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Abstract: "Robots and robotics" are not "new" concepts. The roots can be traced back to Kartel Capek's 1921 stage play, Russen's Universal Robots, R.U.R. This study investigates the current applications of robots and addresses problems associated with implementation of Advanced Manufacturing Technologies (AMTs) into the manufacturing environment. Several proposed strategies for implementation are presented. In addition, clear delineation of robots from other AMTs, such as Computer Integrated Manufacturing (CIM) is explained.

ROBOTS AND ROBOTICS:
A SUBSET OF ADVANCED MANUFACTURING TECHNOLOGIES

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MANUFACTURING MANAGEMENT II-EMGT 510 D

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ABSTRACT

Robots and robotics is not a "new" concept. It's roots can be traced back to Karel Capek's 1921 stage play, Russen's Universal Robots, R.U.R. This paper investigates the current applications of robots and addresses the problems associated with implementations of Advanced Manufacturing Technologies (AMTs) into the manufacturing environment. Several proposed strategies for implementation are presented. In addition, clear delineation of robots from other AMTs, such as Computer Integrated Manufacturing (CIM) is explained.

ROBOTS and ROBOTICS

"Industrial Robots are to factory automation what MRP is to closed loop manufacturing planning"
--A. Dunn

INTRODUCTION

With the current emphasis on regaining U.S. industrial leadership, new manufacturing acronyms and terms are surfacing with increasing frequency. World Class Manufacturing (WCM), Synchronous Manufacturing, Computer Aided Design/Computer Aided Manufacturing (CAD/CAM), Computer Integrated Manufacturing (CIM), Flexible Manufacturing Systems (FMS), Just In Time (JIT), and Total Quality Management (TQM) to name a few. Just where robots fit in is sometimes difficult to accurately identify. One point that does stand out, though, is robotics is not a philosophy or system as is the case of TQM (19) or CIM (10). Robots are an integral part of these philosophies and systems (14, p.2). Whereas Computer Integrated Manufacturing is sometimes considered the "Factory of the Future" or "Automated Factory", robotics is a part of the "Whole" and not a system onto itself.

This paper will focus on the implementation and considerations necessary for implementation into a manufacturing environment.

BACKGROUND

The term 'Robot', in association with human-like machines, originated in Karel Capek's 1921 stage play named Russem's Universal Robots (R.U.R.). In his play, Androids were manufactured to replace human factory workers (sounds familiar) and did so to the extent of killing them off. Thus the negative image of the robot was created and lingers today (7, p. 304).

Issac Asimov, first in 1942, and then restated in 1963, was one of the first credible writers to highlight the possible positive impacts on society of robots. In his book I, Robot , he presents the following basic laws to govern robots, which are surprisingly pertinent to current implementations.

THE THREE LAWS OF ROBOTICS

1. A Robot may not injure a human being, or, through inaction, allow a human being to come to harm.
2. A Robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
3. A Robot must protect its own existence as long as such protection does not conflict with the First of Second Law.

Handbook of Robotics
56th Edition, 2058 AD (1)

In 1962, Unimation installed the first industrial robot in a General Motors assembly plant (7, p. 304). In 1968, Kawasaki Heavy Industries imported a Unimation robot and became the first Japanese Company to enter the "Age of Robotics" (13, p. 3).

The 1970's saw the emergence of numerous robot manufacturing firms in the United States and Japan. The future looked extremely profitable for these companies but then the market for U.S. manufactured robots came crumbling down in the 1980's. During the same time, Japanese sales soared. One-time U.S. industry leaders, Unimation and GCA Industrial Systems, were absorbed by larger corporations. Unimation, absorbed by Westinghouse, is now defunct. Westinghouse failed to see the future of electrically controlled robots and soon saw their market share for the hydraulic Unimation models disappear. As a result, they discontinued robot production. Even today there are few really profitable robotics manufacturers, this includes Japan. One of the main difference between Japan's appearance of success and our failure in the robotics industry has been the driving force behind robot implementation. U.S. companies tended to view robots as the ticket to higher profit margins. When this did not occur, they soon became disillusioned with this technology. These anticipated increases in profits were to have been derived from cost savings by reducing labor. Japanese firms designed robots to boost competiveness and quality. A concept that has finally arrived here.

Another difference has been in the areas of attempted applications. While Japan focused on simple applications, the United States has attempted complex multi-function/multi-axis applications, many of which were doomed from the beginning. Two vivid U.S. misapplications which resulted in failure are at John Deere and Whirlpool. John Deere completely eliminated its robotics tractor chassis painter and replaced it with human workers. An interesting reversal of thinking. They discovered that the re-programming between paintings was consuming too much time.

Whirlpool, on the other hand, attempted to use a robot in its Clyde, Ohio plant that mimicked a human arm, a very complex undertaking. This led to scrapping of the robot and reverting back to fixed automation (22).

CLASSIFICATIONS

Not only is there discrepancy between Japan and the U.S. pertaining to applications, there is confusion in the definition of a robot. In the United States, the Robotics Industries Association (RIA) has defined an industrial robot as "A manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks" (7, p. 305). The

Japanese Industrial Robot Association (JIRA) takes a much different approach to robotics definition. They classify robots into six categories based on type of input and teaching method. Table 1 lists the Japanese Classification System.

Industrial Robot Classification (Japanese)

NAME	DEFINITION
Manual Manipulator	A manipulator operated by a man
Fixed Sequence Robot	A manipulator which operates sequentially in compliance with preset procedures, conditions and positions, and whose preset information cannot be easily changed
Variable Sequence Robot	A manipulator which operates sequentially in compliance with preset procedures, conditions and positions, and whose preset information can easily be changed
Playback Robot	A manipulator that is capable of performing any operation (job) it is previously "taught" to do (physically guided through, step-by-step) by a man
Numerically Controlled (NC) Robot	A manipulator capable of performing operations in compliance with numerical instructions as to sequence of actions, positions and other such information. Numerical instructions are provided to NC robots by means of perforated tapes, cards or digital switches.
Intelligent Robot	A robot capable of determining its own operations via built-in sensing and recognition capabilities

TABLE 1 JMA, Robotization: Its Implications for Management, 1983, (2).

When comparing the U.S. definition and Japan's classification system, it is clear that Japan's first category, and sometimes category 2, do not fit into the definition. This has led to a sometimes distorted comparison between numbers of implemented robots in both countries.

In general, Robots can be separated into four functional application areas, Pick-and-Place/Palletizing, Painting/Welding, Assembly, and miscellaneous (7, pgs. 311-312). Pick-and-Place robots are also called Fixed Sequence robots. Such robots are not reprogrammable via software modifications but are adjusted as a traditional tool would be. Is this a robot? It depends on who you talk to.

Another classification technique is based on the arm configuration. These are fixed/variable sequence robots, servo/non-servo robots, point-to-point/continuous path robots and First/Second/Third Generation robots. Painting and welding robots are classified as point-to-point or continuous robots depending on application i.e. (point-to-point/spot welding and continuous/painting). The generation classifications depend on the degree of environment sensing and learning ability possessed by the robot. First Generation robots are the so-called dumb robots. They have no sensors and are incapable of learning. Second Generation robots are equipped with vision and/or touch sensors. Third generation robots utilize artificial intelligence and sensors to learn and adapt (18, pgs. 22-24). Currently, First Generation robots dominate the industrial scene with an increasing number of Second Generation robots being implemented. Third Generation are still in the development phase but offer great promise of increased flexibility and easier programmability than previous generations.

Even with the many, and sometimes confusing, definitions and classifications of robots, it should be noted that robots are merely a subset of the numerically controlled (N/C) machine family. They only can do what they are told to do. The typical numerical machine is three-dimensional capable but is constrained by its guide devices. A robot, on the other hand, is not constrained by rails, worm-screws etc. and must rely on an onboard navigation system to orient itself.

Numerically controlled machines, of which robots are a subset, play an important role in Computer Integrated Manufacturing. According to Koenig (14, p. 57), 30-35% of flow manufacturing and only 5% of Job Shop manufacturing activity involves machine-process control. This is the value-added portion of manufacturing. The remainder of the time a product spends in the system is merely adding to its final costs. He also stated that increasing the value-added portion of manufacturing is a primary goal of CIM. As a result, proper implementation of robots into the CIM environment will help accomplish this goal.

ROBOTS AND FLEXIBLE MANUFACTURING

Another important and growing application of robotics is in Flexible Manufacturing Systems. As mechanization crept into our manufacturing systems, flexibility was pushed out. Mass production assembly lines were extremely inflexible which dictated that the consumer got what was available, not always what they wanted. Times have changed, however, and consumers have begun to demand high variety and quality. Traditional mass production could not accommodate this trend which led consumers to look toward foreign markets for satisfaction. Global competition has forced U.S. manufacturing to reassess how they do business. The common statement, "Automate or Exterminate", refers to this phenomenon. Perhaps it should be restated as "Flexibly Automate or Exterminate". The success of U.S. manufacturing rests in its ability to adapt to a rapidly changing environment. The days of Henry Ford are over (5):

> "You can buy any color Model-T as long as it's black!".

Dunn (5) believes that Flexible Manufacturing Systems will provide the greatest return for manufacturers considering automation, and that robots are the key to successful implementation of FMS.

It should be noted that FMS has been mentioned as a subset of CIM (15), (16). This clearly illustrates the relationship between CIM and robotics. Robotics is a subset of CIM even though it is a common mistake to equate the two. Robotics and automation are merely the visible components of CIM.

OTHER IMPLEMENTATION REASONS

Other reasons, besides the increased flexibility, to implement robotics include reducing labor costs, elimination of dull and dangerous jobs, increased output rate and quality, and the reduction of material waste (8, p. 341).

If one or more of the previous conditions exists, the next step to investigate what type of automation to install to correct it. Robotics may not be the answer. It may be possible to use fixed automation to accomplish your goal. William Tanner, (21), presents seven factors to be considered and seven associated rules of thumb. The factors are: complexity of operation, degree of disorder, production rate, production volume, justification, long-term potential and employee acceptance.

Complexity of operation refers to how complicated is the operation that is intended to be robotized. Robots tend to perform poorly in very complex environments and hard automation performs simple tasks better than robots. Thus his First Rule of Thumb: "Avoid Extremes of Complexity".

It is commonly accepted that robots cannot perform well in disorderly environments. Parts must be presented, to the robot, will little variance repeatedly. Part position and orientation is critical. Although vision and touch equipped Second Generation robots can tolerate some fluctuations, The Second Rule of Thumb states: "Disorder is Deadly".

Rule of Thumb Three, "Robots Are Generally No Faster Than People" dispels the myth of the speed-of-light machine out-producing people at fantastic rates. People tend to fatigue as the day progresses while robots keep producing at constant rate. This accounts for the misconception that this rule dispels.

Rule four addresses the production run length. For very short runs it is impractical to robotize, or even automate, especially if changeover time is greater than 10% of the batch time. On the opposite end of the spectrum, if the production run is long, the need for flexibility disappears and so does the need for robotics. Simply stated, Rule of Thumb Four: "For Very Short Runs, Use People. For Very Long Runs, Use Fixed Automation."

Rule of Thumb Five:"If It Doesn't Make Dollars, It Doesn't Make Sense." Common payback period analysis is what is still widely used to justify robotics implementation without regard for strategic market positions or such unquantifiable factors such as quality.

The decision to convert to robotics should be long-term. Besides the obvious costs involved, skills need to be developed and maintained by your robot tending workforce. If you commit to robotics, you must commit for the long term. In addition, installing just one robot as a showpiece doesn't make sense. It is very hard to integrate "Islands of Automation." Rule of Thumb Six: "If You Only Need One, You Don't Need Any."

The final one, Rule of Thumb Seven: "If People Don't Want It, It Won't Make it." Unless everyone from the CEO down to the production worker is not committed to robotics, its implementation is doomed from the start.

If none of the previous seven rules applies to your case, then you could probably use robotics in your plant.

ECONOMIC CONSIDERATION

An economic feasibility study is warranted for the implementation before actual purchase of the hardware is considered. One must consider not only the robot cost but the total implementation costs of the proposed robotics application. The most common approach that is used is the simple payback period. The heart of the analysis is, unfortunately, labor savings vs. robotics costs. Other benefits such as higher productivity, higher quality, and improved throughput are ignored since current economic analysis procedures cannot accommodate them. The simple payback period method is easy to calculate and is easy to understand which accounts for its overwhelming use (17, p. 41). This sometimes leads to rejection of a proposed installation even though increased market competiveness may have resulted.

The payback period, P, is defined as (17, p. 43):

$$P = I/wL$$

Where: I = Total Robot Implementation Cost
w = Total Cost Per Worker Per Year
L = Total Workers Replace (workers replaced per shift) x (number of shifts)

Payback periods vary according to application and robot cost. There is a general consensus that the cost of the "robot" accounts for about only 40% of the total installation costs (17, p. 39). The other 60% is peripheral equipment, training, documentation, maintenance etc. Total implementation costs may vary from $100,000 for a single $20,000 robot to $300,000 for a $100,000 robot (17, p. 42). Payback periods for a one $100,000 robot/three worker displaced installation ranges from 4.0 years for a single shift operation to 1.3 years for a three shift schedule. Payback periods of one to two years are commonly accepted, three to four years less so (17, p. 46).

Miller, (17, pgs. 46-47), states:

> "The conclusion here is that if one takes the most conservative view of the economics of robot use (i.e. robots are viewed as labor savers and must pay for themselves in a very short time period), then it appears that substantially fewer robots will be installed than could be used, because many potential applications would not meet requirements for short payback periods."

His statement clearly highlights the need to reassess our current methods of justifying the purchase of new technologies for manufacturing. It may also be advantageous to consider alternatives to purchasing robots such as leasing which has not been addressed in the Literature.

HIGHLIGHTS OF IMPLEMENTATION

Assuming that the economic analysis justifies the purchase of robots, and robots do fit your situation, the next phase would be to begin implementation. It should be emphasized that both management and the employees must buy into the implementation from the beginning, as stated in Rule of Thumb Seven previously mentioned in this paper. This basic, but often ignored assumption, is common to the introduction of change into any organization but even more so in the manufacturing environment. New technologies are normally perceived to present a threat to the livelihood of the employees, whether they really do or not. Without support, the implementation will not be successful or only partially so.

This drastic cultural change doesn't come easy. You don't simply buy CIM (9), and conversely you just don't buy a factory full of robots and expect to be successful. Dean et. al. (3), have collected all of these new technologies, including robotics, into one term, Advanced Manufacturing Technologies (AMTs). They have presented the following seven propositions regarding the managerial decison process for AMT implementation which bear repeating:

1. AMT implementation will be considered successful by those involved to the extent that it meets technical, economic, and political objectives.

2. The higher the level of tolerance, the greater likelihood of successful AMT implementation.

3. The greater the level of technical, economic, and political resources available, the greater likelihood of successful AMT implementation.

4. The more positive the relationships (or fewer the tradeoffs) among technical, economic, and political objectives, the greater likelihood of successful AMT implementation.

5. The more balanced the decisions made during the implementation process, the greater likelihood of successful AMT implementation.

6. The lower the tolerance, the fewer the resources, and the greater the tradeoffs among the technical, economic, and political objectives, the greater will be the impact of balance on AMT implementation success.

7. Unbalanced decision may lead to decrease in tolerance and resources, thus reducing the likelihood of success for subsequent decisions.

While their proposals emphasize the managerial decision process, the underlying tone is cooperation and acceptance by everyone in the plant.

Vernon Estes (6), presents a more practical look at implementation. He has compiled eight rules to apply that will aid in the initial introduction of robotics into the factory. They are:

1. Implementation should start in hostile areas. Typical areas would be were OSHA violations, worker complaints, or injuries have occurred.

2. Consider applications where productivity is lagging. Look at repetitive jobs...boring for workers.

3. Evaluate long-term needs.

4. Implementation cost will be indirectly proportional to the cost of the robot. More expensive (flexible) robots tend to be more self-contained and rely less on peripheral control equipment.

5. Keep it simple. Clearly stated, especially for a first-time application, try to apply robotics to a simple yet potentially lucrative application. Chances for success are greatly enhanced. A first-time failure tends to dampen enthusiasm for future implementations.

6. Assume that if it can happen, it WILL. Murphy's Laws reign in robotics applications. Plan for all contingencies.

7. Don't expect vendors to furnish turnkey implementations. He emphasizes that you are interested in an integrated turnkey. Integrated into your existing system, not a robot that is wheeled into the door and plugged in.

8. Don't forget people requirements. Safety measures, training, retraining and out placement for example.

If management combines the decision flow process with these eight, common-sense, rules. Implementation of a robotics system will have a greater chance for success.

FUTURE and CONCLUSION

The future of robotics looks very promising, though the current U.S. robotics industry is slowly expanding, redirection away from excessively complex applications and management commitment to implementation should fuel the growth. American industry has finally realized that you can't force robots into an inflexible environment. Also successful applications don't have to be complicated ones.

Changes in economic cost analysis will further enhance expansion. This is one area that needs emphasis. As long as decisions to expend capital for equipment is based on traditional Cost-Accounting techniques, many potential applications will be delayed or canceled.

Research is progressing in redundant axis manipulators, fault tolerant robots and, perhaps the most exciting, Third Generation smart robots (4).

Detroit, always a leader in robotics applications has taken a new approach in its design phase. Instead of forcing robots to conform to poor designs, Chrysler engineers have designed the Plymouth Laser - Mitsubishi Eclipse for easy assembly by robots (11). This is a clear indicator of future trends in robotics, design for the robot.

Robotics implementations are not the cure-all for American manufacturing woes. They are the beginning of an ongoing process of continued improvement and redirection in managerial thinking. It took the current global competitive environment and the change in consumer demands to fuel this change.

Clapp (2), has summed up this change in thinking by redefining Isaac Asimov's Laws of Robotics:

1. Organizations may install robots to the Economic, Social or Physical detriment of workers or management.

2. Organizations may not install Robots through devious or "closed" strategies which reflect distrust or disregard for the work-force, for surely they will fulfill their own prophecy.

3. Organizations may only install Robots on those tasks which, while currently performed by men, are tasks where man is like a robot, not the Robot like a man.

I believe his "new" laws are an excellent redirection from thinking about how the robot can benefit from the organization to thinking about how the organization can benefit from the robot.

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1. I. Asimov, _I, Robot_ (Garden City, New York: Doubleday & Company, Inc., 1963) preface.

2. N. W. Clapp, "Three Laws For Robotocists: An Approach to Overcoming Worker and Management Resistance to Industrial Robots," in _Industrial Robots, Vol. 1, Fundamentals, 2nd Ed._, (Dearborn, Michigan: Robotics International of SME, 1981) 169-175.

3. J. W. Dean Jr., G. I. Susman, P. S. Porter, "Technical, Economic, and Political Factors in Advanced Manufacturing Technology Implementation," _Journal of Engineering and Technology Management_ 7(1990): 129-144.

4. R. C. Dorf, _Robotics and Automated Manufacturing,_ (Englewood Cliffs, New Jersey: Prentice Hall, 1983) 171.

5. A. G. Dunny, "Robots and Flexible Manufacturing Systems-A Primer," in _Computer Integrated Manufacturing and Flexible Manufacturing Systems Seminar Proceedings_, (Falls Church, VA: APICS, 1985) 6-27.

6. V. E. Estes, "Vern's Rules of Thumb When Applying Robots," in _Industrial Robots, Vol. 1, Fundamentals, 2nd Ed._, (Dearborn, Michigan: Robotics International of SME, 1981) 53.

7. P. H. Francis, "Robotics," in _Manufacturing High Technology Handbook_, (Marcel Dekker, Inc., 1987) 304-335.

8. P. H. Francis, "Robot Selection Process," in _Manufacturing High Technology Handbook_, (Marcel Dekker, Inc., 1987) 337-358.

9. J. D. Goldhar, M. Jelinek, "Manufacturing as a Service Business: CIM in the 21ST Century," _Computers In Industry_, 14(1990): 225-245.

10. G. Graham, _Automation Encyclopedia A to Z in Advanced Manufacturing_, (Coopers & Lybrand's, 1988), Secondary Reference.

11. W. J. Hampton, "Can Steel-Collar Workers Build Better Cars?," _Business Week_, 12 Sept 1988, 73.

12. R. H. Hayes, S. C. Wheelwright, _Restoring Our Competitive Edge, Competing Through Manufacturing_ (New York: John Wiley and Sons, 1984).

13. JMA Research Institute, Robotization: Its Implications for Management (Tokyo: Fuji Corporation, 1983).

14. D. T. Koenig, Computer Integrated Manufacturing, Theory and Practice (New York: Hemisphere, 1990).

15. M. E. Merchant, "The FMS As a Subsystem of CIM," in Intelligent Manufacturing Systems (Amsterdam: Elsivier, 1988), 53-71.

16. R. D. Miller, "JIT & CIM: An Integrative Look at the Technologies," in Computer Integrated Manufacturing and Flexible Manufacturing Systems Seminar Proceedings, (Falls Church, VA: APICS, 1985), 3-40.

17. S. M. Miller, Impacts of Industrial Robotics (Madison, WI: UW Press, 1989).

18. P. B. Scott, The Robotics Revolution (Oxford, U.K.: Basil Blackwell LTD, 1985).

19. T. R. Stuelpnagel, "Total Quality Management in Business and Academia," Business Forum, Fall 1989/Wtr 1990, 4-9.

20. K. Susnjara, A Manager's Guide to Industrial Robots (Englewood Cliffs, NJ: Prentice Hall, 1982).

21. W. R. Tanner, "Can I Use A Robot?" in Industrial Robots, Vol 1, Fundamentals, 2nd ED., (Dearborn, MI : Robotics International of SME, 1981) 54-55.

22. A. Tanzer, R. Simon, "Why Japan Loves Robots and We Don't," Forbes, 16 April 1990, 148-153.

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1. N. W. Clapp, "Three Laws For Robotocists: An Approach to Overcoming Worker and Management Resistance to Industrial Robots," in Industrial Robots, Vol. 1, Fundamentals, 2nd Ed., (Dearborn, Michigan: Robotics International of SME, 1981) 169-175.

   Clapp addresses the issue of ignoring managerial concerns, the people and the organization, the so-called human factors in engineering. He proposes a reinterpretation of Asimov's classic Three Laws of Robotics from a managerial perspective. This is one of the first papers addressing Robotics from this perspective.

2. J. W. Dean Jr., G. I. Susman, P. S. Porter, "Technical, Economic, and Political Factors in Advanced Manufacturing Technology Implementation," Journal of Engineering and Technology Management 7(1990): 129-144.

   Dean, Susman and Porter present a model for the decision process to ensure successful implementation of Advance Manufacturing Technologies. Their model integrates four major factors that affect the implementation of new technologies: CIM, Robotics, MRP II, etc. into a manufacturing environment. In addition, they use examples from an electronics company to illustrate their model.

3. R. C. Dorf, Robotics and Automated Manufacturing, (Englewood Cliffs, New Jersey: Prentice Hall, 1983) 171.

   Dorf's book, at times dated, is an introduction to automated manufacturing and robotics. It is a good introductory reading for those with little background in the subject.

4. A. G. Dunny, "Robots and Flexible Manufacturing Systems-A Primer," in Computer Integrated Manufacturing and Flexible Manufacturing Systems Seminar Proceedings, (Falls Church, VA: APICS, 1985) 6-27.

   Dunny presents robots as an integral part of Flexible Manufacturing Systems (FMS). He presents a technical description of industrial robotic applications and an implementation procedure. In addition, an introduction to economic cost analysis is presented.

5. V. E. Estes, "Vern's Rules of Thumb When Applying Robots," in Industrial Robots, Vol. 1, Fundamentals, 2nd Ed., (Dearborn, Michigan: Robotics International of SME, 1981) 53.

Estes presents a common-sense listing of the eight factors that need consideration when deciding if robots are applicable to a specific application.

6. P. H. Francis, "Robotics," in Manufacturing High Technology Handbook, (Marcel Dekker, Inc., 1987) 304-335.

7. P. H. Francis, "Robot Selection Process," in Manufacturing High Technology Handbook, (Marcel Dekker, Inc., 1987) 337-358.

Francis' two articles are succeeding chapters in the book. He presents an in-depth, yet non-technical, overview of Robotics. This is an excellent source for robotics knowledge for those beginning their investigation. He goes beyond the generic description of Robotics and introduces a method to follow in selecting a Robot for a first-time application.

8. J. D. Goldhar, M. Jelinek, "Manufacturing as a Service Business: CIM in the 21ST Century," Computers In Industry, 14(1990): 225-245.

They approach CIM as a change in cultural thinking. They propose that manufacturers will gain a competitive advantage by implementing CIM and related Advanced Manufacturing Technologies. CIM advances will enable workers to be freed from routine jobs and elevated to that of a "knowledge" workers. Implications of this will be the need to reassess manufacturing strategic thinking. CIM is addressed as a "concept" and not an entity.

9. G. Graham, Automation Encyclopedia A to Z in Advanced Manufacturing, (Coopers & Lybrand's, 1988), CIM Section, Secondary Reference.

This article is a brief overview of CIM. It introduces the acronym AMT which stand for Advanced Manufacturing Technologies. It addresses the need for information processing by AMTs. The CASA/SME CIM Enterprise Wheel is described as well as grouping of CIM into three families of processes. The CIM Enterprise Wheel approaches CIM from a top-down managerial perspective vs. the conventional manufacturing look.

10. W. J. Hampton, "Can Steel-Collar Workers Build Better Cars?," Business Week, 12 Sept 1988, 73.

A brief but informative sub-article to "GM Bets an Arm and a Leg on a People-Free Plant". Both articles focus on the trend in the automobile industry to implement more robotics. They highlight how Detroit is focusing on designing their products for Robotic Assembly instead of forcing Robotics into a fixed automation environment. These are non-technical articles.

11. R. H. Hayes, S. C. Wheelwright, Restoring Our Competitive Edge, Competeting Through Manufacturing (New York: John Wiley and Sons, 1984).

Hayes and Wheelwright bridge the gap between manufacturing and management in addressing the problem of restoring the U.S. as the international leader in Business. They illustrate that this could be accomplished through analyzing and restructuring or manufacturing infrastructure. They show how this can be accomplished by focusing on four critical activities: developing production facilities, matching equipment and management to those facilities, establishing supplier relationships and striving for continuous improvement not just status quo in manufacturing. This is an outstanding book that addresses the current state of U.S. manufacturing from a blend of technical and non-technical discussions. Actual examples are liberally dispersed throughout the book.

12. JMA Research Institute, Robotization: Its Implications for Management (Tokyo: Fuji Corporation, 1983).

This is a complete book on Robotics from the Japanese perspective. This study focuses on Japanese applications and describes Japanese management philosophies when applying Advanced Manufacturing Technologies, especially robotics. It addresses managerial concerns from top-level down to leaders of organized labor. It also probes problems of implementing technological innovation that will have to be solved on an international scale.

13. D. T. Koenig, Computer Integrated Manufacturing, Theory and Practice (New York: Hemisphere, 1990).

This book is an authoritative analysis of the "philosophy" of CIM and about how to effectively manage this philosophy so that a company can maximize its

competitive advantage. This is a complete book that clearly, and quite deeply, describes CIM and covers both implementation and use of the theory of CIM. Highly recommended.

14. M. E. Merchant, "The FMS As a Subsystem of CIM," in Intelligent Manufacturing Systems (Amsterdam: Elsivier, 1988), 53-71.

Merchant emphasizes the integration of Flexible Manufacturing Systems in the CIM environment. He clearly defines FMS as an integral part of CIM and not a stand-alone application of Advanced Manufacturing Technology. He briefly presents a description of the role and interrelationships of the various elements of the system of manufacturing. He points out that full-scale CIM integration has not been accomplished yet but the shop-floor integration has been accomplished....through FMS. A worldwide analysis of CIM is presented as well as a current review of CIM trends.

16. R. D. Miller, "JIT & CIM: An Integrative Look at the Technologies," in Computer Integrated Manufacturing and Flexible Manufacturing Systems Seminar Proceedings, (Falls Church, VA: APICS, 1985), 3-40.

This article is based on task force findings of the FMC Corporation. The group was formed to analyze resource allocation, activity prioritization, JIT & CIM interactions and non-interactions and the functional impacts of JIT and CIM on FMC's current operations. This report is a condensed version of these findings.

17. S. M. Miller, Impacts of Industrial Robotics (Madison, WI: UW Press, 1989).

This book is a technical analysis of the economic and social impacts that robotics has had and will have on the metalworking industry. He analyzes cost justification of robotic implementation and labor impacts of technological change. Although emphasizing the metalworking industry, this book is one of the few true comprehensive collection of robotic studies and current facts. It is a wonderful source of robotic information and its applications are much wider than the author intended.

18. P. B. Scott, The Robotics Revolution (Oxford, U.K.: Basil Blackwell LTD, 1985).

A general book that covers robotics. Its background, technology, applications, social and economic considerations and a future outlook. This is a general book, that is now dated, but is a good starting point for those first investigating this technology.

19. T. R. Stuelpnagel, "Total Quality Management in Business and Academia," Business Forum, Fall 1989/Wtr 1990, 4-9.

A short narrative work that highlights the need to bring Total Quality Management into the classroom of America's Business Schools NOW. It is an indictment of our current lack of reaction to the changing manufacturing environment and offers a warning that classroom implementation should have started yesterday not tomorrow.

20. K. Susnjara, A Manager's Guide to Industrial Robots (Englewood Cliffs, NJ: Prentice Hall, 1982).

An often cited and recommended handbook of robotics. This is not a textbook on robotics but a common-sense/down to earth introduction to robots and robotic implementation. This book addresses important managerial aspects of planning a robot installation such as trade-offs between using robots and human labor. He also presents a useful "Installation Manual" as an appendix to his book. A good book for the manager's bookshelf.

21. W. R. Tanner, "Can I Use A Robot?" in Industrial Robots, Vol 1, Fundamentals, 2nd ED., (Dearborn, MI : Robotics International of SME, 1981) 54-55.

A brief article that is intended to help potential roboticists analyze their need for a robot. Tanner propose seven rules of thumb which will help determine that need.

22. A. Tanzer, R. Simon, "Why Japan Loves Robots and We Don't," Forbes, 16 April 1990, 148-153.

An brief analysis of the differences between Japan and the U.S. pertaining to robotic applications. It addresses the successes and failures in both countries.

ADDITIONAL REFERENCES

1. R. U. Ayres, S. M. Miller, Robotics: Applications & Social Implications (Cambridge, Mass: Ballinger, 1983).

   Ayres and Miller describe the development of robotics as a technology and outline potential benefits and drawbacks, mainly from a social perspective. A brief outline and survey of applications is presented. A general overview of robotics that is somewhat dated.

2. D. I. Cleland, B. Bidanda, The Automated Factory Handbook (Blue Ridge Summit, PA: TAB Books, McGraw Hill,1990).

   A complete and technical handbook on Computer Integrated Manufacturing. Managerial, operational, and planning for the automated factory are addressed in-depth. A very good addition to the manufacturing manager's book collection.

3. E. Kafrissen, M Stephans, Industrial Robots and Robotics (Reston, VA: Reston Publishing/Prentice Hall, 1984).

   A general work on robotic applications and robots. A fairly informative description on how a robot works is presented at a non-technical level. A chapter on software systems is included as well as a description of a robot work-cell environment.

4. OECD, Industrial Robots: Their Role in Manufacturing Industry (Paris: OECD, 1983).

   A European perspective of robotics in manufacturing industries in the countries that belong to the Organization for Economic Co-operation and Development. This report considers the implications and role of robotics in economic development.

5. D. M. Osborne, Robots: The Application of Robots to Practical Work (Detroit, MI: Midwest SCI-TECH, 1984).

   A comprehensive work that illustrates application areas of robotics to include general areas and specific factory applications.

6. D. J. Todd, Fundamentals of ROBOT Technology (New York:John Wiley & Sons, 1986).

This work could be considered an introductory textbook on Robots. Robotic configurations,operation and programming, actuation, sensing and performance specifications are covered. General topics of applications and classes of robots are also addressed.