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History of Automation in Production Systems

1.1. HISTORY OF AUTOMATION

There is certainly requirement for consistent effort for, innovations and Kaizen in design and production facilities and desperate need for manufacturing investment for countries to remain economically competitive. Since the second world war, the world economy has drastically changed. Countries whose manufacturing base was destroyed, have been able to rebuild, from scratch because of their untiring effort, consistent investment in research and development for innovative processes products, production methods and new management philosophies.

Automation, possibly more aptly termed automation engineering, is a production engineering philosophy that is directed towards enhancing the automatic nature (sometimes called automaticity) of machines, processes, or systems. The objective of automation is to cause the work system to be as automatic, that is, self acting, self regulating and self-reliant as may be possible but against the practical backdrop of various economic, environmental, social and other restraints. Because of these restraints, the work systems are only partially automated, sometimes.

One definition of automation was proposed in 1947 as "the automatic handling of workpieces into, between and out of machines." As viewed in the last half of the 1980s, this is a limited definition, although still accurate as far as it goes. Some authorities claim that automation is a contraction of the more difficult to say word automization. Still other scholars claim that automation was coined from automatic and operation. Even though the derivation of the word is not fully clear, it is well established that the practical application of automaticity to making and getting things done is centuries old than the words used.

As pointed out by Mumford, the curse of labour was described by the early Egyptians; who mentioned the daily hardships, the filth, the danger, the nightly weariness of producing goods. Later the oppression of labour was recognized by the Greeks in the fifth century B.C. and by the Florentines in the twelth century A.D. Prior to the last century or two, earlier people tended to look towards a force that would abolish all work and as described by Mumford, "the most desirable life possible would be one in which magical mechanisms or robots would perform all the necessary motions under their own power, without human participation of any kind. In short, the idea of the mechanical automation, which would obey all orders and do all the work." Thus, the negative connotations of automation in terms of adverse effects on the economy of human work force did not arise seriously until this present century.

1.2. BUILDING BLOCKS OF AUTOMATION TECHNOLOGY

Important scientific and technological developments that contributed to the success of automation are as follows :

(*i*) **Feed Back Control**. Feedback is the fundamental principle and basic mechanism that underlies all self-regulating processes. Some experts have defined feedback method as information about the output at one stage of a process or operation that is returned feedback to an earlier stage so as to influence its action and hence to change the output. Ingenious self-regulating devices and machines date back to many years have existed. The flyball governor, invented in 1788 to control watts steam engine exemplifies the application of feedback control. Long before, the theory for feedback and closed loop control was put forth in use exhaustively. One of the earliest uses of closed loop feedback control was its application to the poser steering of ships, adapted decades later to power steering mechanism for automobiles.

(*ii*) **Information and Communication Theory.** This theory was not brought in use formally until after world war II, when Shannon published his work, "A mathematical Theory of Communication" in 1984. In the same year Wiener published "Cybernetics or control and communication in the Animal and the Machine". The concepts put forth by Wiener created excitement during this period, Cybernetics essentially comprised of three concepts : (1) animal or machine systems (2) communication between systems and (3) regulation or self regulation of systems.

(*iii*) **Sensors and Measurement Devices**. These devices did not develop historically according to any particular master plan. Mostly sensors were developed for learning more and more about the nature of physical and chemical phenomena and not as tools for automation. Measurement of dimension and weight for example, had its roots in antiquity and its needs were largely the basis upon which early trade had been conducted. Although mechanically based sensors have and will continue to be used in automation systems, the measurement field progressed much more rapidly after the development of electromagnetics and electrical circuits by investigators as Ampere, Volt and Ohm in the late 1700s and early 1800s by Faraday, Henry, Wheatstone, Kirchoff and Maxwell. Before the appearance of electronics, it usually was found much easier to measure and control a machine or process by electrical rather than mechanical, pneumatic or hydraulic means. But in the absence of electronics, non-electrical methodologies essentially by default became the approaches of choice. Even today wide use of mechanical pneumatic and hydraulic technologies persist, comparatively new field of micromechanical sensors is successfully re-establishing some of the earlier non-electronic approaches.

(*iv*) **Servopower**. Electric, hydraulic and pneumatic power made possible a lot of actuators ranging from valves, louvers and dampers in the fluid/bulk industries and machine and work piece positioners in intermittent manufacturing. At this time automation was assisted by devices such as electro mechanical, electro hydraulic and electro pneumatic relays and subsystems. The continued research in the design of electric motors resulted in increased size and weight for a given horsepower rating alongwith increased efficiency have also contributed to advancement in automation. During the past decade outstanding progress has been made in DC and AC motor controls in the refinement of stepping motors and in the practical application of linear motors.

(*v*) **Computer and Memory Power**. These developments have been of outstanding importance to automation. The hollerith card that appeared in 1890 (frequently referred to for many years as the IBM card) most likely had its roots in the card programmed jacquard loom invented in 1801. In repeat cycle automated machines, the memory required for operation was designed right into the mechanics of the machine, that still can be found in printing and packaging machines, whose automaticity dates back a number of decades. As the degree of the automaticity and complexity of a machine/process increases, there is enhanced requirement for increased rate of information storage and retrieval. Prior to the development of digital electronics, mechanical computing and memory systems *e.g.* desk calculators (a few decades ago) were large, slow and frequently quite difficult to alter the programme contrary to this controllers of today have made a good-buy to mechanical, pneumatic and hydraulic controllers and are used to determine the error signal in a closed loop feedback system.

(*vi*) **Digital Technology.** This technology for all practical purposes, encompasses the advances of solid state microelectronics and has improved computing speeds for automated systems which in combination with improved response speeds of detectors and sensors greatly enhanced the performance of control systems. Modern computerization, stems directly from digital technology. The two marked trends of decreased size and cost of micro-electronic devices have greatly influenced the availability of components in terms of application feasibility and economics. The components produced from micro-electronics are of small size and are so important that they are widely used in automated systems. The size of such components is directly related to the economics of component part production and where the space available to mount such detectors is limited, such as on robot arms.

(*vii*) **Mechanization.** Mechanization was the logical next step towards automation after the emergence of metal hand tools (in contrast with the earlier stone and wood tools). Mechanization conferred the first degree of automaticity to a system.

(*viii*) **Systematization and Engineering Analysis.** Planning and analysis are and will continue to be the key elements for achieving successful automation. Traditionally production supervisory personnel were the renal store house of knowledge pertaining to all aspects of production, from incoming materials through warehousing and shipping. Because Advanced Manufacturing Automation minimizes the subtleties of human judgement that can be applied directly on the factory floor in the form of minor machinery adjustments of procedural changes in the interest of maintaining smooth production run, are deeply implanted in the minds of production supervisors. This detailed, but very important information is not always easy to retrieve from supervisor. As suggested by a major company, one must "sweat out the details" if success is to be achieved via automation.

(*xi*) **Information Display Technology.** This has progressed beyond earlier expectations prior to the extensive use of the cathode ray tube and has contributed immeasurably to the expansion of automation technology largely by automating the geneous ways of plotting and presenting information now widely assisted by the use of colour monitors have provided an interlinked designing device for manufacture with manufacturing itself so called CAD/CAM (Computer Aided Design/Manufacturing).

1.3. TYPES OF PRODUCTION AUTOMATION SYSTEMS

Success of any enterprises is measured in terms of its financial performance. With globalised economy, quality and productivity in manufacturing have generated a challenge of competition to be faced by developing and under developed countries in selling their products, in their own country and abroad. Production automation is the only reply to this challenge for availability of quality goods in high volume.

Automated Production Systems, are the extension of the conventional production systems, (*i.e.* job-shop, Batch type and continuous production systems) with the use of automation devices, such as feed back control and computer control systems. These are the advancements as a result of consistent research and developments of new technologies. Continuous Production Systems is a kind of automated manufacturing system, but without feed back control device. Thus system with feed back control device is called a fixed or non flexible automated production system and hence use of feed back control system in a mechanised production system is the beginning of automation in industrial production systems. Thus in automation, using feed back control devices for a single machine tool or to the entire production system fixes the degree of automaticity. The automation right from receiving to the shipping dock is called comprehensive automation or computer integrated manufacturing.

Following are the different types of Automated Production Systems.

(1) Fixed or Non Flexible Automation.

(2) Programmable Automation.

(3) Flexible Automation.

(4) Comprehensive Automation or Computer Integrated Manufacturing.

To make the automation systems more understandable between conventional production systems and automated production systems, their operational characteristics are tabulated as below :

Table 1.1 Conventional and Automation Production Systems

S. No.	Conventional Production Systems	Automation Production Systems	Remarks
1.	Continuous Production System.	Fixed or Non Flexible Automation.	Continuous automation may also be called as fixed automation if a feed back control device is used to reduce human control.
2.	Job-Shop Production Systems.	Programmable Automation.	Small jobs in large numbers or big jobs in small number can be machined using CNC machines
3.	Batch Type Production System.	Flexible Automation.	Flexible Automation is named so because batches of components varying in size from 100 to 1500 can be manufactured with this method of automated production system in a cost effective manner with programme controlled machines.
4.	Nil	Comprehensive Automation or Computer Integrated Manufacturing.	Its other name is total automation and is also known as CIM. It is the ultimate in automation in production.

Fixed Automation

In fixed automation sequence of mechanical processing (or assembly) operations are performed as fixed by the job configuration. Some times the operations to be done on the job are fixed by equipment configuration also. For example sequence of mechanical operations such as cutting, forming and trimming are performed by self acting machine tools, with a regular cycle and automatic transfer from one station to another is a kind of fixed automation. In fixed automation many operations on raw material, to shope it to a finished object, are integrated and performed by one piece of equipment thus making the automated system, complex and difficult to maintain. Following are the features of fixed automation :

(*a*) Rigid, as regards to accommodate product design changes.

(*b*) Generally meant for high volume of production.

(*c*) Equipment is made to order and has high cost.

The economic justification for fixed automation is decided by the products with very high demand rates and volumes, thus the high initial cost of the equipment can be spread over a very large number of units, thus making the automation cost economically feasible compared to other alternative methods of production. Examples of fixed automation include mechanized assembly lines and transfer lines.

Programmable Automation

Industrial use of high speed computers in computing data sequentially in production equipment, with capability to change sequence of operations so as to accommodate different product configurations. The sequence of operations according to product configuration are programmable *i.e.* coded set of instructions that a machine or a computer numerical control device can read and interpret and can pass on the information to machine to manufacture a requisite job configuration.

The advantage of a digital computer over other system for processing information is that it combines the speed and flexibility. It can be switched on in a few minutes from computing a design data, to work out a drawing and then a machining data. The principle that makes this possible is the use of coded programme. The machine gets instruction for each new computation from punched tape/floppy disk prepared before hand, and so very little time is needed for resetting. The programming principle has been applied to the operations of machine-tools, for example milling machines, lathes and borers used for machining complex shapes in the aircraft and heavy electrical industries and for die-sinking in the motor car industry. Up till now, this type of work has been carried out provided by the skilled draftsman.

This can be further classified as :

(*a*) Machine Automation: NC Machines; hard wired system, controlled by numerically pre-coded programme for fabricating a part. Such machines are not readily programmable.

(*b*) With a high degree of automaticity the machine is indirectly controlled by a computer and is known as CNC.

(*c*) Direct Numerical Control machine tools.

All the above programmable automation have the following common features :

(*i*) Suitable for one station job configurations in batches or for single job.

(*ii*) Low production rate than fixed automation.

(*iii*) Highest possible flexibility as regards to changes in work configuration.

The programme for a coded or computer controlled milling machine, for example, consists of a series of three dimensional co-ordinates which define the beginning and the end of each flat surface and give a series of points on each curved surface to be machined. When set going, the control mechanism guides the cutting tools to each point in turn and causes it to follow a smooth path in between by fitting a curve to three or more points. Here again programming makes it feasible to change rapidly from one type of work to another and accurate complicated work can be done reliably without the services of a skilled machinist, thus economizing in skilled manpower cost and time.

Flexible Automation

Flexible automation is just an extended version of programmable automation and has developed only over the last two decades. A flexible automated manufacturing system is one which is capable of changing over to adopt to changed physical set up of tooling, machine settings and fixtures arising out of new job (product) configuration, intended to be manufactured. There is no production time lost while re-programming the group of machines and altering physical set-up. Consequently such an arrangement of a group of programmable machines that can produce products requiring various combinations and schedules of machine loading for variety of products to be produced in different lot sizes. Following are the some of the important features of flexible automation.

(*i*) Flexibility to deal with variety of job configuration.

(*ii*) Continuity of production is maintained even with varied product-mix jobs.

(*iii*) Production rates are medium.

Flexible Automation is an integrated system of computer controlled machine tools and other work stations with an automated flow of information, workpieces, tools etc. The control over the flexibility in manufacturing is achieved through computer implemented algorithms which make all the operational decisions. The flexible Automaticity is usually planned by simulation techniques in which a model is drawn. The analysis of model behaviour shows ways for improving the system by carrying out necessary changes. A flexible manufacturing is capable of copping with both external changes as well as internal changes or disturbances.

Flexible Automation gives greater flexibility and makes it possible to reduce throughput times. The basic criteria that determine the application area for the individual type of automated equipment are :

— The number of different parts to be produced on the particular equipment.

— The number of similar parts in each lot *i.e.* the lot size.

The Flexible Manufacturing installation is most practicable where the annual production reaches 4 to 100 lots with each lot size ranging from 150 to 1500 parts.

Flexible automation is advancement of fixed and programmable automation in speed and flexibility. The primary advantage of flexible automation over programmable automation is that the programming and setup can be performed off-line. However, flexible automation machines are more expensive than those for programmable automation because of their physical size and their need to change tools during machining operations. The capability to provide many types of preset tools substantially reduces the need for on-line set up and allows the batch sizes to the reduced. This in turn reduces both work-in-process and lead time.

Comprehensive Automation or Computer Integrated Manufacturing (CIM)

The concept of CIM was described as early as 1973 by Harrington. Conaway defined CIM as "The automation and integration of a manufacturing enterprise through the use of computers". Others have defined CIM as the logical organization of individual engineering, production and marketing/support function into a computer–integrated system. Functional areas of planning being such as design, inventory control, material requirement and manufacturing resource and control distribution, cost accounting, planning and purchasing are integrated through the use of computers. Thus, the loop is closed between the shop floor and its controlling activities. Shop-floor manufacturing data-acquisition devices serve for the control system and often are in direct command. Strategic plans smoothly give way to perform operations, at optimum cost.

CIM is obviously a very ambitious industrial organisation. The up to date manufacturing system in software for CIM is time-consuming and costly. Until there is some universality of approach and until it becomes easier to follow the successful CIM examples from others, the approach for many years will suffer from limitations. In case of firms that have complex, multiple product lines, that change every year CIM may not be affordable for the very large companies. The chances of success are better in case of the small and medium size firms that have few, simple products and the design of which remains relatively stable with time. Meanwhile, until more specific experience is gained, it is feared that a "diarrhea" of planning and conceptualizing may create a "constipation of implementing automation in some circles.

Fortunately, for the majority of industries, many gains from automation can be made from available equipment and existing information. Large strides in the implementation of automation can be taken, long before current conceptualizing and its numerous, often confusing and changing acronyms have run their course.

1.4. ADVANTAGES AND LIMITATIONS OF AUTOMATION

Advantages

Advantages as is apparent from the numerous technological innovations occurring, advanced automated systems are available today and further advances seem close at hand. Thus, a former question, "Is automation possible ?" has been displaced by the query, "Is automation profitable ?" As is essontially true of all business concerns, automation is welcomed most where it contributes to profit. Of the several dividends yielded by manufacturing processing automation, two are upper most. (*i*) improved productivity and (*ii*) better product quality.

(*i*) Improved productivity of machines and people is an advantage that almost always translates into greater profitability and return on investment Several factors enter into improved productivity, but two are most important.

(*a*) *Increased production capacity*. More goods produced per manufacturing floor area, machines installed and the human work force. In terms of machines, automation usually increases the machines thus yielding more machine hours per day.

(*b*) *Better inventory control of raw materials*. Goods in process and finished goods : There is an axiom — "To automate well means to understand and plan exceedingly well." Some authorities have observed that just analysis of a plant's operation and procedures, while considering total automation, is very important even though only a limited amount of automation may be immediately installed. For the first time such analysis may cause an in-depth understanding of the intricacies and interrelationship of a given production situation. A number of special techniques, most supported by excellent software for computerized analysis, have been developed in recent years. These include such concepts as group technology, just in time (JIT) systems, material requirements planning (MRP) and Manufacturing Resources Planning (MRPII) these concepts are described in following chapters of this book.

(*ii*) Enhanced product quality : Which improves competitive position and reduces waste and reworks. Improved competitive position naturally translates into higher volume leading to added economic advantages.

Human inadequacies such as dexterity, awareness, cognition, speed and strength, that far exceed the human limitations, in some of the manufacturing and processing operations, among other variables in same manufacturing and processing industries variables such as temperature, pressure, chemical composition flow, weight etc. are not measurable by human operators. These inadequacies and limitations are among two most compilling forces that necessitated automation.

(*iii*) Upward shift of workers role, that is from numerous arduous, low skilled duties to higher skilled supervisory and maintenance responsibilities.

(*iv*) Reduction of personal accidents through the assumption of accident-prone duties by automated machines and processes.

Limitations

Some of the limitations of automation include :

(*i*) High cost of design, manufacturing and maintaining automated equipment. This cost is finding considerable relief because of the continuous increase in cost of electronic components and equipment, although some of these savings are offset by continuing inflated costs of software. Successful efforts, to date, and that will also continue in future, in terms of standardizing equipment, communication networks. Software costs exists as a barrier to processes that one also likely for automation.

(*ii*) Vulnerability to down time exists because of increasing complexity of automated equipment. However, this is being reduced at an accelerated rate due to improved equipment, self-diagnostics, fault-tolerance techniques and more economic approaches to design redundancy into automatic systems.

(*iii*) Loss of flexibility. This was a very important restraint on automation until relatively recently introduction and refinement of the concept of flexible manufacturing systems (FMS) has largely negated this restraint.

(*iv*) More management attention. Actions in highly automated systems occur sometimes at an almost unbelievably high rate and allow little or no time for human decisions. Currently with state-of-the-art technology, a machine or a process can be driven to make quite a lot of off-spec and scrap material before effective supervision can get into control of a runaway situation. Through the assistance of information networks, ranging from corporate to plant-wide to cells and individual machines and processes, managers can be appraised of factory/floor situations on essentially on a second-by-second basis. Thus, more and better management personnel is needed as a plant increases its content of automation. In the more distant future, a much greater portion, of the almost instantaneously needed decision making will also be done automatically. However, assignment of this important responsibility to computers, needless to say, will require exceedingly careful attention and analysis by very sharp management personnel.

(*v*) Persistence of automation's negative image. Surprising to many authorities has been the acceptance of automation technology by the labour force and the successful negotiation of new union contracts, even though the basic fact remains that jobs are eliminated by automation. Of course, automation also creates new and certainly higher-skilled jobs. As the public and the press and other media that serve it become better acquainted with the real nature of automation, earlier predictions of very adverse effects on the labor force will continue to be tempered. Fortunately, too much automation is frequently identified with the other aspects of so-called high technology, contributing to a reasonably good press for automation.

1.5. IMPLICATIONS OF AUTOMATION ON EMPLOYEE AND EMPLOYER

Automation displaces human workers, is an apparent fact but, what happens to those displaced workers is not apparent. In general the improvements in competitiveness and profitability of the firm means that work is created in the company or as the economy of a country improves jobs will automatically become available in the service sector. At present unemployment is a general problem and it is the result of the present recessionary trend in the world economy. The point of concern is that if recovery takes place by the new technology involving robotics, automated machines and computers instead of humans that may prevent reduction in unemployment. Take for example, the management has to takeup a decision of robotized workers job as shown in Figure 1.1.

Implifications for the Employee

Therefore, when the worker's job is robotized the first possibility is that the worker may be retained with the robot. This situation may occur if the company is installing a automation system. A Robot for health and safety reasons, or justifying it financially *i.e.* brings improvement in quality. Or it may be that three workers are being replaced by one robot, in which case it could be possible to retain one of them and leaving the other alternatives open for the remaining workers. It could also be possible that a number of robots are being installed to do the work of one worker then this worker will still be needed, full time, in that job.

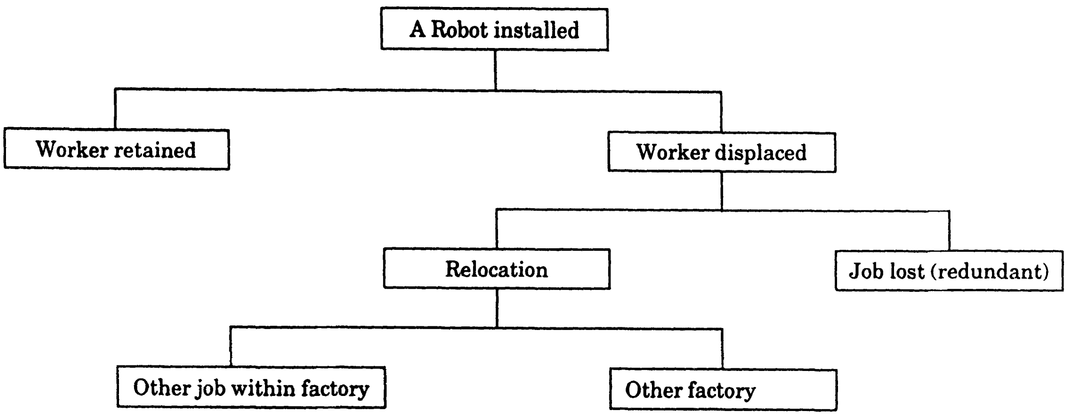

Fig. 1.1. Possible effects of robot installation being an element of Automated Systems.

Suppose, however, that the worker is retained for one of the reasons given above, what are the implications ? There are three possible ways in which the worker can be utilized : (*a*) he may be required to program the robot and set up any jigs and fixtures necessary ; (*b*) he may simply be needed alongside the robot, monitoring and tending it to ensure satisfactory operation; or (*c*) he may have to work with the robot on an associated task.

(*ii*) **Implication for the worker.**

(*a*) If a worker is retained, he may be required to acquire additional skill of robot programming, for palletizing or other related tasks which necessarily requires additional training as mode of rehabiltising the worker.

(*b*) Automation or robotization is made with an objective of enhancing quality, quantity and relieving the workers from main jobs, offensive jobs in hazardous environment such a introduction must not give rise to increased stress or create psychological or physiological stresses, so as to produce alienation in scanty workers population ultimately raising problems of job dissatisfaction.

(*c*) Robotisation or automation must not create a condition for a worker that he is paced by the programmed machinery (Robot) or an assembly line. If the robot is working as a part of assembly line, the human operator may be placed after the robot here in this situation he has not to work at the same rate as the robot, while if the worker is placed before the robot, where it has the capability to go on working at constant speed without a break or relaxation, in this situation the robot is facing to the worker to maintain the same pull as that of robot. This type of organisation can cause stress to the workers as the worker is pursued to follow the same rate as that of the robot.

(*iii*) **Implications for the vendor.** Those who are designing, manufacturing and installing robots are obviously providing a new source of employment for individuals. These firms are not very large in number as yet, nor do they contain a large staff. However, other spin offs occur such as system houses that will take the robots from the supplier, gather from various sources the necessary ancillary equipment, and then install and commission complete systems on the customer's premises. These new job opportunities will demand a higher level of education and training than the jobs that are being lost.

(*iv*) **General implications.** When the benefits of robotizing and automation are considered the end result should be an improvement in the economy. This in turn should mean more money for people to invest in banks or spend on entertainment and travel. That the service industries should prosper providing jobs in this sector. The more than is a shift from 'blue collar' workers to 'white collar' workers. This trend can be self-perpetuating for one unattractive reason, which is perhaps most evident in U.K. Due to the poor economic climate that has existed for some time, companies have been reluctant to employ young people as craft or technician apprentices. This means that now there is a shortage in many areas of the country of skilled craftsmen such as toolmakers and welders. Therefore when the need for skills arises, firms find it difficult to recruit the appropriate people. The new solution will be to find one person who will then be used to train on robots to carry out the work. The gradually the infrastructure of skilled human workers is being eroded away by yet another factor. Care should obviously be exercised here on the widest possible scale, to ensure the country maintains a credible knowledge, skill and experience base on which to build when the economy improves.

(*v*) **Workforce response.** Usually a workforce will be amenable to new technology providing it is not seen as a threat. Unions say that they realize investment in new production methods must be made to enable their company to remain competitive. This approach includes automation, which unions increasingly see as being just one other tool to aid survival. Careful discussion between unions and management is necessary to ensure a smooth transition from manual to automated operations. It is worthwhile to ensure that the unions or workforce representatives are brought in at an early stage, possibly even at the initial planning before the systems are purchased. Sometimes protective agreements are made and signed by management to state that no redundancies will arise as a direct result of automation.

(*vi*) **Working conditions.** It should be remembered that industrial robots can improve working conditions considerably. For example, although they have the potential to be dangerous if safety precautions are not taken, they commonly reduce accidents due to their *application* in hazardous environments and tasks. Many occupational diseases and injuries are caused by poor environments and dangerous and heavy labour. Robots can be put into the these jobs. As mentioned elsewhere they are also ideal for the monotonous, and boring jobs that can cause both accidents through complacency and industrial unrest.

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