ECONOMIC AND TECHNOLOGICAL FACTORS IN INDUSTRIAL AUTOMATION

Dana Bryan Hoffer
University Undergraduate Fellow, 1986-1987
Texas A&M University
Department of Economics

APPROVED

Fellows Advisor Morgan Reynolds

Honors Director Laurie Canfield

Acknowledgment

In the Spring of 1986 it was my view that industrial automation, a technology with promise to improve the standard of living of every man, was stalled in its infancy. As a senior mechanical engineering student on his way to Bristol, England, on cooperative education assignment, I requested that I be allowed to participate in the Honors Undergraduate Fellows Program to research the cause of the slow accptance of automation even though I would be absent from the A&M campus for one of the two semesters of the program, violating the residency requirement of the program. Additionally, I requested that I be allowed to study the problem from both engineering and economics viewpoints. I would like to thank Dr. Lawrence Cress for allowing me to participate in the Fellows Program. I would like to thank my mechanical engineering advisor in at the University of Bristol, Mr. Koorosh Khodabandehloo and my economics advisor, Dr. Morgan Reynolds, Texas A&M University. Dr. Cress presented the opportunity, and Mr. Khodabandehloo and Dr. Reynolds made this endeavor a fantastic learning experience for which I will always be grateful.

Table of Contents

Table of Tables

Abstract

Many businesses are not persuaded that advanced manufacturing technology (AMT) will bring large gains in manufacturing efficiency. The businesses, however, which rely upon traditional financial decision tools may be in error due to their restrictive application of justification analyses which indicate that investment in AMT is unprofitable. This study analyzes the characteristics of AMT and appropriate justification techniques in an effort to explain the paradox between the promise of AMT and impression of AMT in the business world. The discussion reviews the factors in the AMT investment decision process. Journal articles and survey results—a questionnaire survey conducted by the author in England in November 1986 to gauge current corporate attitudes and actions about AMT—are the primary bases for discussion.

Introduction

Business success and failure can be understood by reviewing the prevailing market demands. Business failure (losses) occurs when companies do not pay attention to the market. Being 'out of touch' with the market, characterized by declining competitiveness, typically implies bad decision making by management. In the case of advanced manufacturing technology (AMT) investment, management can be 'out of touch' while making, according to quantitative financial analyses, good business decisions. The cause of this apparent paradox in Western manufacturing industries is threefold.

First, managers appraising AMT for their factories find the cost staggering and the benefits amazing which turns them very cautious, greatly slowing decision making. Second, cautious management is not encouraged by internally conducted investment analysis to accept the investment risk. The cause for the slow adoption rate of AMT is the financial analysis undertaken to justify the investment. Financial decision tools are restrictively applied and do not capture significant AMT benefits and therefore indicate a potentially viable investment infeasible. Third, while beneficial for most who have adopted AMT systems, AMT seems overly risky, requiring a rare breed, the high risk taker with authority, an executive-level entrepreneur, to move a company towards the promise of advanced manufacturing technology.

AMT: Promising Technology

There is promise in Western societies for additional manufacturing activity. The promise is in the form of technological advance coupled with adaptive organizational philosophy to exploit the technology. The potential is revolutionary because it usually requires clean sweeps of factory floors, installation of high technology manufacturing equipment, and reorganization of the entire company, including non-manufacturing units.

Such technology permits efficient information usage within a company. Efficient use of information results in manufacturing more efficiently than subcontracting overseas with inexpensive foreign labor. The technology includes information- collecting automation equipment and managerial strategy called computer-integrated-manufacturing (CIM). Automation equipment and CIM strategy together comprise advanced manufacturing technology (AMT).

Definition of Terms

The following definitions are supplied for clarity:

CIM—"computer-integrated-manufacturing"; a management philosophy for the control of company information; the strategy of information integration; CIM is a concept to be implemented within a company; company policy regarding standard operating procedure; the whole of the parts with the parts being the just-in-time, shop floor data collection and others.

Automation Equipment—any equipment that performs a function and returns information to central information base

AMT—CIM plus its physical elements, computer numerically controlled (CNC) machine tools, conveyor systems, industrial robots, computerized engineering design and analysis centers, and other tools of automation.

The Basic Principle of AMT: Information Integration

CIM is wholly based and dependent upon integration, the integration of product information. CIM, like other 'all-or-nothing' systems, has very few benefits without integration. The concept of CIM strategy is to integrate usage of an information set to coordinate and drive the entire manufacturing process.

Information in manufacturing industry tends to be used in isolation. For example, communication is slow and infrequent between order processing and the production floor, similarly, design is isolated from production and accounting. Integration of information allows the entire organization to act in concert as required, in principle, to move with agility and efficiency in accord with the signals of the market.

Many companies may have this set of information today, but do not use it in integral fashion. Instead, companies commonly ignore worthwhile information which affects their competitiveness. By contrast, to improve its competitiveness, one Chrysler manufacturing plant is being set up to operate 100% of the time at 100% capacity by efficiently using available information. Companies not manufacturing at 100% capacity are not using the information at their disposal in an integrated manner.

The physical elements necessary for CIM are tools that allow information to be collected and acted upon. These elements range from mainframe and mini- computers to computerized engineering design and analysis work centers to automation equipment of production and assembly including computer controlled presses, lathes, conveyors and handling systems, and robotics. These physical elements allow humans to move from rigid, narrow jobs including routine labor and information collection to broader, more flexible roles including setup, trouble-shooting, and off line repair of defective products.[1]

In any manufacturing organization all information originates from the design process. Change in design will affect the organization's information. For instance, a designer adding an exterior color to those already available for a car model will effect many operational departments, from accounting and purchasing to production and warehousing. CIM captures the design information in the center of an information distribution net which spreads across the organizational structure of the company. The information can be used for every function within the organization, from accounting to marketing and sales, from incoming goods to production control and shipping.

More Integration Coming

AMT (CIM and its automation equipment) holds considerable promise. According to Hulas H. King, manager of manufacturing systems engineering for McDonnell Aircraft Company,

> Design functions will be handled in a paperless environment with the blueprint becoming obsolete. The geometric and nonshape digital data from the design model will provide the means to drive downstream operations such as tooling, planning, numerical control (NC) machine tools, and robots. Information-management systems will provide the data to support day-to-day activities such as material handling, production scheduling, manpower allocations, and cost charging. Computer-based tooling will replace physical hard tooling and master models. Cellular manufacturing will be prevalent throughout the production shop."[2]

In addition, Mr. King sees: [3]

- o Material, tools, and work-in-process inventory will arrive at the work cell on a just-in-time basis.
- o Automated setups will minimize justification of small-lot production.
- o Inventories will be managed at minimum levels.
- o Grouping of machines and equipment will enable full completion of parts within a work cell.
- o The role of robotics will grow and be integrated with other shop-floor automation initiatives.
- o The office and the shop floor will be more closely linked.

Thus AMT promises realizing heretofore unattainable efficiencies in every aspect of the manufacturing process through information integration. These efficiencies are constituents of competitiveness and have focused the attention of manufacturing industry upon AMT.[4]

AMT Requires Strategy

The automation equipment is only as valuable as the corporate CIM strategy. Without strategy, AMT will suffocate companies unprepared to strategically put the high equipment cost investment to work. With strategy and equipment, CIM pays as in the oft cited success story at Allen-Bradley's electrical contactor facility in Milwaukee.

> The $15 million, 50-machine flexible-assembly complex reads parts-insertion requirements from bar codes and can produce motor starters in 125 different configurations at the rate of 600 an hour. Manufacturing, assembly, shipping, and packaging operations are integrated.
>
> Part of the company's successful program to sustain its worldwide marketing momentum, "the project might have been at risk if we had approached it the traditional way," says Allen-Bradley CEO O'Rourke. "After we decided to make the product here in Milwaukee and compete anywhere on price, the issue was to find the enabling manufacturing strategy. In essence, we 'bought' the investment in terms of quality, cost, market share and size, competition, and profitability. If there is a time to ignore conventional return-on-assets calculations, it's when your long term goals are at stake. Justification has to become more of a policy decision than an accounting practice," he insists.
>
> The performance of the contactor plant has contributed significantly to the company's export growth—from 5% of total sales in 1979 to 25% in 1985. One measure of Allen-Bradley's satisfaction with its automation strategy: The company currently is building new state-of-the-art electronics facilities in Milwaukee and Great Britain and adding flexible automation at an existing sheet-metal operation.[5]

The benefit of CIM strategy matched with investment to Allen-Bradley has produced a 60% cost advantage over older assembly methods.[6]

While Allen-Bradley is now making life tough on its competitors world-wide, other companies' investments in AMT are not yielding benefits. These unfortunate companies invest without strategy, thereby missing opportunities to improve productivity and wasting investment capital. Using competitiveness as a gauge, Haas reports:

> The $200 billion that U.S. companies poured into new domestic facilities and equipment between 1980 and 1985 has scarcely slowed the erosion of U.S. global competitiveness. The U.S. auto industry, which alone invested $40 billion in capital improvements in that period, continues to lose ground. Six years ago, Japan's automakers were turning out subcompacts at a cost $1,500 less than Detroit's; today the gap has widened to $1,800. Nor is cost the only problem. Last year, American-made cars were still three times as likely as their Japanese counterparts to need repair in the first 12 months of ownership. Comparable cost and quality problems continue to plague nearly every corner of U.S. manufacturing industry.

Haas concludes companies lack guiding strategy and have a day-by-day operations attitude. [7] Clearly the Allen-Bradley example is the exception to the U.S. norm.

AMT's Painful System Nature

Investment in AMT is a systems investment, not a piecemeal stand-alone equipment investment. Systems investments allow information integration and are generally larger investments than stand-alone investments. AMT requires substantial investment, investment that can easily be discussed in terms of millions of dollars, $15 million in the Allen-Bradley case, or percentage of company net worth. The costly systems nature of AMT reflect the synergistic benefits to be gained from information integration.

The large investment required by AMT stuns the most progressive Western industrial managements. The result has been declining Western manufacturing competitiveness. Continuing competitive pressures and marketplace demands are forcing manufacturing companies to review their manufacturing processes and systems—and the benefits of AMT. Yet most company managements remain paralyzed at the investment justification stage. Companies fail to see strategic economic considerations that can justify the investment; they continue to use financial analysis tools which appear to be overly conservative. Companies that do move ahead take risk generally associated with entrepreneurial activity and not standard request for capital equipment. As entrepreneurs usually bet on the attractiveness and economics of a proposal, a review of AMT related economics and its desirable characteristics is in order.

The Economics Behind AMT

AMT is a technological innovation which responds to the need for enhanced manufacturing efficiency. Competitive manufacturers must

1) reduce production costs,
2) implement multi-variety small lot production,
3) shorten and sustain production lead time, and,
4) maintain high quality and low price.[8]

AMT is the innovation that can allow companies to get to the market first (3 above), with the desired products in the desired quantities (2 and 4 above) at the competitive price (1 above). The result is greater market share and profit enhancement.

Do American business executives recognize that AMT can help their companies become more competitive? Table 1 shows how 29 senior American executives rate the benefits of AMT in a recent interview survey conducter by Farley et al.[9]

Table 1

Evaluating the Importance of Automation's Benefits*

	Mean Importance	
	General Category	Specific Item
Cost Reduction	7.90	
Lower Direct Labor Cost		7.79
Lower Inventory		7.79
Fewer Rejects		6.72
Lower Costs of Materials		5.34
Lower Fixed Costs		5.21
Product Quality	7.79	
More Consistent Quality		8.62
Better Designs		6.06
More Features		5.03
Shorter New Product Lead Time	7.00	
Shorter Design Time		7.35
Shorter Tool-Up Time		6.69

*0-10 scale, with 1 not at all important and 10 very important

Farley et al review their findings:

> Of the general benefits, cost reduction is considered the most important by a small margin. Interestingly, this overall rating is not consistent with the subelements' ratings. Of the specific benefits, more consistent quality outweighs even the most important elements of cost reduction—lower labor and inventory costs. Overall, benefits of greater flexibility (e.g. more features) are seen as unimportant.

Lessons learned from the market are apparent in the survey. With the highest subelement ratings going to lower direct labor cost, lower inventory, and consistent quality, the executives appear to be telling the story about Japanese competitiveness in the U.S. automobile market. Automation is important is U.S. executives in their quest for competitiveness.

Does AMT help companies in the various aspects of competitiveness? Outlined below, the answer is yes AMT does.

Market Share

Ogawa states, "The correct way to cope with tough competition is to develop new markets or to enhance one's share of an exisitng market through the introduction of new products." [10] AMT allows companies to be more competitive in this manner through reduction of new product lead times, including shorter design time and shorter tool-up time.[11]

Cost Reduction

A sure way to competitiveness is cost reduction. An AMT investment yields many areas for saving including lower direct labor costs, lower inventory, fewer rejects, lower costs of materials, lower fixed costs, and a requirement for less floor space. [12] In the Allen-Bradley case, the company is manufacturing 4.5 times the 1982 volume as many programmable controller modules while utilizing the same amount of factory floor space. [13]

Changing Tastes

Customers' tastes are always changing causing the market to move unexpectedly. Companies must be alert to changes in consumer tastes to keep production facilities from becoming obsolete. Teresko points out that auto production in the U.S. was down one million cars in 1927 because Ford shut down factories to switch from producing Model T's to Model A's. In today's marketplace, Teresko adds, a long changeover can spell corporate suicide as customers put a premium on timely delivery. The modern automation equipment comprising AMT can be quickly reprogrammed to handle a product variation or an entirely different product, thereby allowing quick changes in response to market demands. [14]

Diversification in Demand

In addition to changing, consumers' needs have been diversified. Needs are diversified even for the same type of product. For instance, there is a vast variety of television sets available to meet the varying needs of consumers. With AMT, small batch production becomes economical allowing one plant production of an entire product range as in the case with Anderson Strathclyde Plc., Motherwell, Scotland. At Anderson the AMT system allows the production of 800 huge castings annually in 30 varieties—with no single variety requiring more than 95 units a year—the system saves 54,000 manhours annually and has trimmed inventory by $1.5 million. In making componentry for coal-cutting machinery, it slashed leadtime by 75%, from six months to six weeks. [15]

Shorter Product Life

As with the audio eight-track tape, video laser disk player and potentially the audio compact disk player, product lifetimes are becoming shorter. The automation equipment of AMT is usually general purpose equipment, conveyors, robots, or numerically controlled machine tools that is programmed or temporarily modified for a certain task. This equipment is reprogrammable and reusable for other tasks, thereby preserving investment in capital when it is time to switch the product being manufactured. Investment in AMT is protected from short lived product runs because of its flexibility.

High Quality and Low Price

Quality is the key determinant of product acceptance in the market. Customers are becomingly increasingly demanding of quality. Stauffer points out, "The robot's contribution to quality is well established. Its repetitiveness helps build quality into every function it performs and quality checks and inspections can be built into the robot's routine."[16] Thus AMT production processes can ensure high quality production as robots perform every operation in the same manner.

Desirable AMT Characteristics

Maximizing Capital Equipment Usage. Maximizing the use of capital equipment is an economic concept linking advanced manufacturing technology with business efficiency. The statement "labor productivity depends on the amount of capital equipment", is an economic law. Modern automation equipment can be used to perform a variety of operations, termed 'flexible' by industry, and can be used in the manufacture of more than one good. Thus, by using capital equipment to make different goods, capital equipment can be utilized 100% regardless of market conditions for any one good. However, the optimum 100% percent utilization (where downtime for preventative maintenance is considered utilized time) requires masterful control of company information.

Increasing utilization can increase labor productivity (total output divided total labor where total labor is direct and indirect labor). With CIM strategy enabling more efficient control of information and thus capital equipment, adoption of CIM strategy and corresponding investment in automation equipment makes good economic sense.

Operating at one hundred percent capacity is possible. The capital plant utilization approach at Chrysler Corporation's Sterling Heights, Michigan, assembly plant serves as an example. Richard E. Dauch, executive vice president for manufacturing states: "We will have the capability of adjusting our production to build 100% mid-size sport sedans, 100% compact 'P' cars, or any percentage mix of the two."[17]

This example demonstrates the promise of information control. Only through information integration does Dauch have the manipulative power to be successful with this approach. In this instance, adjusting production between models different from the floor pan up gives Chrysler cost advantages over competitors producing the same quantities at much lower capital utilization rates at two plants.

Manufacturing Agility. Another concept linking AMT to business efficiency is manufacturing agility. Today's flexible automation equipment is largely controlled by computer software which is easily changeable. Manufacturing plants with AMT are able to move from product to product with market changes. AMT eliminates production overruns and other overhead such as 30 day inventory, bestowing agility upon corporate users.

Quality Prescription and Attainment. At the London MANUTECH tradeshow in 1986 a manufacturer of robotic equipment had its robot building the convention give-away pens. The message to the convention audience was: automation allows specification of quality level and subsequent attainment. The quality of the pens was dependent on the design and the materials specified by the engineering team, not on the labor required for manufacture. AMT automation equipment produces each part identically and performs every assembly step every time. This puts the quality burden on the design engineer, not on the production line.

With AMT, companies can expect to design quality in and expect the quality to be there at the end of the production line. Overdesign necessitated by anticipated deviation from product assembly guidelines isn`t needed.

Regardless of how AMT looks on paper, the corporate world is not chasing the technology with wallets in hand. In reality, the fledgling AMT industry, termed 'sunrise' just a couple of years ago, is struggling to survive. For many companies, the problem is not having the technology to sell, but finding courageous customers to invest in AMT.

AMT and the Cautious View of Upper Management

The requirements for a successful AMT implementation are many and only begin with requiring corporate strategy and a initial investment large enough for a system implementation. Farley et al identified four problem areas for review in their survey of American executives: gaining initial management approval, employee resistance, starting up the system, and keeping the system running (table 2).[18]

> 'Human' problems, particularly employee resistance and gaining initial management approval, were perceived as most important. Respondents also anticipated start-up problems, but reliability was perceived as less problematic. Table 2 also shows that respondents ratedthe problems as less important than the benefits on an absolute scale.[19]

Table 2 [20]

Evaluating the Importance of Automation's Problems*

	Mean Importance	
	General Category	Specific Item
Gaining Initial Management Approval	4.54	
Insufficient Short Term Benefits		5.21
Initial Investment		5.00
Insufficient Long-Term Benefits		3.32
Plant Will Become Obsolete		2.86
Downstream Costs Scary		2.50
Employee Resistance	4.50	
Hourly Workers		3.43
Factory Floor Management		2.96
Finding Good Maintenance and Technical Support		5.46
Plant Management		3.75
Engineers		3.36
Startup and Breakin	4.32	
Design and Debugging		5.75
Integration		5.14
Software Shortage		2.96
Keeping the System Running	3.79	
Short Production Runs		4.43
Bypassing a Process When Down		3.39
New Product Introductions		2.74

*0-10 scale, with 1 not at all important and 10 very important

At the root of the problem is the way Western management justifies AMT. Simply, the strong positive economics of AMT (i.e. maximizing use of capital equipment, manufacturing agility, etc) are not being included in the financial justification. This manifests itself in opinion data where insufficient short term benefits and initial investment score relatively high as problems. Currently used conservative discounted cash flow techniques do not take accurate accounting of AMT benefits, resulting in management believing there are insufficient benefits when the obstacle is the justification procedure.

Justification Problems

Financial justification of AMT is troublesome for the following reasons which have been summarized by Suresh and Meredith[21].

High Capital Costs and Risk. High capital cost and the risks involved suppress investment in AMT. AMT capital costs are much higher and the payback period much longer than conventional machine tools. AMT also poses higher risks due to, for most firms, unfamiliar technology and the fact that it has system wide implications. Coupled with the inherent manufacturer's bias toward short-term results and risk aversion, Western industries have invested in areas without the high capital costs, risk levels and sophistication of technology.

Myopic Approaches to Equipment Justification. Western industry primarily relies on the payback method in considering investment proposals. The payback is limiting because it neglects returns after the payback period, emphasizes liquidity, etc. The use of this method almost guarantees rejection of investment in AMT.

Inappropriate Capital Budgeting Procedures. Conventional machine tool capital budgeting procedures are used for AMT capital budgeting procedures. Thus capital budgeting for AMT tends to be bottom-up, be subject to narrow levels of analysis, restrained by traditional capital budgeting procedures for evaluation, which virtually guarantees that companies will defer investment in AMT.

The Difficulty of Quantifying Indirect Benefits. Significant AMT benefits are indirect. The capital budgeting procedures used in industry are still first order (cost avoidance, such as labor savings) as opposed to a second order (strategic considerations, such as increasing response times) analysis. AMT promises reductions in throughput time, work-in-process (WIP) inventory reductions, and other reductions typically difficult to measure. Inadequate tracking systems exclude many major savings areas in the justification exercise, which contributes to showing inaccurately long payback periods for AMT investment. Additionally, there is considerable scope for conjecture when it comes to evaluating such savings items as strategic value of 'quality increases'. Existing capital budgeting procedures have also been seen to be too quantitatively oriented and tend to emphasize single-valued criteria such as return-on-investment or net-present-value and do not favorably consider conjectures concerning strategic advantages.

Prediction of Benefits over an Extended Period of Time. AMT demands longer investment planning horizons which require estimation of distant future performance and distant future cash flows. Market forces and operating policies play a significant role in determining these cash flows and systems performances, complicating estimation of these factors.

Technological Uncertainties. The rapid evolution of new technologies has created a sizable knowledge gap between the benefits available from investment in stand alone capital equipment and the benefits of investment in total manufacturing systems among both manufacturing and financial professionals. This has reinforced a 'wait and see' attitude, favoring rejection of proposals.

Inadequacies in Costing Methods. Conventional cost accounting has its origins in mass production and classical job shop situations. In the job shop situation, a major focus of control is direct labor time through elaborate time standards and work measurements. As the material proceeds from work center to work center, overhead allocations are typically made on the basis of direct labor. This tracking system is inadequate for use with AMT systems and poses difficulty with evaluating indirect benefits.

Differing Nature of Operations. AMT introduces different methods of operation and control, thereby radically changing the structure of a company. This structural reconfiguration is often overlooked and must be taken into account.[22]

Analysis Still Based on Subsystems and Suboptimization. Mathematical models based on operations research have been characterized by single-valued criteria and tend to focus on subsystems and not systems.[23] Engineering economy continues to be formula oriented, emphasizing such factors as cost of capital, tax rates, inflation rates and the corresponding sensitivity analyses. These are applicable for traditional, stand alone technologies at the tactical level of decision making, but not for integrated systems. AMT requires analyses based on multiple-criteria decision making approaches and capital budgeting procedures geared to system wide analyses. Cash flows arising from systems is an aspect which must be included in a net-present-value type financial analysis.

The Misleading Financial Justifications

George Kuper, executive director of the Manufacturing Studies Board, National Academy of Sciences (Washington, D.C.) makes some pointed observations,

> "If you look at the way we cost things now, we're relying on an antique system. Thus, there is currently no good solution to the cost justification problem, because there are no definitive answers.
>
> Kuper continues, "The reason we're talking about cost justification for robotics and automated technologies, in general, is because we don't have the fire in our bellies that's necessary to go out and make the stuff work for us.
>
> Kuper believes there are two basic problems that are being camouflaged by cost justification arguments. "One is a lack of understanding of how the investment is going to make a strategic impact on the business. We just don't think it through enough to figure that out. The second involves the systems nature of the technology that we have to acquire now for our factories. This means it's extremely expensive, and the paybacks are going to come from other than direct cost avoidance. They'll come from organizational design issues being remedied, which are very hard for mid-level managers to capture. Generally, this has to be done by the boss.
>
> In other words," he continues, "we're talking about removing layers of middle management entirely. And it's not just unit cost reduction we're after. We're looking

> at a full-scale revolution in some respects. And that's very hard for a midlevel manager to understand and justify.♦[10]♦

Kaplan supports Kuper's assertions:

> When the Yamazaki Machinery Company in Japan installed an $18 million flexible manufacturing system, the results were truly startling: a reduction in machines from 68 to 18, in employees from 215 to 12, in the floor space needed for production from 103,000 square feet to 30,000, and in average processing time from 35 days to 1.5. After two years, however, total savings came to only $6.9 million, $3.9 million of which has flowed from a one-time cut in inventory. Even if the system continued to produce annual labor savings of $1.5 million for 20 years, the project's return would be less than 10% per year. Since many U.S. companies use hurdle rates of 15% or higher and payback periods of five years or less, they would find it hard to justify this investment in new technology——despite its enormous savings in number of employees, floor space, inventory, and through put times. [24]

Not surprisingly then, investment in AMT has perplexed the majority of Western businesses because businessman continue to overlook strategic market economics in search for traditional numerical arguments. Considerable attention has been given to AMT's complex systems nature which drives the cost and thus the associated risk of the projected benefits to very high absolute amounts, or in relative terms, a high percentage of corporate net worth [25]. In response to the confusion, many numerical and non-numerical justification schemes have been proposed but discounted cash flow analysis cannot logically be abandoned in search of potentially biased arguments for investment in AMT. [26]

With the logic of the time value of money seemingly indisputable, surely discounted cash flow (DCF) investment justification analysis can be applied to gain a more representative investment analysis. The key to success is understanding of the economics linking AMT to business efficiency which will instill confidence when nontraditional revenue streams, such as factory floor savings are brought into DCF analyses.

Kaplan has provided an excellent discussion on appropriate application of discounted cash flow techniques to proposed AMT investment. The example used in his discussion is presented here.[27]

Example of a FMS Justification Analysis [28]

With the following analysis, one U.S. manufacturer of air-handling equipment justified its investment in an FMS installation for producing a key component:

1
Internal manufacture of the component is essential for the division's long-term strategy to maintain its capability to design and manufacture a proprietary product.

2
The component has been manufactured on mostly conventional equipment——some numerically controlled——with an average age of 23 years. To manufacture a product in conformance with current quality specifications, the company must replace this equipment with new conventional equipment or advanced technology.

3
The alternatives are:

Conventional or numerically controlled stand-alone.
Transfer line.
Machining cells.
FMS.

4
FMS compares with conventional technology as Table 3 shows.

5
Intangible benefits include a virtually unlimited flexibility for FMS to modify the mix of component models to the exact requirements of the assembly department.

6
The financial analysis for a project life of ten years compares the FMS with conventional technology (static sales assumptions, constant, or base-year, dollars) as Table 4 shows.

7
With dynamic sales assumptions showing expected increases in production volume, the annual operating savings will double in future years and the financial yield (still using constant, base-year, dollars) will increase to more than 17% per year.

On the basis of this analysis and recognizing the value of the intangible item (5), which had not been incorporated formally, the company selected the FMS option.

Table 3

	Conventional Equipment	FMS
Utilization	30%-40%	80%-90%
Number of employees needed including indirect workers, such as those who do materials handling, inspection, and rework)*	52	14
Reduced scrap and rework	-	$60,000 annually
Inventory	$2,000,000	$1,100,000#
Incremental investment	-	$9,200,000

* Each employee costs $36,000 a year in wages and fringe benefits.
\# Inventory reductions because of shorter lead times and flexibility.

Table 4

Year	Investment	Operating Savings	Tax Savings ITC and ACRS Depreciation	After-tax Cash Flow 50%
0	$9,200	$ 900α	$ 920	$ -7,380
1		1,428β	1311	1,370π
2		1,428	1923	1,675
3		1,428	1835	1,632
4		1,428	1835	1,632
5		1,428	1835	1,632
6		1,428		714
7		1,428		714
8		1,428		714
9		1,428		714
10		1,428		714

After-tax yield: 11.1%.
Payback period: during year 5.

α $ 900 = Inventory reduction at start of project.
β $ 1,428 = 38 fewer employees at $36,000/year + $60,000 scrap and rework savings.
π $ 1,370 = (1,428)(1-0.50) + (1,311)(0.50).

Survey

Some managers are beginning to consider AMT important. How important? Vitally important. In the words of Jack Ring, director of long range planning at Honeywell Inc.,, Phoenix, "The survivors in manufacturing are those who are now getting ready to live in AMT." [29]

It is a well-publicized view that a key reason for US and UK loss of leadership in many important industries has been failure to implement advanced manufacturing technology. Haas' statistics show there has not been any widespread improvement in U.S. competitiveness during the 1980's. At the heart of the implementation problem is still another problem, which can be summed up in a word: justification. It represents one of the toughest challenges facing today's manufacturing engineers and managers. Getting top management commitment to accept and implement automated systems is a major task.

How many managers share Mr. Ring's view and how has the implementation/justification problem affected companies? A questionnaire survey was conducted during the last quarter of 1986 at the University of Bristol and the area chosen was southwestern England and southern Wales. The purpose of the survey was to elicit the attitude of the surrounding British industry toward AMT. An attitude survey was thought necessary as sales data reflecting investment in new capital plant gives little indication of how effectively the new investment is being used.

For example, an assembly plant in south Wales owned by a multinational consumer electronics manufacturer discarded recently acquired tooling. The reason being that product design change made the equipment useless. Reviewing sales data, such as the sale of the tooling in the example, does not indicate the amount of money spent on technology that is actually performing effectively. The method to elicit information regarding AMT was to question company managers.

Four hundred questionnaires were sent to middle and upper level managers in medium to large size firms (Appendix 2). Fifty questionnaires or 12.5% were returned. The results of the survey appear conclusive. Investment has been kept low, avoiding risk, and thereby preventing system wide implementation. The survey shows management accepting and believing they understand AMT concepts but unable to justify large expenditure. In essence, the survey shows managers very conservative when it comes to AMT investment analysis.

The companies responding to the survey were generally divisions of large or private limited UK companies. The divisions had large numbers of employees, vendors, and customers. The companies batch produced a variety of products. Over 60% of the respondents were in either the electrical goods, metal products, or transport equipment manufacturing industries (Appendix 2—Company Background). The responses came from companies and industries likely to benefit from AMT.

The responses show these companies have adopted computerized subsystems such as production planning and control and inventory control (Appendix 2—Computer Facilities and Usage). These subsystems are department-wide, have smaller risk and require less planning than AMT. These departmental systems seem to indicate a willingness to adopt new technology, albeit in a modular manner.

A key indicator of technological acceptance is the respect of top management for AMT. As seen by from table 5, 90% of management is favorable to automation technology. This view is crucial as the large investments and organizational adoption require top management commitment.

Table 5

Managerial View of Industrial Automation Technology	
Strategic, Vital to Future	63%
Part of Everyday Business	27%
Management is Generally Resistive	8%
No Response	2%

Technologically, companies do not feel overwhelmed by automation (table 6). This result is encouraging as attitude toward new technology is critical for success. The 58% team view (table 7) of technology is also favorable to success with new technology, as is 73% indicating ability to develop proficiency within staff (table 8). The factors inhibiting progress in advanced manufacturing technologies do not appear to be associated with lack of competence or confidence.

Table 6

Company Feels Overwhelmed by Technology	
Yes	8%
No	75%
No Response	17%

Table 7

Number of People with Overall View of Technology	
One Man	6%
Team	58%
No One	15%
No Response	21%

Table 8

Company Able to Develop Proficiency within Staff	
Yes	73%
No	4%
No Response	23%

Tables 9 and 10 however show a telling sign of attitude and action toward AMT. There is a lack of project simulation and broad front implementation. Total system implementation is the only approach to automation as piecewise automation doesn't return the global or systems benefits that 'broad front' automation does. Almost half, 44%, of the companies responding indicate they are not investing in systems but in subsystem flexible manufacturing modules and cells (table 11). Only 11% have invested in complete lines of automation (table 11).

Table 9

Furthest Planning Stage before Implementation	
Design	48%
Simulation	13%
Prototype	21%
No Response	29%

Table 10

Manner which Company is Implementing Automation	
Broad Front	19%
"Piecewise"	58%
No Response	23%

Table 11

Most Advanced Efforts	
Flexible Manufacturing Module	25%
Flexible Manufacturing Cell	19%
Flexible Manufacturing Line	13%
No Response	44%

The affirmative response (table 12) signalling ability to analytically determine financial viability indicates that piecewise automation is being justified currently. The methods used are traditional (table 13), reported to handle automation benefits (table 14), and are reported changing to accept more automation benefits (table 15).

Table 12

Analytically Able to Determine Financial Viability	
Yes	54%
No	10%
No Response	35%

Table 13

Was Analysis of IA Done	
Newly Developed	19%
Traditional	29%
No Response	52%

Table 14

Present Accounting Procedures Able to Handle Benefits	
Yes	44%
No	15%
No Response	42%

Table 15

Are Accounting Procedures Changing to Accommodate Benefits	
Yes	33%
No	13%
No Response	54%

Companies say that they are able to determine the financial viability of their investments. However, table 16 reveals a major factor slowing adoption of AMT. The four benefits listed are the benefits created by synergy of the system. These benefits are not being considered in discounted cash flow (DCF) or net present value (NPV) analyses. Without these benefits, the initial investment level drops, precluding large systems investments. The result is a self fulfilling prophecy: benefits are not included in the justification thereby limiting investment to subsystems and, when installed, the subsystems do not deliver the synergistic benefits of AMT systems. Executives invest in AMT for strategic benefits (table 17). However, the benefits they do receive are not strategic, are disappointing, and, in all likelihood, foster a 'go slow' approach. Unfortunately, 'going slow' keeps companies distanced from the competitiveness AMT has to offer.

Table 16

Intangible Benefits Quantified and Included in Justification	Yes	No / NR
Flexibility	17%	83%
Boost Quality Level	44%	56%
Achieve Quality Goals	27%	73%
Response to Market Changes	25%	75%

Table 17

Reason for Investment in Automation	
Panacea	13%
Strategy	48%
Chance	0%
No Response	40%

Keeping intangible benefits out of automation not only prescribes subsystems but keeps corporate growth down. Leaving any benefit, tangible or intangible, out of DCF or NPV calculations closes the door on revenue streams that can belong to the company. Teresko quotes Henry Ford, "You pay for the investment whether you purchase or not."[30]

Kaplan comments,

> Although intangible benefits may be difficult to quantify, there is no reason to value them at zero in a capital expenditure analysis. Zero is, after all, no

> less arbitrary than any other number. Conservative accountants who assign zero values to many intangible benefits prefer being precisely wrong to being vaguely right.[31]

Favorable responses were in key areas such as managerial view of AMT, staff resistance to technology, staff facility with the new technology, and lack of negative labor and public opinion influences (Appendix 2). Unfortunately, the data clearly represents restrained financial justification procedures limiting investment levels. The idea of automating a little bit at a time or "piecewise" does not raise alarms on the first sounding, after all, AMT is an expensive beast that could be best purchased in bite sized pieces. However, AMT doesn't really reward investors until the entire setup is in operation, much like no elephant pulls until one has the whole elephant.

The survey corroborates what US and UK industry journalists [32] have been writing about for months: manufacturing managements are perplexed and paralyzed by the task of justifying large scale investment in AMT.

Summary and Conclusion

The survey was conducted, as mentioned above, in southwestern England and southern Wales. The survey can be considered as part of a whole, with the whole being all of the Western manufacturing societies. The survey results should not be extrapolated to make sweeping generalizations regarding the state of management expertise with AMT financial justification for the entire United Kingdom or Western manufacturing societies as a whole. What can be of interest to readers is the lack of systemwide investment and the corresponding cry that, as reported in journals, the investments are not yielding strategic benefits.

AMT is widely agreed upon as the future for manufacturing in Western societies. Without AMT, the high cost of Western labor dictates that, in general, products will be assembled in countries with low labor rates. Overseas labor is not an in view of successes like Allen-Bradley. Allen-Bradley is close to its market, both its suppliers and its customers. Delivery times therefore are low, inventory is not on container ships in the middle of the ocean, et cetera. But AMT is not as easy to become familiar with as we would like it to be. AMT requires change of business, almost entirely, is costly, and has to be adopted all-at-once not section-by-section. These characteristics and traditionally applied financial decision tools challenge businessmen to take large risk. As O'Rourke said, "justification has to become more of a policy decision than an accounting practice," and that policy was to take the risk on AMT and make it work for Allen-Bradley.

Appendix 1—Survey Questionnaire

UNIVERSITY OF BRISTOL
Department of Mechanical Engineering

Professor of Mechanical Engineering
Head of Department
E G Ellison BSc PhD CEng FIMechE

Queen's Building
University Walk
Bristol
BS8 1TR

telephone: (0272) 303030
direct line: (0272)

Dear Sir/Madam

The Mechanical Engineering Department at the University of Bristol is conducting research in manufacturing automation. We feel that a review of progress in manufacturing automation is entirely appropriate at this time. We ask of you to assist us in this task by answering the attached questionnaire. Your participation and that of others in manufacturing industries will allow us to provide information regarding the nation's automation successfulness.

Great care has been taken to prepare an efficient questionnaire. We hope that you will find the questionnaire thought inspiring as well as respectful of your valuable time.

Please help us by using your own envelope to return the questionnaire and this letter to the following address:

Mr. D. B. Hoffer
c/o Mr. K. Khodabandehloo
Mechanical Engineering Department
University of Bristol
Queen's Building
University Walk
Bristol BS8 1TR

Please find details of other research and interest areas on the last page of the questionnaire.

No reference will be made to the source of information in the publishing of this research.

Thank you for your time and for aiding British industry.

Sincerely yours,

Dana Bryan Hoffer
Researcher

Sincerely yours,

Koorosh Khodabandehloo
Lecturer

__ Please tick if you care to have a copy of the research findings sent to you.

University of Bristol
Mechanical Engineering Department

QUESTIONNAIRE

INDUSTRIAL AUTOMATION IN THE UNITED KINGDOM

Please circle or tick your selection to indicate your response.

Company Background

Industry		
	Electrical goods manufacturing	1
	Food industries manufacturing	2
	Instrument manufacturing	3
	Machinery manufacturing	4
	Metal products manufacturing	5
	Transport equipment mfg	6
	Other	7

The principal ownership of the company is:

UK USA EEC Japan Other

The company is: State owned Limited liability Private

And is: an individual company a division of a larger company

On your site the approximate employment is:

less than 25 25-49 50-99 100-199 200-400 more than 400

The approximate number of vendors to your company is:

less than 25 25-49 50-99 100-199 200-400 more than 400

The approximate number of customers your company supplies is:

less than 25 25-49 50-99 100-199 200-400 more than 400

The approximate number of products your company produces is:

less than 25 25-49 50-99 100-199 200-400 more than 400

The predominant method of production at your facility is:

Job Batch Mass production

Computer Facilities

Does your company have computing facilities? Yes No

How would you categorise the facilities?

On-site or Off-site mainframe Mini Bureau Micro

Computer Usage

Do you currently use a computer to assist in any of the procedures listed below? Please circle 'yes' or 'no' for each procedure. If 'no', please indicate with the appropriate number if the use of a computer

1 is being considered
2 has been considered and rejected
3 has been tried and abandoned
4 has not been considered

Production planning & control	Y	N	1	2	3	4
Sales order entry to Prod Plan & Control	Y	N	1	2	3	4
Sales order entry to production & design	Y	N	1	2	3	4
Inventory control	Y	N	1	2	3	4
Supplier order generation	Y	N	1	2	3	4
Raw material stock control	Y	N	1	2	3	4
Just-in-time stock control	Y	N	1	2	3	4
Work-in-progress stock control	Y	N	1	2	3	4
Computer aided design	Y	N	1	2	3	4
Parts list post to Prod Plan & Control	Y	N	1	2	3	4
Computer assisted redeploy of manufacturing	Y	N	1	2	3	4
Automatic update to manufacturing line	Y	N	1	2	3	4
NC generation-CAM	Y	N	1	2	3	4
Robotics	Y	N	1	2	3	4
Shop floor data collection	Y	N	1	2	3	4
Time/cost estimating	Y	N	1	2	3	4
Materials estimating	Y	N	1	2	3	4
Performance analysis	Y	N	1	2	3	4
Maintenance	Y	N	1	2	3	4
Raw material/production quality control	Y	N	1	2	3	4

Production Management Computing Resource

Is the production management computing resource:

On-site or Off-site mainframe Mini Bureau Micro

Was the reason for computerisation:

a panacea part of corporate strategy chance happening

How was the system justified: part of a computerisation budget

return on investment analysis conducted

Is the software that is being used:

custom coded pre-packaged combination of both

Was a design team organised to oversee computerisation: Yes No

Who was on the design team: hardware/software vendor

professional consultant your managing director

your production manager plant foreman any plant labour

Did you receive support from your hardware supplier: Yes No

Did you receive support from your software supplier: Yes No

Did your personnel require formal training: Yes No

Industrial Automation Resource

Would you describe your most advanced efforts in industrial automation as:

Flexible mfg module Flex mfg cell Flex mfg line

Was the reason for automation:

a panacea part of corporate strategy chance happening

How was the system justified: part of a computerisation budget

return on investment analysis conducted

Is the associated overhead: within projections unknown

Is the automation implemented:

custom designed pre-packaged combination of both

Was a design team organised to oversee automation: Yes No

Who was on the design team: equipment vendor

professional consultant your production manager

your engineering manager plant foreman any plant labour

Did you receive planning support from the equipment vendor: Yes No

Did you receive programming support from your vendor: Yes No

Economic Justification

Was your company able to analytically determine the financial viability of the industrial automation resource: Yes No

If yes, was the scheme used: newly developed traditional

Industrial automation has intangible benefits associated with it. Were you able to quantify any of the following intangible benefits to incorporate into a financial justification:

flexibility gained from soft automation (as opposed to hard)

greater control over goods quality level of production

higher level of quality goals achievement

ability to vary production to respond to market changes

Does your company use market forecasts to determine investment levels in automation: Yes No

Does your company believe that if its methods of production remain the same over time that the effects are:

positive negative neither positive or negative

Has your company found its accounting procedures:

able to handle the benefits of automation technology? Yes No

changing to accommodate these benefits? Yes No

Managerial Decision

How does your company's management view automation technology:

strategic, vital to future part of everyday business

management is generally resistive to accept new technology

Is the drive to use automation technology coming from:

manufacturing production engineering director-level

Is your company's commitment to automation:

total   trial   image only

Does your company have an automation technology manager:

in place   planned   not thought necessary

Has your company found staff resistance to technology:

manageable   unmanageable   no staff resistance

Have you been able to project and manage manpower commitment: Y N

Technological

Does your company feel overwhelmed by automation technology: Yes No

How many people at your company have an overall view of automation technology:

one man   team   no one

What stage of planning does your company go to before commencing with implementation:

design   simulation   prototype

Is your company automating: on a broad front   "piecewise"

Is your company able to develop proficiency within staff: yes no

Labour

After implementing automation technology, have you found relations with labour unions to be: changed unchanged

Have you found labour unions to be adversely affecting automation implementation: yes no

Public Opinion

Has public opinion ever entered into any decision process to automate factories: yes no

Area for your business card (requested, not required):

ROBOTICS AND AUTOMATION IN THE MECHANICAL ENGINEERING DEPARTMENT

Robotics and Automation Courses

Course Title
-Manufacturing Systems I - Robotics (Part of MEng Degree Course)
-Introduction to Robotics and Hands-on Robot Programming (Extra-Mural)
-Control and Robotics (Part of MEng Degree Course)
-Manufacturing Systems II - FMS (Part of MEng Degree Course)
-Hands-on Courses in: Computer Vision Technology, Sensor Guided Robotics, Performance Evaluation of Robotics

Robotic and Related Equipment

-Reflex Robot with AR-Basic & AR-Smart
-Puma 550 with VAL 1
-AV4 Computer Vision System
-Newall Hydraulic Robot
-GRASP Software
-Other Allied Robotics Equipment and Teaching Robots

Robotic Related Research Project Areas

-Intelligent Robot Systems

-Computer Aided Design and Reliability Analysis of Manufacturing Systems

-Mechanical Hands with Sensors

-Fault Tolerant Control System Design and Analysis

-Robotics and Automation in the Food Industry

Contact Mr K Khodabandehloo - Robotics and Manufacturing Systems Group

Department of Mechanical Engineering, University of Bristol
Queen's Building, University Walk
Bristol BS8 1TR

Tel (0272) 303030 ext 3240/3380 or (0272) 303240 direct

Appendix 2—Survey Data

Total Questionnaires Returned: 48

Company Background

Industry

Electrical Goods Manufacturing	19%
Food Industries Manufacturing	0%
Instrument Manufacturing	4%
Machinery Manufacturing	4%
Metal Products Manufacturing	31%
Transport Equipment Manufacturing	13%
Other	31%

Ownership		Type of Company		Sovereignty	
UK	73%	State	0%	Division	75%
USA	19%	Limited	71%	Individual	19%
EEC	4%	PLC	2%	No Response	6%
Japan	4%	Private	21%		
Other	0%	No Response	6%		

Business Volumes

	Employment #	# Vendors	# Customers	Number of Products
<25	2%	6%	4%	23%
25-49	2%	6%	2%	4%
50-99	10%	10%	8%	13%
100-199	17%	19%	21%	8%
200-400	44%	35%	17%	8%
400+	25%	21%	46%	35%
No Response	0%	2%	2%	8%

Production Methods

Job	10%
Batch	75%
Mass	10%
No Response	4%

Appendix 2—Survey Data

Total Questionnaires Returned: 48

Computer Facilities & Usage

	Y	N	N1	N2	N3	N4	NR
Production Planning & Control	65%	0%	21%	6%	2%	2%	4%
Sales Order Entry to PP&C	69%	0%	19%	2%	0%	6%	4%
Sales Order Entry to P & D	48%	4%	23%	4%	0%	8%	13%
Inventory Control	79%	0%	15%	2%	0%	0%	4%
Supplier Order Generation	58%	2%	27%	2%	0%	2%	8%
Raw Material Stock Control	75%	2%	17%	2%	0%	2%	2%
Just-in-time Stock Control	25%	4%	27%	10%	0%	19%	15%
WIP Stock Control	48%	0%	31%	6%	0%	6%	8%
Computer Aided Design	31%	10%	33%	6%	2%	8%	8%
Parts List Post to PP&C	54%	2%	25%	0%	0%	10%	8%
Comp Assist Redeploy of Mfg	8%	6%	21%	6%	0%	40%	19%
Auto Update to Mfg Line	8%	6%	27%	4%	0%	42%	13%
NC Generation-CAM	21%	8%	10%	4%	2%	40%	15%
Robotics	23%	8%	23%	8%	0%	27%	10%
Shop Floor Data Collection	23%	0%	48%	6%	0%	15%	8%
Time/cost Estimating	35%	6%	21%	8%	2%	21%	6%
Materials Estimating	46%	6%	19%	6%	2%	17%	4%
Performance Analysis	44%	4%	40%	0%	0%	4%	8%
Maintenance	21%	6%	25%	4%	2%	27%	15%
Raw matl/prod Quality Control	42%	6%	29%	2%	0%	10%	10%

Y - Have technology in place.
N - Do not have technology.
N1 - Are considering technology.
N2 - Have rejected technology.
N3 - Have tried and abandoned technology.
N4 - Have not considered technology.
NR - No Response No response

Appendix 2—Survey Data

Total Questionnaires Returned 48

Production Management Computing Resource

Reason for Investment		Justification		Software	
Panacea	8%	ROI Analysis	31%	Custom	13%
Strategy	77%	Budget	44%	Pre-packaged	15%
Chance	0%	No Response	27%	Combination	54%
No Response	17%			No Response	19%

Design Team Personnel*

Vendor	33%
Professional Consultant	23%
Managing Director	17%
Production Manager	44%
Plant Foreman	2%
Plant Labor	2%
No Response	38%

* Frequency count
- Total > 100%

Hardware Supplier Support

Yes	54%
No	19%
No Response	27%

Software Supplier Support

Yes	67%
No	6%
No Response	27%

Personnel Required Training

Yes	73%
No	6%
-	21%

Appendix 2—Survey Data

Total Questionnaires Returned: 48

Industrial Automation Resource

Justification	
ROI Analysis	46%
Budget	13%
No Response	42%

Associated Overhead	
Within Projections	42%
Unknown	15%
No Response	44%

Most Advance Efforts	
Flexible Mfg Module	25%
Flexible Mfg Cell	19%
Flexible Mfg Line	13%
No Response	44%

Reason for Investment	
Panacea	13%
Strategy	48%
Chance	0%
No Response	40%

Automation Implemented	
Custom Designed	19%
Pre-packaged	10%
Combination	31%
No Response	40%

Design Team Personnel*	
Vendor	33%
Professional Consultant	13%
Production Manager	38%
Engineering Manager	40%
Plant Foreman	17%
Plant Labor	6%
No Response	42%

* Frequency count
Total > 100%

Vendor Planning Support	
Yes	54%
No	10%
No Response	35%

Vendor Programming Support	
Yes	54%
No	8%
No Response	38%

Appendix 2—Survey Data

Total Questionnaires Returned 48

Economic Justification

Analytically Able to Determine Financial Viability		Was Analysis of IA Done	
Yes	54%	Newly Developed	19%
No	10%	Traditional	29%
-	35%	-	52%

Intangible Benefits Quantified and Included in Justification

	Yes	No / -
Flexibility	17%	83%
Boost Quality Level	44%	56%
Achieve Quality Goals	27%	73%
Response to Market Changes	25%	75%

Investment Levels Determined by Market Forecasts		Effect if Methods of Production Remain the Same Over Time	
Yes	50%	Positive	13%
No	21%	Negative	42%
-	29%	Neither + or -	13%
		-	33%

Present Accounting Procedures Able to Handle Benefits	
Yes	44%
No	15%
-	42%

Are Accounting Procedures Changing to Accommodate Benefits	
Yes	33%
No	13%
-	54%

- equals No Response

Appendix 2—Survey Data

Total Questionnaires Return 48

Managerial Decision

Managerial View of Industrial Automation Technology

Strategic, Vital to Future	63%
Part of Everyday Business	27%
Management is Generally Resistive	8%
-	2%

Drive to Automation Technology Coming From

Manufacturing	27%
Production	38%
Engineering	31%
Director Level	65%
-	10%

Company Commitment to Automation

Total	46%
Trial	35%
Image Only	2%
-	17%

Company Have Automation Technology Manager

In Place	17%
Planned	0%
Not thought Necessary	67%
-	17%

Staff Resistance to New Technology

Manageable	42%
Unmanagable	0%
No Staff Resistance	42%
-	17%

Able to Project and Manage Manpower Commitment

Yes	73%	- equals
No	6%	No Response
-	21%	

Appendix 2—Survey Data

Total Questionnaires Return 48

Technological

Company Feels Overwhelmed by Technology

Yes	8%
No	75%
-	17%

Number of People with Overall View of Technology

One Man	6%
Team	58%
No One	15%
-	21%

Furthest Planning Stage before Implementation

Design	48%
Simulation	13%
Prototype	21%
-	29%

Manner which Company is Implementing Automation

Broad Front	19%
"Piecewise"	58%
-	23%

Company Able to Develop Proficiency within Staff

Yes	73%
No	4%
-	23%

- equals No Response

Labor

Have Relations with Labor Unions Changed after Implementing Automation

Changed	15%
Unchanged	54%
-	31%

Are Labor Unions Adversely Affecting Automation Plans

Yes	13%
No	52%
-	35%

Appendix 2—Survey Data

Public Opinion

Public Opinion a Consideration

Yes	2%
No	79%
-	19%

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