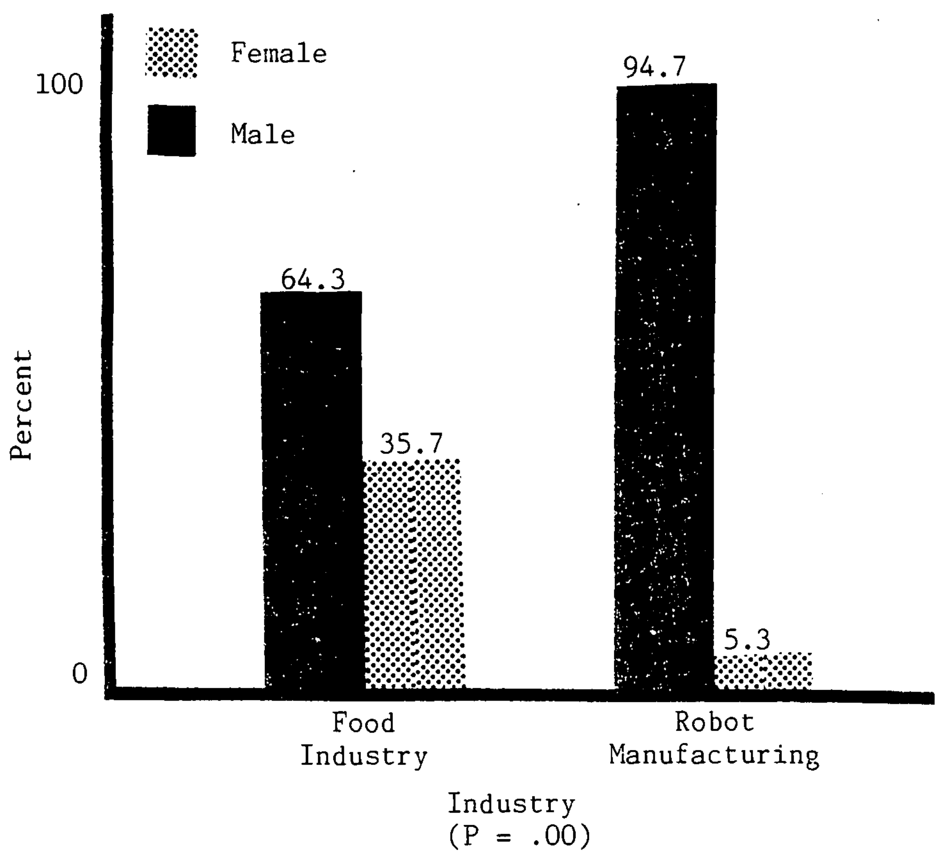

Figure 4

Ratio of Males to Females in Food Industry and Robot Manufacturing; Percent Distribution Significance

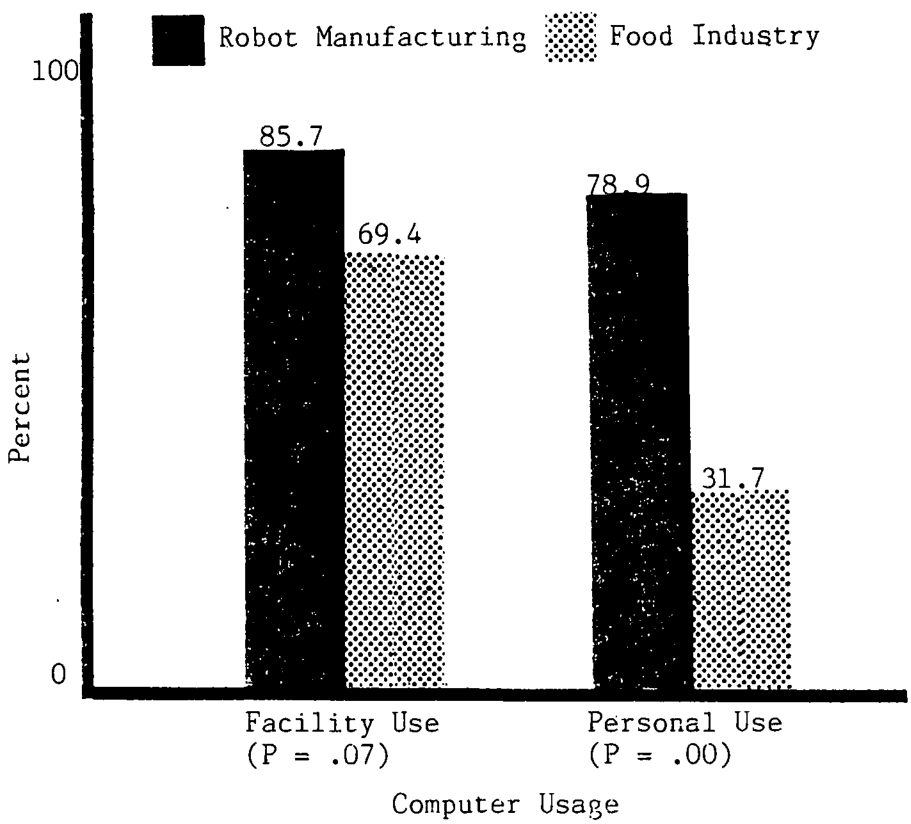

Figure 5

Computer Usage of Respondents in Food Industry and Robot Manufacturing for Facility and Personal Use; Percent Distribution, Significance

Level of Education

There was no significant difference (P = .70) in the level of education between food industry and robot manufacturing respondents (Figure 6, page 66). All respondents had completed, at least, grade school. In the food industry, 0.4 percent of the respondents had only some high school education while all robot manufacturers had received at least a high school degree. For both industries, the data represented an increase in the number of respondents with a progressively higher degree, up through bachelor's degree for the food industry and some graduate work for robot manufacturers. Of the food industry respondents, 31.3 percent had a bachelor's degree, 21.1 percent had completed some graduate work and 23.8 percent had received a master's degree. In comparison, 21.1 percent of the robot manufacturers had only completed a bachelor's degree, 31.6 percent had completed some graduate work and 18.4 percent had received a master's degree. Twice the number of robot manufacturers (2.6 percent) had received a doctorate degree as respondents from the food industry (1.3 percent). Only in the food industry did respondents have other types of education. These included trade school, internship, master's equivalency and miscellaneous courses. The majority of respondents from both the food industry (77.9 percent) and robot manufacturing (73.7 percent) had received a bachelor's degree or greater.

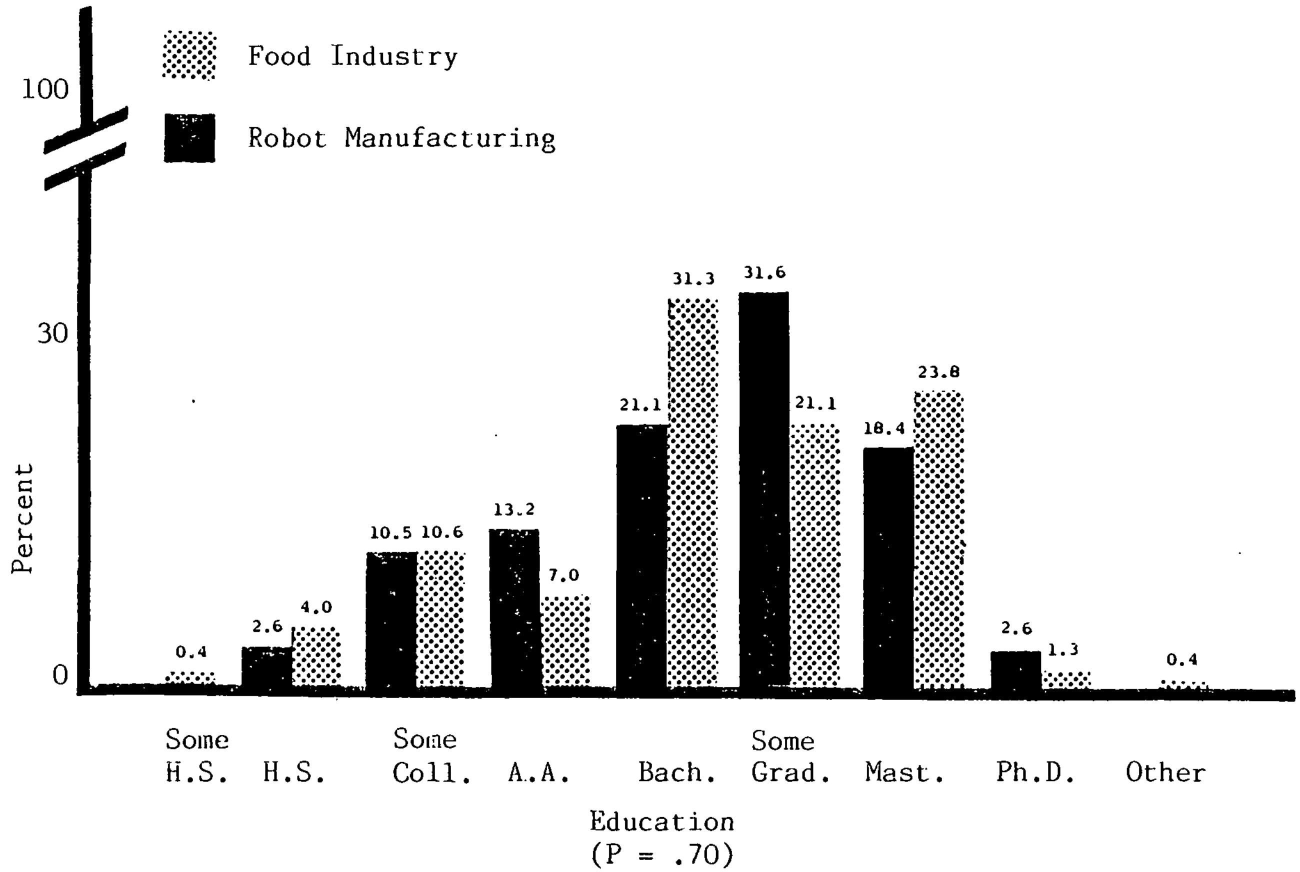

Figure 6

Level of Education of Respondents in Food Industry and Robot Manufacturing; Percent Distribution, Significance

Results Between Foodservice and Food Processing

Analysis was done on the sixteen job functions identified as most feasible for robotics implementation in food industry to determine any difference in response between foodservice and food processing (Table 3, page 68). Twelve job functions of the sixteen did not show significant disagreement ($P > .05$) between the two sectors of the food industry. Two job functions had very high level of agreement; (1) steam cleaning carts, shelves and racks and (2) sorting and picking operations. Four job functions identified by an asterisk in Table 3, showed a significant difference ($P > .05$) in the percentage of yes responses between foodservice and food processing. These job functions were (1) loading/unloading in receiving and storage, (2) chopping/dicing with equipment, (3) feeding equipment and (4) metering ingredients.

The goals and purposes of foodservice versus food processing differ, which suggest a difference in priority placed on job functions. Foodservice is directed toward production and service of food while food processing is directed toward processing of food prior to production and service of recipe items. Therefore, it is logical that there would be a significant difference in responses of foodservice and food processing toward feeding equipment ($P = .02$) and metering of ingredients ($P = .04$). With 96.9 percent and 86.9 percent, respectively, of food processors responding positively these are typical food processing functions done on a large scale basis. In comparison, loading/unloading in

Table 3

RESPONSES OF FOODSERVICE AND FOOD PROCESSORS FOR SIXTEEN IDENTIFIED JOB FUNCTIONS FOR ROBOTICS APPLICATION; SAMPLE SIZE, NUMBER AND PERCENT YES RESPONSES, SIGNIFICANCE

	Foodservice N = 157		Food Proc. N = 72	
Job Function Significance	Yes Responses (Obs)	(%)	Yes Responses (Obs)	(%)
Loading/unloading (receiving & storage) P = .00	123	83.7*	37	63.8
Lifting and stocking shelves P = .12	114	81.4	37	69.8
Steam clean carts, shelves, racks P = 1.00	123	83.1	47	82.5
Loading/unloading glass racks (dishmachine) P = .18	116	80.6	35	70.0
Loading/unloading dishes (dishmachine) P = .73	111	79.3	37	75.5
Chopping/dicing with equipment P = .01	97	72.4*	49	90.7
Slicing with equipment P = .09	105	74.5	47	87.0
Stirring functions P = .09	108	76.6	53	88.3
Filling operations (individual cartons) P = .49	125	88.0	60	92.3
Filling cases P = .21	122	87.1	63	94.0
Sorting/picking operations P = 1.00	100	76.9	48	76.2
Feeding equipment P = .02	113	84.3*	63	96.9
Metering of ingredients P = .04	92	72.4*	53	86.9

Table 3 Continued

Job Function Significance	Foodservice N = 157 Yes Responses (Obs)	(%)	Food Proc. N = 72 Yes Responses (Obs)	(%)
Loading delivery cart (trayline) P = .20	100	74.6	36	85.7
Delivery of supplies from inventory to production P = .79	123	86.6	50	89.3
Delivery of prepared products to storage or service area P = .58	113	83.1	49	87.5

* Significance difference in responses

receiving and storage (P = .00) is a job function performed for many and various items in foodservice. It was identified as valuable for robotics implementation with 83.7 percent of foodservice respondents answering positively. Food processors (64.8 percent yes responses) saw less need for this job function, as receiving of foods would tend to be large volume and on a limited delivery schedule.

Chopping/dicing with equipment also showed a significant difference (P = .01) in responses between foodservice and food processing. Of foodservice, 72.4 percent indicated yes while 90.7 percent of the food processors responded positively to this job function. Though it is easy to see that food processors might do a large volume of chopping and dicing, foodservice also chops and dices many food items. The difference may be in the length of time spent chopping and dicing in food processing versus a lesser period of time in foodservice.

The difference in responses between foodservice and food processing varied for the remaining ten of the sixteen identified job functions (P = .09 to P = .79). The percent of yes responses from foodservice ranged from 88.0 for filling operations for individual cartons (P = .49) to 74.5 for slicing with equipment (P = .09). In comparison, the percentage of yes responses from food processors ranged from 94.0 for filling cases to 69.8 for lifting and stocking shelves. The smaller range of responses of foodservice compared to food processing may be accounted for by the increased variety of job functions in foodservice. Food processors tend to be more specialized in processes.

Age

In analyzing demographic data between foodservice and food processing, there was no significant difference (P = .25) in the ages of respondents between the two groups (Figure 7, page 72). In the foodservice fraction, 25.3 percent of the respondents were in the twenty-five to thirty-four age category, 27.9 percent in the thirty-five to forty-four age category and 27.3 percent in the forty-five to fifty-four age category. This resulted in 80.5 percent of the respondents falling between the ages of twenty-five and fifty-four. In food processing, 15.3 percent of the respondents were in the twenty-five to thirty-four age category, 27.8 percent in the thirty-five to forty-four age category and 41.7 percent in the forty-five to fifty-four age category. This resulted in 84.8 percent of the food processors falling between ages twenty-five and fifty-four. In all but two categories, the percent from foodservice or food processing were essentially the same. Foodservice had ten percent more respondents in the twenty-five to thirty-four age category where food processing had 14.4 percent more in the forty-five to fifty-four category.

Years of Managerial Experience

Years of managerial experience in each category was essentially the same between foodservice and food processing (Figure 8, page 73).

Figure 7

Age of Respondents in Foodservice and Food Processing; Percent Distribution, Significance

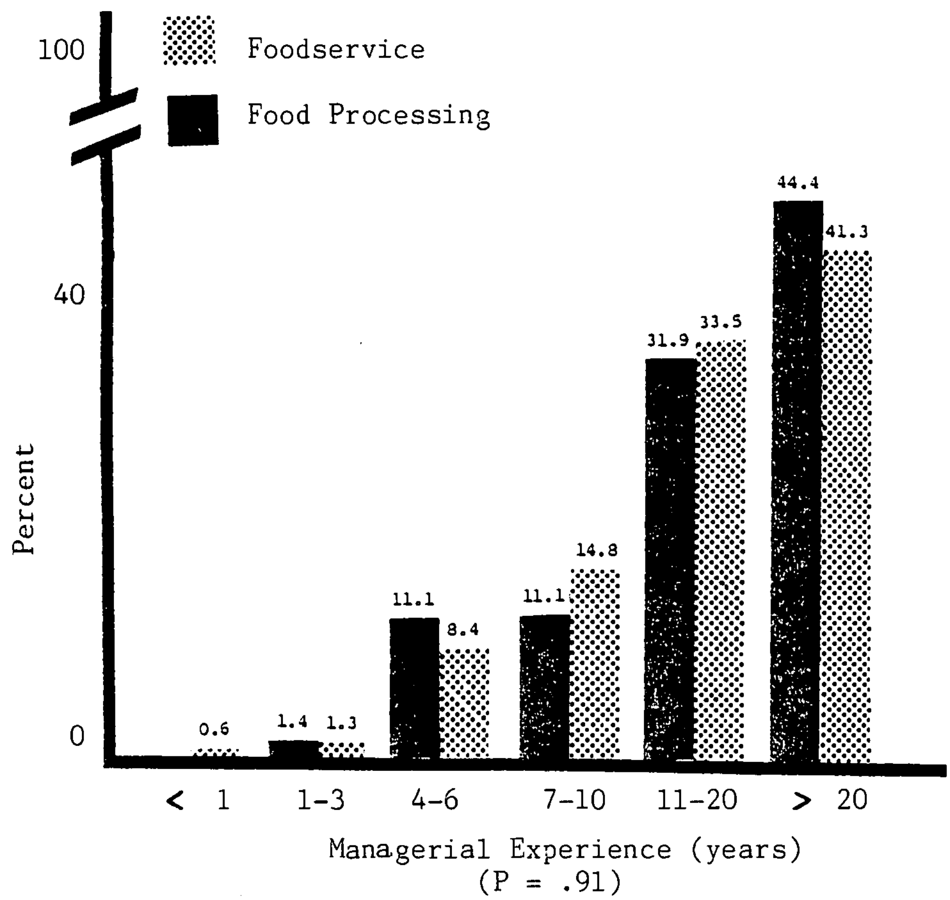

Figure 8

Years of Managerial Experience of Respondents in Foodservice and Food Processing; Percent Distribution, Significance

In both fractions of the food industry, respondents had increasingly more experience as the length of the service period increased, with no significant difference between groups (P = .91). Of the foodservice respondents, 33.5 percent had between eleven and twenty years of managerial work experience and 41.3 percent had over twenty years of experience. In comparison, 31.9 percent of the food processors had between eleven and twenty years of managerial work experience and 44.4 percent had over twenty years of experience. A total of 76.3 percent of the food processors had greater than eleven years managerial experience.

Sex

There was a significant difference (P = .00) in the ratio of males to females between foodservice and food processing (Figure 9, page 75). The foodservice sector of the food industry had exactly fifty percent in each category. In contrast, 94.4 percent of the food processors were male.

Computer Usage

Figure 10 (page 76), shows the ratio of respondents in the foodservice and food processing industries using computers in facilities and for personal use. There was a significant difference between foodservice respondents utilizing computers in the facility (64.9 percent) and food processors using computers in the facility (78.9 percent). Personal computer usage by respondents was reduced by approximately fifty percent from facility use for both groups

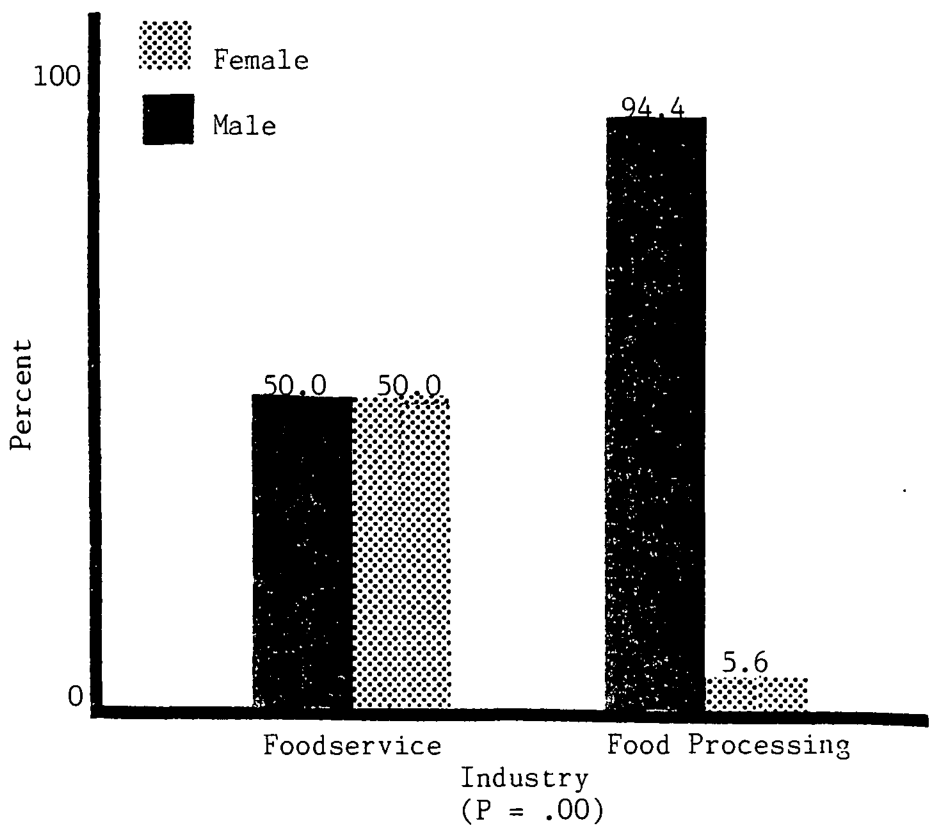

Figure 9

Ratio of Males to Females in Foodservice and Food Processing; Percent Distribution, Significance

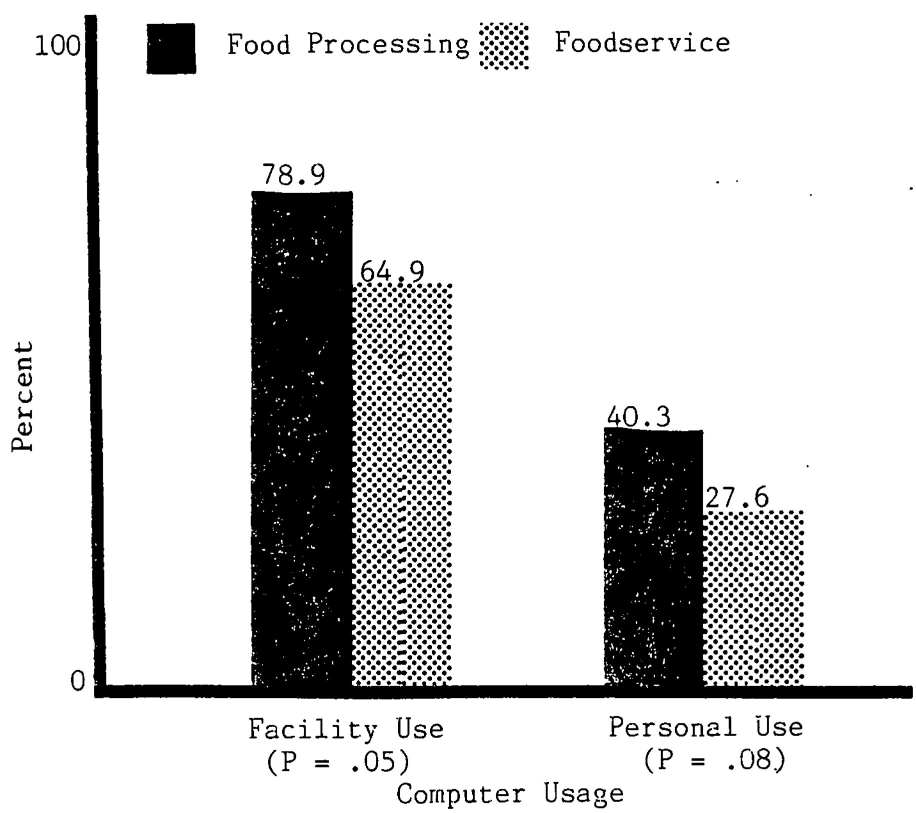

Figure 10

Computer Usage of Respondents in Foodservice and Food Processing for Facility and Personal Use; Percent Distribution, Significance to 27.6 percent and 40.3 percent, respectively. There was no significant difference (P = .08) in personal computer usage between foodservice and food processing.

Level of Education

There was no significant difference (P = .30) between foodservice and food processing respondents in the level of education (Figure 11, page 78). All respondents in both groups completed, at least, grade school. In food processing, 1.4 percent of the respondents had only some high school while all foodservice respondents received a high school degree. For both industries, the majority of respondents had received a bachelor's degree or greater. In foodservice, 29.0 percent of the respondents had received a bachelor's degree, 25.2 percent had completed some graduate study and 25.2 percent had received a master's degree. In comparison, 36.1 percent of the respondents from food processing had received a bachelor's degree, 12.5 percent had completed some graduate study and 20.8 percent had received a master's degree. Essentially the same percentage of respondents, 1.3 percent in foodservice and 1.4 percent in food processing, had received a doctorate degree. Only the foodservice sector of the food industry indicated other levels of education, with 0.6 percent of the respondents marking that category. A total of 81.3 percent of the respondents in foodservice had completed a bachelor's degree or greater while only 70.8 percent of food processors fell in the same category.

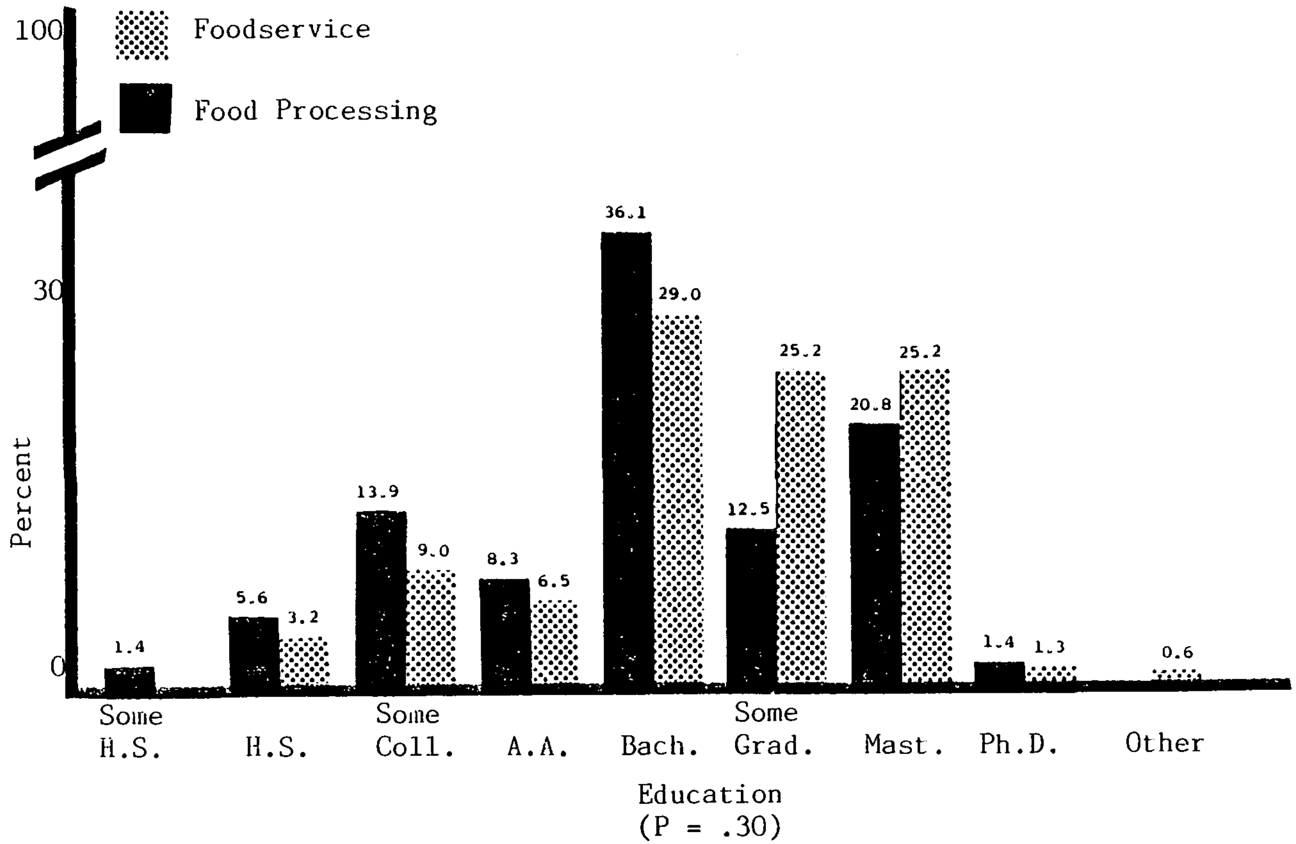

Figure 11

Level of Education of Respondents in Foodservice and Food Processing; Percent Distribution, Significance

Effect of Demographic Data on Responses

Age

Of the sixteen identified job function applications for robotics, only two represented any significant difference between age groups (Table 4, page 80). Marked with an asterisk in the table, these were (1) filling operation for individual cartons and (2) filling cases. However, there were only three respondents in the less than twenty-five age category for both job functions. The percent of respondents answering yes in the less than twenty-five age category was 33.3 percent in only those two job functions showing significant difference. All other job functions had 66.7 percent or greater yes responses in the less than twenty-five age category. The percentage of yes responses in other age categories ranged from 89.7 to 100.0 percent. The fact that there were only three respondents in this category caused the percentage of yes responses to change dramatically, depending on the response of one individual. Had that one individual responded positively, the percentage of yes responses would have increased to 66.7 and would not have been a significant difference.

Years of Managerial Experience

The number of years of managerial experience significantly affected responses between the age categories for three job functions (Table 5, page 83). These were (1) filling operations for individual cartons, (2) filling cases and (3) feeding equipment.

Table 4

AGE CATEGORIES: RESPONSES TO THE SIXTEEN IDENTIFIED JOB FUNCTIONS;
TOTAL NUMBER OF RESPONDENTS ANSWERING YES OR NO BY CATEGORY,
PERCENT YES RESPONSES BY CATEGORY, SIGNIFICANCE

Job Function Significance		Age Categories (in years)					
		Less than 25	25 - 34	35 - 44	45 - 54	55 - 64	65 and Greater
Loading/unloading (receiving & storage) P = .56	Total [a]	3	60	68	74	36	2
	Percent Yes	100.0	83.3	76.5	81.1	72.2	50.0
Lifting and stocking shelves P = .61	Total	3	56	65	70	34	2
	Percent Yes	100.0	73.2	75.4	81.4	82.4	50.0
Steam clean carts, shelves, racks P = .65	Total	3	58	69	75	37	2
	Percent Yes	66.7	82.8	76.8	84.0	75.7	50.0
Loading/unloading glass racks (dishmachine) P = .38	Total	3	54	69	68	34	2
	Percent Yes	66.7	75.9	79.7	82.4	64.7	50.0
Loading/unloading dishes (dishmachine) P = .68	Total	3	54	63	67	33	2
	Percent Yes	100.0	81.5	73.0	74.6	78.8	50.0
Chopping/dicing with equipment P = .70	Total	3	53	66	68	31	2
	Percent Yes	100.0	71.7	75.8	80.9	77.4	100.0
Slicing with equipment P = .62	Total	3	57	66	70	34	2
	Percent Yes	66.7	77.2	72.7	84.3	76.5	100.0

Table 4 Continued

Job Function Significance		Age Categories (in years) Less than 25	25 - 34	35 - 44	45 - 54	55 - 64	65 and Greater
Stirring functions P = .92	Total	3	54	67	75	37	2
	Percent Yes	66.7	81.5	76.1	80.0	81.1	100.0
Filling operations (individual cartons) P = .04	Total	3	59	69	78	36	2
	Percent Yes	* 33.3	89.8	87.0	92.3	91.7	100.0
Filling cases P = .04	Total	3	58	69	78	37	2
	Percent Yes	* 33.3	89.7	91.3	91.0	91.9	100.0
Sorting/picking operations P = .79	Total	3	56	65	72	33	2
	Percent Yes	100.0	76.8	80.0	76.4	72.7	50.0
Feeding equipment P = .14	Total	3	54	64	77	37	2
	Percent Yes	66.7	92.6	82.8	88.3	94.6	50.0
Metering of ingredients P = .10	Total	2	51	64	74	33	2
	Percent Yes	0.0	80.4	71.9	81.1	75.8	50.0
Loading delivery cart P = .67	Total	3	49	60	63	32	2
	Percent Yes	100.0	81.6	73.3	73.0	78.1	50.0
Delivery of supplies from inventory to production P = .36	Total	3	57	68	69	35	2
	Percent Yes	100.0	84.2	83.8	94.2	82.9	100.0

Table 4 Continued

Job Function Significance		Age Categories (in years) Less than 25	25 - 34	35 - 44	45 - 54	55 - 64	65 and Greater
Delivery of prepared products to storage or service area P = .34	Total	3	55	64	67	35	2
	Percent Yes	66.7	85.5	78.1	91.0	80.0	100.0

* Significant difference in responses

[a] Total number of respondents answering yes or no; don't know and non-responses omitted

Table 5

YEARS OF MANAGERIAL EXPERIENCE: RESPONSES TO THE SIXTEEN IDENTIFIED JOB FUNCTIONS; TOTAL NUMBER OF RESPONDENTS ANSWERING YES OR NO BY CATEGORY, PERCENT YES RESPONSES BY CATEGORY, SIGNIFICANCE

Job Function Significance		Years of Managerial Experience					
		Less than 1	1 - 3	4 - 6	7 - 10	11 - 20	Greater than 20
Loading/unloading (receiving & storage) P = .78	Total[a]	4	8	27	31	78	96
	Percent Yes	75.0	100.0	77.8	80.6	79.5	77.1
Lifting and stocking shelves P = .96	Total	4	8	25	28	74	92
	Percent Yes	75.0	87.5	76.0	78.6	75.7	80.4
Steam clean cart, shelves, racks P = .60	Total	4	8	26	30	77	99
	Percent Yes	50.0	75.0	84.6	86.7	80.5	78.8
Loading/unloading glass racks (dishmachine) P = .47	Total	3	7	26	27	76	92
	Percent Yes	66.7	71.4	65.4	77.8	84.2	76.1
Loading/unloading dishes (dishmachine) P = .92	Total	3	6	26	26	71	91
	Percent Yes	66.7	83.3	76.9	84.6	77.5	74.7
Chopping/dicing with equipment P = .99	Total	4	8	26	24	74	88
	Percent Yes	75.0	75.0	76.9	83.3	75.7	77.3
Slicing with equipment P = .45	Total	3	8	26	28	73	94
	Percent Yes	33.3	87.5	73.1	82.1	79.5	78.7

Table 5 Continued

Job Function Significance		Years of Managerial Experience					
		Less than 1	1 - 3	4 - 6	7 - 10	11 - 20	Greater than 20
Stirring functions	Total	3	8	25	26	77	99
P = .68	Percent Yes	66.7	100.0	80.0	80.8	81.8	76.8
Filling operations (individual	Total	3	8	27	29	82	98
cartons) P = .00	Percent Yes	* 33.3	100.0	81.5	96.6	86.6	93.9
Filling cases	Total	3	8	27	28	84	97
P = .00	Percent Yes	* 33.3	100.0	81.5	96.4	90.5	92.8
Sorting/picking operations	Total	3	6	28	27	75	91
P = .53	Percent Yes	66.7	66.7	66.7	88.9	78.7	76.9
Feeding equipment	Total	3	6	27	27	75	99
P = .02	Percent Yes	* 33.3	100.0	92.6	96.3	84.0	89.9
Metering of ingredients	Total	4	7	22	26	72	94
P = .75	Percent Yes	50.0	85.7	72.7	80.8	79.2	75.5
Loading delivery cart	Total	2	8	22	23	73	82
P = .62	Percent Yes	100.0	87.5	77.3	87.0	76.7	72.0
Delivery of supplies from							
inventory to production	Total	2	7	26	27	79	93
P = .98	Percent Yes	100.0	85.7	84.6	85.2	88.6	88.2

Table 5 Continued

Job Function Significance		Years of Managerial Experience					
		Less than 1	1 - 3	4 - 6	7 - 10	11 - 20	Greater than 20
Delivery of prepared products to storage or service area P = .98	Total	2	6	26	25	77	90
	Percent Yes	100.0	83.3	80.8	84.0	85.7	84.4

* Significant difference in responses

[a] Total number of respondents answering yes or no; don't know and non-responses omitted

As in the analysis for the effect of age on responses, the same phenomena seemed to occur for the effect on work experience or responses. All three questions that showed significant difference in responses between the work experience categories had only 33.3 percent answering yes in the less than one year experience category. The range of percent yes responses in the other work experience categories ranged from 81.5 to 100.0 percent. The deviation of one respondent in the less than one year experience category caused the significance level to change from no difference to significant difference.

Sex

There was no significant difference between males and females for any of the sixteen identified job functions (Table 6, page 87). Three job functions showed that males and females did not disagree (P = 1.0). These were (1) sorting and picking operations (2) metering of ingredients and (3) delivery of prepared products to storage or service area.

Computer Usage

Of the sixteen identified job functions, only one job function represented significant difference (P = .04) between computer users and non-computer users (Table 7, page 89). Identified by an asterisk in Table 7, this job function was lifting and stocking shelves and was only significant between computer users and non-computer users in facilities. Computer users in facilities responded

Table 6

SEX: RESPONSES TO THE SIXTEEN IDENTIFIED JOB FUNCTIONS; TOTAL NUMBER OF RESPONDENTS ANSWERING YES OR NO BY CATEGORY, PERCENT YES RESPONSES BY CATEGORY, SIGNIFICANCE

Job Function Significance		Male	Female
Loading/unloading (receiving & storage)	Total	166	75
P = .25	% Yes	76.5	84.0
Lifting and stocking shelves	Total	155	73
P = .19	% Yes	74.8	83.6
Steam clean carts, shelves, racks	Total	166	76
P = .52	% Yes	78.3	82.9
Loading/unloading glass racks	Total	154	74
(dishmachine) P = .83	% Yes	77.9	75.7
Loading/unloading dishes (dishmachine)	Total	146	74
P = .91	% Yes	77.4	75.7
Chopping/dicing with equipment	Total	153	68
P = .84	% Yes	77.1	79.4
Slicing with equipment	Total	159	71
P = .83	% Yes	78.0	80.3
Stirring functions	Total	163	73
P = .15	% Yes	77.3	86.3
Filling operations (individual cartons)	Total	169	76
P = .43	% Yes	91.1	86.8
Filling cases	Total	169	76
P = .52	% Yes	91.7	88.2
Sorting/picking operations	Total	163	66
P = 1.00	% Yes	76.7	77.3
Feeding equipment	Total	164	71
P = .67	% Yes	87.2	90.1
Metering of ingredients	Total	158	66
P = 1.00	% Yes	77.2	77.3

Table 6 Continued

Job Function Significance		Male	Female
Loading delivery cart (trayline)	Total	138	69
P = .77	% Yes	75.4	78.3
Delivery of supplies from inventory	Total	161	71
to production P = .55	% Yes	86.3	90.1
Delivery of prepared products to	Total	154	70
storage or service area P = 1.00	% Yes	84.4	84.3

[a] Total number of respondents answering yes or no, don't know and non-responses omitted.

Table 7

COMPUTER USAGE IN FACILITY AND PERSONAL USE: RESPONSES TO SIXTEEN IDENTIFIED JOB FUNCTIONS; TOTAL NUMBER OF YES AND NO RESPONSES BY CATEGORY, PERCENT YES RESPONSES BY CATEGORY, SIGNIFICANCE

		Computers in Facility			Personal Computers		
Job Function		Users	Sign.	Non-users	Users	Sign.	Non-users
Loading/unloading (receiving & storage)	Total[a]	171		63	92		149
	Percent Yes	75.4	.13	85.7	78.3	.89	79.9
Lifting and stocking shelves	Total	158		64	86		142
	Percent Yes	73.4	.04 *	87.5	76.7	.83	78.9
Steam clean carts, shelves, racks	Total	171		63	91		151
	Percent Yes	80.1	1.00	79.4	76.9	.41	82.1
Loading/unloading glass racks (dishmachine)	Total	161		61	85		143
	Percent Yes	78.9	.53	73.8	77.6	1.00	76.9
Loading/unloading dishes (dishmachine)	Total	151		62	79		141
	Percent Yes	76.8	1.00	75.8	75.9	.95	77.3
Chopping/dicing with equipment	Total	158		58	87		134
	Percent Yes	79.7	.33	72.4	79.3	.70	76.1
Slicing with equipment	Total	164		60	88		142
	Percent Yes	78.7	.89	76.7	81.8	.39	76.1

Table 7 Continued

Job Function		Computers in Facility			Personal Computers		
		Users	Sign.	Non-users	Users	Sign.	Non-usera
Stirring functions	Total	165		65	89		146
	Percent Yes	78.8	.78	81.5	80.9	.82	78.8
Filling operations (individual cartons)	Total	173		64	96		148
	Percent Yes	90.8	.40	85.9	91.7	.56	88.5
Filling cases	Total	174		64	97		147
	Percent Yes	90.8	.88	89.1	94.8	.10	87.8
Sorting/picking operations	Total	160		62	89		139
	Percent Yes	80.0	.21	71.0	80.9	.51	76.3
Feeding equipment	Total	165		64	90		144
	Percent Yes	89.1	.66	85.9	92.2	.23	86.1
Metering of ingredients	Total	156		62	86		137
	Percent Yes	78.8	.42	72.6	81.4	.30	74.5
Loading delivery cart (trayline)	Total	143		61	83		124
	Percent Yes	74.8	.35	82.0	73.5	.63	77.4
Delivery of supplies from inventory to production	Total	162		65	88		143
	Percent Yes	85.2	.22	92.3	89.8	.53	86.0

Table 7 Continued

Job Function		Computers in Facility			Personal Computers		
		Users	Sign.	Non-users	Users	Sign.	Non-users
Delivery of prepared products to storage or service area	Total	155		64	84		139
	Percent Yes	83.2	.56	87.5	89.3	.16	81.3

* Significant difference in responses

[a] Total number of respondents answering yes or no; don't know and non-responses omitted

yes 73.4 percent of the time while 87.5 percent of the non-users responded yes. There was no significant difference (P = .83) between personal computer users and non-computer users for the same job function.

Two job functions showed a lack of disagreement (P = 1.0) between users and non-users of computers in facilities. These were (1) steam clean carts, shelves and racks and (2) loading and unloading dishes on the dishmachine. In studying data for personal computer usage, one job function showed lack of disagreement (P = 1.00). This was loading/unloading glass racks on the dishmachine.

Level of Education

There was no significant difference on responses to the sixteen identified job functions between the eight different levels of education (Table 8, page 93). Though only four in number, the doctorate recipients agreed almost unanimously that robots should be implemented in all sixteen job functions. Four job functions showed lack of disagreement (P = .90 to P = .99) between all categories of educational background. These were (1) metering of ingredients, (2) filling cases, (3) filling operations (individual cartons) and (4) feeding equipment.

Current Use of Robots in the Food Industry

There was no significant difference (P = .36) between foodservice and food processors in the use of robots. Two respondents in foodservice (1.3 percent) and three respondents in food processing (4.3 percent) reported the utilization of robots. Among the

Table 8

LEVEL OF EDUCATION: RESPONSES TO THE SIXTEEN IDENTIFIED JOB FUNCTIONS
TOTAL NUMBER OF RESPONDENTS ANSWERING YES OR NO BY CATEGORY: PERCENT YES RESPONSES BY CATEGORY, SIGNIFICANCE

	Some H.S.		H.S. Degree		Some Coll.		Assoc. Degree		Bach. Degree		Some Grad.		Master Degree		Doct. Degree	
Job Function Significance	Yes Resp. (Obs)	(%)	Yes Resp. (Obs)	(%)	Yes Resp. (Obs)	(%)	Yes Resp. (Obs)	(%)	Yes Resp. (Obs)	(%)	Yes Resp. (Obs)	(%)	Yes Resp. (Obs)	(%)	Yes Resp. (Obs)	(%)
Loading/unloading (receiving & storage P = .40	1	0.0	9	77.8	24	87.5	19	78.9	73	74.0	56	82.1	57	78.9	4	100.0
Lifting and stocking shelves P = .32	1	0.0	8	75.0	24	87.5	19	84.2	70	71.4	53	79.2	51	78.4	4	100.0
Steam clean carts, shelves, racks P = .49	1	100.0	9	88.9	26	76.9	20	90.0	71	81.7	55	81.8	58	70.7	4	100.0
Loading/unloading glass racks (dishmachine P = .72	1	100.0	10	70.0	22	86.4	18	72.2	66	71.2	57	80.7	54	77.8	3	100.0
Loading/unloading dishes (dishmachine) P = .79	1	100.0	9	66.7	21	76.2	17	88.2	65	76.9	54	72.2	52	76.9	4	100.0
Chopping/dicing with equipment P = .81	1	100.0	9	77.8	22	86.4	19	78.9	66	74.2	48	79.2	54	72.2	4	100.0
Slicing with equipment P = .79	1	100.0	10	80.0	23	78.3	20	90.0	70	75.7	51	78.4	53	73.6	4	100.0
Stirring functions P = .62	1	100.0	10	80.0	26	84.6	19	73.7	68	83.8	55	70.9	54	79.6	4	100.0
Filling operations (individual cartons) P = .95	1	100.0	8	100.0	27	92.6	19	89.5	75	88.0	56	87.5	56	89.3	4	100.0
Filling cases P = .99	1	100.0	8	87.5	28	92.9	20	90.0	74	87.8	56	91.1	55	90.9	4	100.0
Sorting/picking operations P = .22	1	0.0	6	66.7	25	80.0	19	73.7	70	72.9	51	72.5	54	87.0	4	100.0
Feeding equipment P = .90	1	100.0	9	88.9	25	88.0	20	90.0	70	91.4	53	88.7	54	83.3	4	75.0

Table 8 Continued

Job Function Significance	Some H.S. Yes Resp. (Obs)	Some H.S. Yes Resp. (%)	H.S. Degree Yes Resp. (Obs)	H.S. Degree Yes Resp. (%)	Some Coll. Yes Resp. (Obs)	Some Coll. Yes Resp. (%)	Assoc. Degree Yes Resp. (Obs)	Assoc. Degree Yes Resp. (%)	Bach. Degree Yes Resp. (Obs)	Bach. Degree Yes Resp. (%)	Some Grad. Yes Resp. (Obs)	Some Grad. Yes Resp. (%)	Master Degree Yes Resp. (Obs)	Master Degree Yes Resp. (%)	Doct. Degree Yes Resp. (Obs)	Doct. Degree Yes Resp. (%)
Metering of ingredients P = .99	1	100.0	6	83.3	23	73.9	19	78.9	66	75.8	52	73.1	54	79.6	4	75.0
Loading delivery cart (trayline) P = .42	1	0.0	8	87.5	22	72.7	18	77.8	60	80.0	47	68.1	50	78.0	3	100.0
Delivery of supplies from inventory to production P = .17	1	100.0	8	87.5	27	92.6	18	94.4	69	76.8	53	88.7	53	92.5	4	100.0
Delivery of prepared products to storage or service area P = .46	1	100.0	9	88.9	26	92.3	17	76.5	65	78.5	51	80.4	52	90.4	4	100.0

three subdivisions of the foodservice industry, one hospital (2.0 percent) and one university (1.9 percent) reported using robots. There was a significant difference (P = .00) in robot usage between hospitals, universities and primary/secondary schools. Two factors affect the conclusions to be drawn regarding current robot usage in the food industry. First, there were no means of indicating, in completing the questionnaire, what type of robot or application was being implemented. Therefore, it is difficult to determine whether the robot would meet the RIA definition as a multifunctional, reprogrammable manipulator, the criterion set for the purposes of this research. Second, there were only five respondents out of the total two hundred seventy-five valid returns who indicated robot usage. Therefore, it appears that robots are not currently being utilized in the food industry.

Job Functions Not Appropriate for Robotics Application

Results were analyzed to determine which job functions were seen by respondents as not appropriate for robotics applications. These were determined by studying frequencies and chi square both. Any job function with twenty-five percent or less of the respondents answering yes and $P > .05$ were determined to be rejections for robotics application. Five job functions fell into this category (Table 9, page 96). They were (1) quality control inspection, (2) cashier in the cafeteria, (3) waiting on tables in the cafeteria and (5) diet instruction.

Table 9

JOB FUNCTIONS NOT APPROPRIATE FOR ROBOTICS APPLICATION AS IDENTIFIED BY FOOD INDUSTRY AND ROBOT MANUFACTURERS; OBSERVATIONS AND PERCENT RESPONSES FOR YES, NO, DON'T KNOW AND BLANK, SIGNIFICANCE

		Food Industry N = 229				Robot Manufacturers N = 38			
Job Function Significance		Yes	No	Don't Know	Blank	Yes	No	Don't Know	Blank
Quality Control Inspection	Obs	42	144	37	6	9	19	7	3
P = .38	%	22.6	77.4			32.1	67.9		
Cashier (Cafeteria)	Obs	37	146	37	9	2	26	9	1
P = .16	%	20.2	79.8			7.1	92.9		
Dishing Food (Cafeteria)	Obs	63	122	36	8	7	22	8	1
P = .40	%	34.1	65.9			24.1	75.9		
Catering	Obs	27	133	58	11	2	25	11	0
P = .33	%	16.9	83.1			7.4	92.6		
Diet Instruction	Obs	41	145	35	8	6	24	8	0
P = .99	%	22.0	78.0			20.0	80.0		

General Discussion of Survey Response

Comments from respondents completing the survey and returning it with explanation of difficulties indicated a mixed response to the application of robotics in the food industry. The factor presenting the most difficulty for survey participants was lack of knowledge, either of the food industry by robot manufacturers or of robots by the food industry. Several respondents indicated a desire to retain the personalized attributes of the foodservice business while the cost factors associated with robot implementation were considered prohibitive by several respondents. Others felt that many job functions in the survey could be implemented more practically with hard automation.

There were several respondents who supplied additional ideas for robotics implementation that were not included in the survey questionnaire. Some of these included (1) storage and retrieval of dry goods, (2) palletizing in receiving and storage, (3) cleaning refrigerators and freezers, (4) dishmachine sanitation, (5) feeding traywasher, (6) rotating stock and (7) combining the use of robots and humans for inservice and nutrition education and diet instruction. The inclusion of additional ideas by respondents indicates a positive and receptive attitude towards robotics use in the food industry.

Study Outcomes

There were four major outcomes from this research. First, job functions deemed appropriate for robotics application were identified by management personnel in the food industry. This included hospitals, universities, primary/secondary schools and food processors. Second, robot manufacturers isolated those job functions that robots are technologically capable of performing in the food industry. Third, comparisons were made between the responses of the food industry and robot manufacturers to identify those job functions that both industries viewed as feasible for robotics implementation. Job functions were also identified that both industries viewed as not appropriate for robotics use. Fourth, comparisons were made to determine whether any of the demographic data had any relationship to responses for job function applications for robotics. An additional outcome of this research was to expose both the food industry and robot manufacturers to the potential of robots in the food industry.

The results of the survey identified only five job functions of the sixty-four where the food industry and robot manufacturers did not disagree on the lack of appropriateness for robotics implementation. These five job functions were (1) quality control inspection, (2) cashier in cafeteria, (3) dishing food in cafateria, (4) catering and (5) diet instruction. Sixteen job function applications showed lack of disagreement between the two industries for the feasibility of robotics implementation. These were

(1) loading/unloading in receiving and storage, (2) lifting and stocking shelves, (3) steam clean carts, shelves, racks, (4) loading/unloading glass racks on the dishmachine, (5) loading/unloading dishes on the dishmachine, (6) chopping/dicing with equipment, (7) slicing with equipment, (8) stirring functions, (9) filling operations (individual cartons), (10) filling cases, (11) sorting/picking operations, (12) feeding equipment, (13) metering of ingredients, (14) loading delivery cart from trayline, (15) delivery of supplies from inventory to production and (16) delivery of prepared products to storage or service area. The responses to the other forty-three job functions ranged between twenty-six and seventy-four percent yes responses with varying degrees of agreement ($P > .05$) between the two industries. Operations management personnel in the food industry and robot manufacturing responded positively for robot usage in the food industry.

SUMMARY AND CONCLUSIONS

As labor costs rise and employees become more dissatisfied with boring, tedious jobs, several industries have turned to the use of robots as a means of improving quality and productivity. However, a review of the literature revealed that few, if any, in the food industry have moved toward robotics application. Studies have been done in other countries toward that goal. Just recently, professional food industry journals in the United States have begun to address the possibility of robotics applications.

In an effort to provide direction for the development of robotic applications in the food industry, a nationwide survey was conducted of management personnel in food and robot industries. The goal of this study was to determine job functions in the food industry that were viewed by management personnel in both industries as feasible for robots. Demographic data were collected on age, years of work experience, sex, computer use and level of education for determining the effect on job function responses.

Of six hundred sixty-seven surveys mailed to hospitals, universities, primary/secondary schools, food processors and robot manufacturers, forty-one percent were returned with valid responses. Using frequencies and chi square test of significance, sixteen of the sixty-four job functions were identified as showing lack of disagreement between food industry and robot manufacturing on feasibility for robotics application. These were (1) loading/unloading in receiving and storage, (2) lifting and stocking shelves,

(3) steam clean carts, shelves, racks, (4) loading/unloading glass racks on the dishmachine, (5) loading/unloading dishes on the dishmachine, (6) chopping/dicing with equipment, (7) slicing with equipment, (8) stirring functions, (9) filling operations (individual cartons), (10) filling cases, (11) sorting/picking operations, (12) feeding equipment, (13) metering of ingredients, (14) loading delivery cart from trayline, (15) delivery of supplies from inventory to production and (16) delivery of prepared products to storage or service area. Five job functions were identified as not feasible for robotics implementation at this time, including (1) quality control inspection, (2) cashier in cafeteria, (3) dishing food in cafeteria, (4) catering and (5) diet instruction. Analysis of the demographic data with the sixteen identified job functions resulted in no significant difference in responses by age, years of managerial work experience, sex, computer usage and level of education.

Comments from survey respondents in the food industry indicated lack of education about robots and robotics applications. This appeared to cause problems for some participants in completing the questionnaire with regard to feasibility of the job functions for implementation with robots. At the same time, some robot manufacturers indicated lack of knowledge of the food industry. Therefore, it can be concluded that both industries are somewhat naive to the operations, needs, services and products of the other.

One hospital, one university and three food processors of two hundred twenty-nine respondents in food industry indicated the use of robots in operations. Without knowledge of the system, it is impossible to judge whether the robot in use meets the Robot Institute of America's definition as a reprogrammable, multifunctional manipulator or whether it is highly sophisticated hard automation. Regardless of definition, with only two percent of the total food industry population responding positvely to the robot usage question, it can be concluded that robots are not currently being utilized in food industries in the United States.

RECOMMENDATIONS

Due to an apparent lack of knowledge in the food industry of robotics, educational materials need to be developed. While this survey exposed some individuals to the concept of robots in the food industry, workshops, seminars and courses in robotics need to be incorporated into university and high school academia as well as into continuing education opportunities for professionals. At the same time, robot manufacturers need to be educated on the needs of the food industry for robotic implementation. This could be accomplished through research, publications, active information seeking and sharing, personal contact and visitation to miscellaneous expositions of current robotic technology. With a two-way communication system between the two industries, successful and profitable robotics implementations could be developed for any and all areas in the food industry. As food industry professionals become more educated on robot technology and capabilities, other job function applications not identified by this survey can be developed and implemented.

Having identified potential job functions for robots in the food industry, further research is now needed with actual robotic implementations. A robotics system and program needs to be developed that will best utilize the robot's capabilities and potential for food industry applications. The hardware and technology are available; they just need to be customized to meet the needs in food production and service. This needs to include a means of mobility, if not actually a mobile robot, so that the highest utilization of the robot's time can be achieved.

Concern was expressed by survey respondents for human workers replaced by robots in the food industry. As employees in the food industry tend to be less educated and unskilled (i.e. dishroom employees), research needs to be conducted in an effort to find appropriate replacement work for these individuals. Questions that need to be answered may include (1) what type of food-related skills will be needed, (2) what is the requirement for robot-related skills, (3) what is the level of retrainability of food industry employees and (4) how much time, effort and money will be involved in retraining programs.

The opportunity and need for robots in the food industry is there. Management personnel need to think innovatively and creatively in the fight against rising costs and increased competition and robots can provide a solution to these problems.

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APPENDICES

APPENDIX A

Survey Questionnaire

Pilot Study Cover Letter

Cover Letter, Initial Mailing

Cover Letter, Second Mailing

Cover Letter, Third Mailing

Survey Questionnaire

USE OF ROBOTS IN FOOD SYSTEMS
Survey

Based on experience and knowledge in your field, with the assumption that robots are technologically capable of all job functions, please provide your assessment of the use of robots in the food industry in general, not restricting usage to your facility. Job functions have been categorized according to specific areas of work and broken down into more detailed tasks for each area to assist you in completing this questionnaire. Provisions have been made for you to include suggestions for other job functions not included on the list. Numerical coding of responses is strictly for computer tabulation and is not meant to assign a weight to the response.

PART I. JOB FUNCTION APPLICATIONS

In the following list of job functions for receiving and storage and sanitation, please indicate whether or not each job function should be performed by a robot. (Circle one number for each).

1. Receiving and Storage	YES	NO	DON'T KNOW
a. loading and unloading	1	2	3
b. opening and emptying boxes	1	2	3
c. lifting and stocking shelves	1	2	3
d. physical inventory/dry goods	1	2	3
e. physical inventory/refrigerators	1	2	3
f. physical inventory/freezers	1	2	3
g. filling requisitions	1	2	3
h. other (specify) ________	1	2	3
i. other (specify) ________	1	2	3
j. other (specify) ________	1	2	3

2. Sanitation	YES	NO	DON'T KNOW
a. empty and reline trash containers	1	2	3
b. mop floors/sweep carpets	1	2	3
c. steam clean carts, shelves, racks	1	2	3
d. clean equipment	1	2	3
e. wash pots - three sink method	1	2	3
f. wash pots with equipment	1	2	3
Dishmachine functions:			
g. scraping	1	2	3
h. loading/unloading glass racks	1	2	3
i. loading/unloading dishes	1	2	3
j. sorting flatware	1	2	3
k. other (specify) ________	1	2	3
l. other (specify) ________	1	2	3
m. other (specify) ________	1	2	3

Oregon State University
Institution Management
Corvallis, OR 97331
January, 1984

In the areas of food production and service, please indicate whether or not each job function listed should be performed by a robot. (Circle one number for each).

3. Food Production	YES	NO	DON'T KNOW
a. weighing/measuring	1	2	3
b. panning/portioning	1	2	3
c. chopping/dicing manually	1	2	3
d. chopping/dicing with equipment	1	2	3
e. slicing manually	1	2	3
f. slicing with equipment	1	2	3
g. combining functions	1	2	3
h. stirring functions	1	2	3
i. grilling	1	2	3
j. deep-fat frying	1	2	3
k. ability to complete entire recipe	1	2	3
l. quality control inspection	1	2	3
m. filling operations (individual cartons)	1	2	3
n. filling cases	1	2	3
o. prepreparation	1	2	3
p. product orientation on assembly line	1	2	3
q. sorting/picking operations	1	2	3
r. feeding equipment	1	2	3
s. metering of ingredients	1	2	3
t. other (specify)________________	1	2	3

4. Food Service			
Trayline functions:			
a. tray starter (condiments, flatware)	1	2	3
b. placing foods on plate	1	2	3
c. placing foods on tray (pre-dished)	1	2	3
d. set-up of trayline	1	2	3
e. tray check for accuracy	1	2	3
f. loading delivery cart	1	2	3
g. restocking of cooked foods	1	2	3
Cafeteria functions:			
h. cashier	1	2	3
i. dishing food	1	2	3
j. waiting on tables	1	2	3
k. cleaning/clearing tables	1	2	3
l. setting up tables	1	2	3
m. other (specify)______________	1	2	3

Please indicate whether or not each of the following job functions should be performed by a robot in the areas of food distribution and other food related job functions. (Circle one number for each).

5. Food Distribution	YES	NO	DON'T KNOW
a. delivery of meals and snacks to floors	1	2	3
b. delivery of meals and snacks to rooms	1	2	3
c. delivery of supplies from inventory to production	1	2	3
d. delivery of prepared products to storage or service area	1	2	3
e. satellite delivery	1	2	3
f. other(specify)________________	1	2	3

6. Related Job Functions

a. menu collection	1	2	3
b. catering	1	2	3
c. menu tally	1	2	3
d. equipment maintenance	1	2	3
e. other (specify)__________	1	2	3

Please indicate whether or not each of the following job functions should be performed by a robot in the areas of education and entertainment. (Circle one number for each).

7. Education	YES	NO	DON'T KNOW
a. diet instruction	1	2	3
b. nutrition information	1	2	3
c. safety inservice	1	2	3
d. sanitation inservice	1	2	3
e. equipment inservice	1	2	3
f. other (specify)__________	1	2	3
8. Entertainment			
a. games	1	2	3
b. reading	1	2	3

PART II. DEMOGRAPHIC DATA

These last questions are for use in the statistical analysis of the collected data. Please circle one number for each question.

9. What type of facility are you associated with?

1 HOSPITAL
2 UNIVERSITY FOODSERVICE
3 SCHOOL FOODSERVICE
4 FOOD PROCESSOR
5 ROBOT MANUFACTURER

10. What is your current job title?

1 FOODSERVICE DIRECTOR/MANAGER
2 PRODUCTION MANAGER
3 MARKETING/RESEARCH AND DEVELOPMENT
4 QUALITY CONTROL
5 ADMINISTRATIVE DIETITIAN
6 OTHER (SPECIFY)__________________

11. How many years of experience have you had in foodservice or industrial management?

1 LESS THAN ONE
2 ONE TO THREE
3 FOUR TO SIX
4 SEVEN TO TEN
5 ELEVEN TO TWENTY
6 GREATER THAN TWENTY

(Please turn the page)

12. Are you currently using computers in your department?

1 YES
2 NO (skip to question number 14)

13. Please indicate the degree of computer usage in your department. (Circle one number for each).

	EXTENSIVE	MODERATE	NOT USED	NOT APPLICABLE	LIKE TO USE YES	LIKE TO USE NO
a. inventory	1	2	3	4	1	2
b. production	1	2	3	4	1	2
c. purchasing	1	2	3	4	1	2
d. payroll	1	2	3	4	1	2
e. administrative tasks	1	2	3	4	1	2
f. nutritional analysis	1	2	3	4	1	2
g. forecasting	1	2	3	4	1	2
h. food cost accounting	1	2	3	4	1	2

14. Are you currently using robots?

1 YES
2 NO

15. Do you utilize computers for personal use?

1 YES
2 NO

16. Are you: (Circle one)

1 MALE
2 FEMALE

17. Your current age is: (Circle one)

1 UNDER 25
2 25 - 34
3 35 - 44
4 45 - 54
5 55 - 64
6 OVER 65

18. Your highest level of education is: (Circle one)

1 NO FORMAL EDUCATION
2 SOME GRADE SCHOOL
3 COMPLETED GRADE SCHOOL
4 SOME HIGH SCHOOL
5 HIGH SCHOOL DEGREE
6 SOME COLLEGE
7 ASSOCIATE DEGREE
8 BACCALAUREATE DEGREE
9 SOME GRADUATE STUDY
10 MASTER'S DEGREE
11 DOCTORATE DEGREE
12 OTHER (SPECIFY)____________________

COMMENTS:

Thank you for your participation. Results of this study will be published. If you would like to receive a copy of the results, please provide your name and address in the space below.

Pilot Study Cover Letter

College of Home Economics | Oregon State University | Corvallis, Oregon 97331 | (503) 754-3551

January 13, 1984

Dear

As labor costs rise and employees become more dissatisfied with boring, tedious jobs, several industries have turned to the use of robots as a means of improving quality and productivity. Since the food industry is composed of many labor intense, monotonous or repetitive job functions, it is appropriate for managers to look at robot usage in food-related job functions.

In order to assess the feasibility of robot use in the food industry, we are planning to conduct a survey of management personnel of the food service, food manufacturing and robot manufacturing industries. Prior to a nationwide mailing, we would appreciate your participation in completing and evaluating the questionaire for our pilot study. Comments and suggestions may be written directly on the questionaire.

To clarify the distinction between robots and automated equipment, a robot has the capability of being retooled and reprogrammed to perform entirely different job functions. Automated equipment, on the other hand, is functional only in the job for which it was designed.

Please complete and evaluate the survey questionaire and return it by January 23 in the enclosed self-addressed stamped envelope to Elaine Adams or Ann Messersmith at Oregon State University. If you have any questions or comments, please call the Department of Institution Management at 754-3101. Thank you for your time and participation in this pilot study.

Sincerely,

Elaine A. Adams

Elaine A. Adams, R.D.
Graduate Teaching Assistant
Institution Management
Oregon State University
Corvallis, OR 97331

Ann M. Messersmith

Ann M. Messersmith, PhD., R.D.
Associate Professor and Head
Institution Management
Oregon State University
Corvallis, OR 97331

Cover Letter, Initial Mailing

College of Home Economics | Oregon State University | Corvallis, Oregon 97331 | (503) 754-3551

January 31, 1984

Dear Reader:

As labor costs rise and employees become more dissatisfied with boring, tedious jobs, several industries have turned to the use of robots as a means of improving quality and productivity. Since the food industry is composed of many labor intense, monotonous or repetitive job functions, it is appropriate for managers to look at robot usage in food-related job functions.

In order to assess the feasibility of robot use in the food industry, we are asking you to complete and return the enclosed questionnaire. All responses will be treated with total confidentiality and the results will be tabulated according to the population groups of foodservice facilities, food processors and robot manufacturers. Questionnaires are number coded solely for the purpose of survey administration and responses will not be linked to your name or corporation.

To clarify the distinction between robots and automated equipment, a robot has the capability of being retooled and reprogrammed to perform entirely different job functions. Automated equipment, on the other hand, is functional only in the job for which it was designed.

Please have an individual in a management position complete and return the survey questionnaire in the enclosed business reply envelope to the Survey Research Center at Oregon State University. If you have any questions regarding this study, please call the Department of Institution Management at (503) 754-3101. Thank you for your cooperation and participation in this survey.

Sincerely,

Ann M. Messersmith

Ann M. Messersmith, Ph.D., R.D.
Associate Professor and
Head, Institution Management

Elaine A. Adams

Elaine A. Adams, R.D.
Graduate Teaching Assistant
Institution Management

Cover Letter, Second Mailing

College of Home Economics
Oregon State University
Corvallis, Oregon 97331
(503) 754-3561

February 20, 1984

Dear Reader:

About two weeks ago, we wrote to you seeking your assessment on the use of robots in food systems. As of today, we have not yet received your questionnaire. If you have recently returned it, thank you and please disregard this letter.

This survey was undertaken in an effort to determine the potential usefulness of robots in the food industry. It is hoped that a guideline can be developed to aid robot manufacturers in their development of robotic applications for the food industry.

Each survey questionnaire is of great significance to the results of this study. Participants receiving a questionnaire were selected through a scientific sampling process to assure that all qualified had an equal chance of being included. In order for the results of the survey to be representative of the food and robot industry populations involved, it is essential that each person in the sample return his or her questionnaire.

We are writing again to encourage you to return your survey questionnaire. A replacement copy is enclosed in the event that the original may have been misplaced.

Thank you for your time and participation in this study.

Sincerely,

Elaine Adams

Ann Messersmith

Elaine Adams, R.D.
Graduate Teaching Assistant
Institution Management
Oregon State University
Corvallis, OR 97331

Ann Messersmith, Ph.D., R.D.
Associate Professor and Head
Institution Management
Oregon State University
Corvallis, OR 97331

Cover Letter, Third Mailing

College of
Home Economics

Oregon State University

Corvallis, Oregon 97331

(503) 754-3551

March 8, 1984

Dear Reader:

Due to the uniqueness of our research project on usage of robots in food systems, participants seem to be having problems responding to the questionnaire. If you are experiencing difficulties of any type with the survey, please take a moment now to simply jot down your problem at the top of the questionnaire or complete it in its entirety. If you have already returned your questionnaire, thank you and please disregard this letter.

In order to draw conclusions of any type with regard to this study, it is essential that an adequate response rate be achieved. Whether you complete the survey in its entirety or simply state your reason for not filling it out, your response is critical to this study and would be deeply appreciated.

To refresh your memory about the distinction between robots and automated equipment, a robot has the capability of being retooled and reprogrammed to perform entirely different job functions. Automated equipment, on the other hand, is functional only in the job for which it was designed.

Thank you for your time and patience.

Sincerely,

Elaine A. Adams

Elaine A. Adams, R.D.
Graduate Teaching Assistant
Institution Management
Oregon State University
Corvallis, OR 97331
(503) 754-3101

Ann M. Messersmith

Ann M. Messersmith, Ph.D.,R.D.
Associate Professor and Head
Institution Management
Oregon State University
Corvallis, OR 97331
(503) 754-3101

APPENDIX B

Table 1: Sixty-Four Job Functions for Robotics Application; Percent Yes Responses, Significance

Table 1

SIXTY-FOUR JOB FUNCTIONS FOR ROBOTICS APPLICATION
PERCENT YES RESPONSES, SIGNIFICANCE

Job Function	Yes Responses (%)	Significance
Receiving and Storage		
Loading and unloading	79.0 *	.26
Opening and emptying boxes	69.3	.10
Lifting and stocking shelves	77.9 *	.93
Physical inventory/dry goods	43.3	.91
Physical inventory/refrigerators	30.8	.72
Physical inventory/freezer	34.0	1.00
Filling requisitions	56.2	.20
Sanitation		
Empty and reline trash containers	73.3	1.00
Mop floors/sweep carpets	73.9	.00
Steam clean carts, shelves, racks	80.8 *	.06
Clean equipment	69.9	.14
Wash pots - three sink method	59.7	.57
Wash pots with equipment	72.6	.46
Dishmachine functions:		
Scraping	73.0	.00
Loading/unloading glass racks	77.0 *	.61
Loading/unloading dishes	76.6 *	.20
Sorting flatware	79.7	.00
Food Production		
Weighing/measuring	73.3	.80
Panning/portioning	68.0	1.00
Chopping/dicing manually	58.4	.07
Chopping/dicing with equipment	76.4 *	.38
Slicing manually	54.4	.27
Slicing with equipment	77.6 *	.96
Combining functions	69.9	1.00
Stirring functions	79.9 *	1.00
Grilling	42.4	.52
Deep-fat frying	61.3	1.00
Ability to complete entire recipe	28.7	1.00
Quality control inspection	23.8	.38
Filling operations (individual cartons)	89.3 *	1.00
Filling cases	90.1 *	.55
Prepreparation	61.3	.21
Product orientation on assembly line	69.2	.09

Table 1 Continued

Job Function	Yes Responses (%)	Significance
Food Production Continued		
Sorting/picking operations	77.0 *	.77
Feeding equipment	88.4 *	1.00
Metering of ingredients	75.9 *	.42
Food Service		
Trayline functions:		
Tray starter (condiments, flatware)	77.7	.00
Placing food on trays	46.9	.24
Placing foods on tray (pre-dished)	67.3	.49
Set-up of trayline	62.2	.85
Tray check for accuracy	44.8	.93
Loading delivery cart	77.2 *	1.00
Restocking of cooked foods	49.5	.02
Cafeteria functions:		
Cashier	18.5	.16
Dishing food	32.7	.40
Waiting on tables	12.9	.46
Cleaning/clearing tables	41.9	.00
Setting up tables	51.0	.00
Food Distribution		
Delivery of meals and snacks to floors	73.1	.01
Delivery of meals and snacks to rooms	34.0	.89
Delivery of supplies from inventory to production	86.9 *	.80
Delivery of prepared products to storage or service area	83.7 *	.68
Satellite delivery	63.8	1.00
Related Job Functions		
Menu collection	43.6	.20
Catering	15.5	.33
Menu tally	66.8	.00
Equipment maintenance	39.9	.01

Table 1 Continued

Job Function	Yes Responses (%)	Significance
Education		
Diet instruction	21.8	.99
Nutrition information	39.7	.13
Safety inservice	33.3	.27
Sanitation inservice	37.3	.27
Equipment inservice	41.6	.63
Entertainment		
Games	71.4	.92
Reading	53.5	1.00

* Job functions identified for further analysis