"TECHNOLOGY, WORK, AND THE ORGANIZATION: THE IMPACT OF EXPERT SYSTEMS"

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Technology, Work, and the Organization:

The Impact of Expert Systems

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Abstract

This article examines the near term impact of expert system technology on work and the organization. First, an approach is taken for forecasting the likely extent of diffusion, or "success", of the technology, under the assumption that extent of diffusion is linked to extent of impact. It is stressed that any attempt at predicting the growth potential of the expert system market should be based upon good market research and not on an extrapolation of purely technical capabilities. Next, an attempt is made to understand the complex relationship between technology, and organizational structures and skill requirements by examining the case of advanced manufacturing technologies. From this analysis, a framework is constructed for viewing the impact of these technologies, and of technologies in general, as a function of the technology itself, market realities, and personal, organizational and societal values and policy choices. Applying this framework to expert systems, two scenarios are proposed. The first concludes that expert systems will have little impact on the nature of work and the organization. The second scenario posits that expert system diffusion will be pulled by, and will be a contributing factor towards the evolution of the lean, flexible, knowledge intensive "post-industrial" organization.

> Over the last decade a new technology has begun to take hold in .... business, one so new that its significance is still difficult to evaluate. While many aspects of this technology are uncertain, it seems clear that it will move into the managerial scene rapidly, with definite and far reaching impact on managerial organization.
>
> Harold Leavitt and Thomas Whisler
> "Management in the 1980's"
> Harvard Business Review
> November - December 1958

I. Introduction

Some thirty years from the publication of the article which began with the above quotation, the impact of technology on business is still being discussed, debated, predicted and assessed. Indeed, while the technology itself advances at seemingly breakneck speed, the questions surrounding the technology have remained remarkably stagnant:

> How will (or should) organizational structures change?
>
> How will current jobs and tasks change?
>
> Will some jobs disappear altogether? Which jobs will be created? What net change in number of jobs will occur?
>
> What can be expected as the ripples of secondary and tertiary effects - social, economic and political - are realized?
>
> How can government, industry, academia and labor best plan for (or direct) technological innovations and their impact?

These questions constitute an imposing intellectual pie. The focus of this paper is on but a small piece of the pie: to examine the impact of one technology, expert systems, on non-skilled, semi-skilled, skilled workers and first line management, over the coming three to five year time period.

Assessing trends and future events is a forecasting problem. This paper approaches estimating the impact of expert systems from this perspective. Two different but related forecasts are required: the first is an estimate of the extent of diffusion or success of expert system technology in the marketplace, and the second involves determining the actual impact of the technology once in place. While I do tread on dangerous ground and suggest possible future scenarios, the major thrust of this work is to stipulate an appropriate methodology for forecasting the impact of a technology in general, and expert systems in particular.

Further, I argue that the diffusion and impact of a technology is never purely a function of the technology itself. Rather the extent and manner of use of a technology is a complex function of the technology, market forces, and the values and policy choices of the society, organization, and individuals which make up the environment in which the technology is introduced.

The paper is organized in the following fashion. Section II is a working definition of expert systems. Section III discusses the artful science of forecasting and begins to specify the implications for this work. Section IV continues this theme, more specifically looking at the forecasting process for new products and markets. Section V outlines the current manufacturing environment and attempts to draw parallels between recent technological advances in manufacturing, and expert systems. A model for better understanding and communicating the impact of a technology is proposed in section VI; then, the focus is drawn back to expert systems with the suggestion of two likely scenarios over the three to five year horizon. Section VII provides a summary and suggests directions for future research.

II. Expert Systems

> I have one final thing to tell you; I am not actually a human being. I am in fact a robot built by Marvin Minsky in 1968.
>
> Michael Arbib, Professor of Biomedical Engineering, Computer Science, Neurobiology, and Physiology, at a recent conference on the Mind - Body Problem, 1987

Expert systems (ES's) are computer programs for solving difficult, "fuzzy" problems in domains where human expertise is normally associated with a great deal of training and experience. Verifiable application areas to date include such domains as medical diagnosis, chemical analysis and computer system configuration. Expert systems are typically characterized by:

Performance levels at, or exceeding, those of experts in the problem domain.

The utilization of large amounts of domain specific knowledge.

The ability to use incomplete or uncertain information.

The capacity to explain their behavior (a kind of self-knowledge).

A logical and physical separation of the domain knowledge contained in the system, and the mechanism by which that knowledge is accessed and utilized.

Symbol manipulation, that is "reasoning" about objects, as opposed to numerical manipulation (which typifies traditional computer programs).

The power of expert systems hinges on the appropriate utilization of the heuristic knowledge, or "rules of thumb" that human experts utilize during problem solving. The term "knowledge based system" is used somewhat interchangeably with that of "expert system", but while the former stresses the source of expertise, the latter implies its degree. The benefits of this technology are impressive. Expert systems:

Can solve, or assist in solving difficult problems that have eluded previous solution by other computer based technologies.

Can perform with high reliability and consistency.

Allow for experts to concentrate on rarer, more interesting tasks.

Provide a central, standard, accessible cache of knowledge.

Make knowledge explicit, thereby promoting knowledge enhancement.

Can provide a tool for training neophytes.

On the negative side, expert sytems

Work in relatively narrow fields of expertise; they are not general problem solvers.

Are suitable for problems that are "difficult but not too difficult".

Rely for their construction, on expertise being recognized as both useful and available for the problem selected.

Are resource (i.e., time, money, and people) intensive to build.

Generally do not learn.

Do not know the limits of their own expertise.

Reason from superficial or "surface" knowledge.

A thorough, general overview of expert systems is provided by Harmon and King (1985). Hayes-Roth, et al., (1983) present a more technical description.

III. Forecasting

I think there is a world market for about five computers.

Thomas J. Watson, Sr.
Chairman of the Board of IBM
1943

Forecasts like the one expressed in the above quotation, absurd in retrospect, are easy to find. Many events have happened which were not predicted significantly in advance of their occurrence (the popularity of jogging shoes, extent of women in the U.S. workforce, the Walkman) while many predictions simply never materialized (free, unlimited energy, automated computer translation, the running out of oil). Further, expertise in the domain in question does not correlate well with better forecasting. Witness Henry Warner's comment in 1921: "Who the hell wants to hear actors talk?". (See Makridakis 1988 for these and other examples.) Why is this the case? The evidence points to human information processing limitations and biases. Hogarth and Makridakis (1981) working from the psychological literature on human judgmental abilities cite, among a litany of other factors, "the 'illusion of control', accumulation of redundant information, failure to seek possible disconfirming evidence, and overconfidence in judgement [as] liable to induce serious errors in forecasting and planning."

Forecasting requires predicting what will happen and when it will happen along with an associated statement of confidence. Claiming that due to expert systems, there is a 90% chance that first-line managers will disappear within the next three to five years, is an example. For certain very regular events, like predicting when the sun will rise tomorrow, forecasting is easy. For less regular events and for longer time horizons, the task is more difficult. There is a large body of empirical and theoretical research in the field of forecasting which specifies the factors in a particular problem contributing to forecast difficulty and, given the difficulties, how one should proceed to forecast. (See Armstrong 1985 and Makridakis 1986, for example.)

The following factors contribute to the difficulty of the problem at hand.

Current Status

In order to forecast where we will be in the future (say, three to five years from now) it is always helpful to know where we are now. In this case, we don't. That is to say, the extent to which verifiable expert system technology has permeated the workplace is at the moment less than well known. There exists a pervasive argument that few working expert systems are publicized due to the strategic value of this resource to the company. (That is, much as with male bravado, those who do "it" don't talk about it while those who talk about it, don't do it.) The counter argument is that expert systems are difficult and expensive to develop, while limited in application, and therefore will not be widely utilized until the underlying technology takes a quantum leap forward. Further, given the relatively small sample of verifiable, successful applications of ES technology, it is naturally difficult to generalize about the currently observed impact of ES introduction.

Forecasting Horizon

Forecasting horizon is inversely related to forecasting accuracy. This is an intuitive result: the likelihood of unforseen events increases as the time period over which the forecast is made increases. In this case, three to five years is, generally speaking, neither short term nor long term, but rather medium term. This three to five year window implies that the likelihood of the diffusion of some technological breakthrough, as described in the previous section, will be low over the forecasting horizon. A longer time horizon would force a methodology which allowed for technological forecasting. Under the assumed conditions, some form of an extrapolation of recent trends is possible.

In one way, for this problem the long term forecast is easier. The trend is for ES's to substitute or supplement human mental tasks. The hard part is determining the rate at which this will happen.

One final note is in order here: for the medium term time horizon people tend to overestimate the amount of change caused by technology.

Methods

Qualitative forecasting, that is forecasting based on human judgement, is difficult, as described above, due to human biases and the limitations of human information processing. To illustrate the point, when quantitative methods are feasible, for example in forecasting time series or when using econometric techniques, the empirical evidence indicates that (human) judgemental methods are not more accurate than even the simplest of these quantitative methods. Nevertheless, there are problems such as this one where there is no recourse but to rely on judgement. (What is needed is an expert system for assisting in the forecasting process! For a view of one such system, see Weitz 1986.) Makridakis, Wheelwright and McGee (1983) describe a number of these methods, among them the Jury of Executive Opinion, Surveys, Scenario Development, and Analogy. A jury in the qualitative forecasting sense is simply a group of knowledgeable individuals gathered in one place and through their interaction coming to some estimate of future outcomes and their likely occurrence. In Scenario Development, multiple sets of plausible assumptions are made, and the likely outcomes for each set of assumptions is derived. Whether or not Scenario Development has predictive validity, it is certainly useful for contingency planning. As the name suggests, Analogy methods draw on previously occurring circumstances similar to the one in question. The sequence of events in the analogy are seen as guides to likely future patterns. For example, studies of the life cycle of many products indicate an S-shaped growth pattern. In forecasting the sales of a relatively new product, this rate of growth analogy can provide guidance.

None of these methods are known for their stunning successes. The growth rate analogy example points to some of the difficulties. One must assume the new product will exemplify growth characteristics of this shape, and then predict the "size of the S". Before release, or even early in the product release, this determination is not trivial.

IV. Forecasting New Markets

> There doesn't seem to be any real limit to the growth of the computer industry.
>
> Thomas J. Watson, Jr.
> Chairman of the Board, IBM
> 1968

To reiterate, the problem here is to forecast the diffusion of the technology and its impact; the two are different but not independent. Widespread effects would be impossible without large scale exploitation of ES's. On the other hand, it is conceivable, and therefore the possibility should be considered, that wide acceptance and utilization of ES's could simply result in small, incremental changes in the nature of work and the organization - that these systems for example will simply aid and enhance current tasks and processes. I presume therefore that significant exploitation of ES's is a necessary but not sufficient condition for widespread impact on work and the organization. It should be clear however that moderate or small scale utilization of ES technology could have significant though localized effects, (i.e., within certain companies or industries), or not very significant effects. All possibilities of extent of acceptance of the technology and subsequent effects are diagrammed in Figure 1.

Extent of Diffusion	Extent of Impact
Large Diffusion	Widespread, significant impact Widespread, moderate-slight impact No impact
Small Diffusion	Local, significant impact Local, moderate-slight impact No impact

Figure 1: Diffusion and Impact of a Technology

In the previous section I outlined issues of importance in forecasting and how they apply to this problem in a general sense. In this section I focus on the particular guidelines involved in forecasting the success of a technology or product, that is, the left hand side of Figure 1. The right hand side will be addressed later in this paper.

Will the diffusion of ES technology be widespread? Forecasting the future extent of utilization may be viewed as trying to determine if expert systems are a strong growth market. Schnaars and Berenson (1986) systematically sampled the popular business press between 1960 and 1979 and assessed the growth market forecasts appearing there. The purpose was to see which lessons, if any, could be drawn from the successes and failures they encountered. The study included forecasts for "significant new products, markets, and emerging technologies". Of the 90 growth markets in the sample, 48 never materialized while 42 were successful forecasts.

Included in the mistaken growth market forecasts (and the year in which they were made, and their time horizon) are: a tooth decay vaccine (1968, 10 years), rotary automobile engines (1971, 4 years), ultrasonic dishwashers (1967, 5 years), and turning fuel (i.e., oil) into food (1961, unspecified). The primary reasons cited for the failure of these growth markets forecasts were:

Overvaluation of technology - that is, an infatuation with technology for technologies' sake.

Failure to realize that the product or technology did not offer a real benefit to the consumer at a reasonable cost.

Inability to predict social or demographic changes which altered significantly the relative advantage, (for example, the cost/benefit) of the product or technology to the consumer.

The successful forecasts included predicting the elderly market, the "baby boom" market, personal computers, microwave ovens and home pregnancy tests. Correct forecasts tended to be those:

Demographic in nature.

Where fundamental market research was undertaken.

Where a real benefit was offered to the consumer at the price offered.

It was relatively easy to predict the number of senior citizens or "baby boom" adults, for example, by simple extrapolation techniques. Obvious needs of these groups could then be predicted without great difficulty. Where clear demands of cohort groups could not be determined, good market research pointed the way to possible changes in historical patterns of consumer behavior. Finally, successful markets involved providing the consumer with a real cost/benefit advantage.

The authors conclude with the following guidelines for successfully predicting growth markets.

Stress market fundamentals.

Be aware of the assumptions underlying the forecast, particularly those based on "immutable trends".

Avoid being dazzled by technology.

Avoid forecasts made by those "in bed" with the technology.

Use of scenario analysis might be helpful.

The study emphasizes that

> "Regardless of technological dazzle, true growth markets have been driven by fundamentals: Who are the customers? How large is the market? Will the proffered technology offer them a real benefit over existing and subsequent substitutes? Is the derived benefit worth the price you will have to charge? Are cost efficiencies probable? Are social trends moving towards or away from this product? Place the bulk of your effort into answering these questions. The potential for the market depends more on these issues that any other factor."

In the next section I draw on the manufacturing environment to illustrate the interplay of new technologies, value systems, economic realities and the nature of work and the organization. In focussing on the current experience with new technologies in manufacturing I attempt to draw an analogy for the extent and impact of expert system introduction in the workplace. It should be kept in mind that manufacturing includes a host of tasks ranging from the non-skilled to the very skilled, and up through management. Skilled tasks include such areas as design, scheduling, monitoring, maintenance and repair - ideal domains for expert systems.

V. Advanced Manufacturing Technology

What is the sound of one hand?

Zen Riddle, attributed to
Hakuin Ekaku (1686-1769)

What is it about the Japanese that has made their manufacturing so successful? The answer to this more recent riddle is more forthcoming, and may be summarized under the headings technology, just-in-time scheduling policies, and "participatory" management. The technology includes robotics and computer-aided design, manufacture and process planning. The technology itself however does not account for the success of the Japanese. Linked to the technology are a set of policies that allow for it's maximal utilization.

Just-in-time (JIT) scheduling revokes the decades old notion that maintaining sizeable inventories (of cars at dealerships for example) is necessary in order to smooth response to demand. While the traditional mechanism for reducing carrying costs was to minimize inventory, JIT dictates the ultimate minimum in-process inventory level, zero. The implications are enormous: rapid, flexible manufacturing processes, from supplier to customer, must be assured.

Participatory management breaks from Taylor's "scientific management" developed at the beginning of the century. Taylorism is perhaps best exemplified by Henry Ford's assembly line: intellectual content is removed from work, required movements of the worker are minimized and regularized, and a distinct separation between hourly workers and their salaried supervisors is enforced. Participatory schemes, while taking different forms, typically have workers doing a variety of tasks, with some intellectual satisfaction and sense of accomplishment associated with the tasks. For example, quality control, (which under a Taylorized system would be performed after assembly by supervisors), is done by the workers themselves as part of their responsibilities during assembly. In Japan a chief component of this management policy is that workers are given the time, incentive and resources to reflect upon and improve their jobs. Hayes and Wheelwright (1984) treat these topics in more depth.

It has been argued that the Japanese developed these policies as an outgrowth of the values and ethics inherent in their society. These underlie a philosophy which, for example, promotes a team spirit and a sense of orderliness. An important question then is, to what extent are the policies directing the acceptance and utilization of a technology inextricably linked to the technology itself, and to what extent are the policies an outgrowth of the country/company culture in which they originate?

Walton and Susman (1987) report on a study of 24 plants that are pioneering the use of Advanced Manufacturing Technologies (AMT) in the U.S. The focus of the report is on human resource strategies associated with the new technologies. When AMT is introduced into the workplace, they observe:

"Closer interdependence of activities.

Different skill requirements - usually higher average skill levels.

More immediate - and more costly - consequences of any malfunction.

Output more sensitive to variations in human skills, knowledge, and attitudes, and to mental effort rather than physical effort.

More dynamism, that is, continual change and development.

Higher capital investment per employee and fewer employees responsible for a particular product, part, or process."

While AMT has generally been introduced into a company on a piecemeal basis, the growth and interdependence of automation and information technology make essential:

"A highly skilled, flexible, coordinated and committed workforce.

Lean, flat, flexible, and innovative management.

The ability to retain developed talent.

A strong partnership between management and labor unions."

The technology, coupled with economic imperatives, has led these companies to reduce the number of job classifications while broadening them in scope, promote team structures, revamp conmensation and appraisal systems, and revise or consider revising, training and selection procedures. JIT and participatory management are, of course, implicit in this package.

A general upgrading of skill requirements is observed with operators handling multiple functions, some of them previously performed by technicians, while technicians in turn took on responsibilities previously afforded only to engineers. The task of supervisor has evolved into one of "facilitator" as opposed to "task master". Lower management as well has seen its responsibilities upgraded and/or broadened. The authors note however that

- "the policy choices... constitute a strategy to upgrade workers' knowledge and skills. Had management simply followed practice, the more demanding AMT tasks in most of the companies we reviewed probably would have been assigned to managers or other professionals. Whether they use the term explicitly or not, companies seem to be weighing benefits and risks and deciding in favor of upgrading. Downgrading, however, remains a live option in the minds of some managements, and the choice is still a judgement call" (emphasis mine).

The authors note that the new technologies and practices require fewer overall jobs. The implications, since flexibility and the ability to learn are fundamentally important qualifications, is that those workers without these abilities lose out in the new manufacturing world.

In summary, while the technology and today's business environment seem to force certain policies, others apparently remain a function of choice.

VI. Implications

> ... we predict that [in the 1980's] large industrial organizations will recentralize...
>
> Leavitt and Whisler, as above

> If you look at the way truly decentralized companies outperform centralized companies, you've got to say it's a trend that's got to force itself on even the most reluctant CEO's.
>
> Thomas J. Peters
> co-author, In Search of Excellence
> (in Business Week, April 25, 1983)

As Peters implies, and others in the popular press echo, the successful organization today, whether manufacturing or not, is lean, flexible and (correspondingly) decentralized. Huber (1984) refers to the "post-industrial society [which] will be characterized by more and increasing knowledge, more and increasing complexity, and more and increasing turbulence. These, in combination, will pose an organizational environment qualitatively more demanding than those in our experience." This is the overall business environment in which organizations find themselves moving at the present time.

In assessing the future impact of a technology one must determine the likely policies of organizations and individuals. These policies include first whether or not to use a particular technology, and then, who shall use it and how. I have argued that these policies are a function of not only the technology itself, but also of the broader economic realities and, further, what I've termed values as well. The overall picture is complex, and merits further exploration. Figure 2 is a diagram of the four factors, with arrows between them representing all possible directions of interaction.

```
TECHNOLOGY  <----------------->  MARKET
    /|\   /\                  /\   /|\
     |      \                /      |
     |       \              /       |
     |        \  /                  |
     |        /  \                  |
     |       /              \       |
     |      /                \      |
    \|/   \/                  \/   \|/
     VALUES  <------------------->  POLICIES
```

Figure 2: Impact of Technology Matrix

From this perspective, the main purpose of this paper is to explore the arrow going from Technology to Policies; that is, to determine the effects of expert system technology on particular corporate or governmental policies (i.e., job descriptions, qualifications, work processes, lines of communication, etc.). But is there, in fact, a direct link between

Technology and Policies, or is the effect always mediated by the other two factors, Market and Values? The following examples of the links which exist between the four factors of Figure 2 will serve to clarify this question, and the matrix in general. (These examples are meant to be illustrative of each link and not exhaustive).

Market ---> Technology

Section IV established that new technologies are widely successful only when a market exists and the economics involved allow the development of such technology. Further, it's clear that the direction of development of existing technologies will likely be pulled by demand; an obvious example is the demand for cheaper, faster, easier to use microcomputers and the resultant more powerful CPU's, larger and cheaper memory devices and the explosion of user friendly software.

Technology ---> Market

New technologies can create or shape new markets. As examples, the internal combustion engine and the subsequent popularization of the automobile gave birth to the tire industry and dozens of related businesses. The electric light bulb and audio recording made the film industry conceivable, and more recently, the microcomputer has provided the opportunity for software developers to flourish. New technologies can also destroy demand for existing products: witness the buggy whip and mechanical calculator.

Market ---> Values

Can market forces affect values? Under this category I suggest that the market, operating in the guise of advertising, certainly shapes our notions of such things as beauty, appropriate behavior, and worthy goals.

Values ---> Market

This case refers to how our culture specific values and ethics direct the price (or existence) of goods in the market. Simple supply and demand arguments only superficially explain the huge salaries paid to football players, $500 per night hotel rooms, $75 dollar haircuts, the existence of psychotherapists for dogs or why rabbits are raised and sold for human consumption in France while this market essentially does not exist in the United States.

Market ---> Policies

A clear example on a micro-economic level is the situation of high demand for a product, and suppliers or would-be suppliers attempting to satisfy that demand. A manufacturer might respond to this demand by enacting policies to increase production: hiring additional workers or buying new machines, for example. On a macro-economic level, free market excesses may result in government policies (minimum wage laws, anti-trust regulations, etc.) to curb those excesses.

Policies ---> Market

A case in point is joint action by suppliers who form an oligopoly (i.e., oil producers). Possible policies include enforcing minimum price standards or restricting production. Government policies such as setting interest rates, commodity price supports or tariffs on imported goods clearly have serious impact on the market.

Technology ---> Values

How does technology in and of itself shape the way we view the world? Two examples should make this relationship evident. The first is that modern technology tends to foster the belief that we are masters of nature and not part of it. Natural disasters are shocking not only due to the immediate toll of human life and property, but also in forcing the realization that technology does not offer absolute protection from the elements. Secondly, the argument can be made that Western Europe's technical prowess in transportation and weaponry in the 17th, 18th and 19th centuries not only made colonial expansion possible, but also fostered the moral arguments (i.e., "the white man's burden") which, sincerely or not, were supplied as ethical justification.

Values ---> Technology

Here the issue is how our value systems dictate the development and use of technology. The most direct examples in this area are personal decisions by scientists and engineers concerning the areas of research they will or will not engage in, based on their moral convictions. This may relate to weapons or nuclear power research, or something less dramatic: do I design computer systems to replace humans in their tasks, or to assist humans in their tasks?

Values ---> Policies

Laws and government regulations are the clearest cases of policies reflecting society's values. Widely accepted ethical rules of behavior also illustrate the point.

Policies ---> Values

I return here to Taylorism and the policies which dictated assembly line behavior. The results of these policies, including bored, disinterested and alienated workers, fed the belief that workers (or at least certain workers) are inherently bored, disinterested and alienated. (Here is a case of a policy supporting values which helped create the policy in the first place.)

Policies ---> Technology

Companies, research laboratories and governments, in deciding where to spend their research and development funds, exemplify how policy decisions directly affect the direction of technological developments.

These interactions are more complicated than the simple factor to factor effects described. Feedback may occur, as in the case of Values affecting Policies affecting Values described above, or Market affecting Policy affecting Market (market excesses resulting in government policies causing other market problems which are dealt with by government policies, and so on). Further, it's likely that most interactions involve more than two factors; one can imagine Values resulting in Policies which have an impact on the Market and thus direct Technology.

However, I can think of no examples of technology directly dictating policy decisions. The mediating variables of Values and Market always have substantial impact. Technology provides options. In the manufacturing case, JIT, participatory management, increased flexibility, etc., are simply not possible without the support of computer based technologies. They are not, however, the inescapable, immediate result of the technology itself.

Given the matrix and its foundations, what can be said about the impact of expert system technology on work and the organization? I propose two scenarios.

Scenario 1: No Widespread Impact

First, note that nowhere in the study of leading edge manufacturers cited in the previous section was there a single word regarding expert systems. Underlying this scenario is the presumption that expert systems are simply not broadly applied due to their fundamental limitations, and until some breakthrough occurs, their drawbacks will continue to limit their use. Such breakthroughs might, for example, be along the fronts of commonsense reasoning, improved knowledge engineering, and/or reasoning from basic principles. Again, my assumption is that no such breakthrough will occur and be ready for commercialization in the three to five year time horizon of this exercise. Referring to the technology matrix, this scenario stipulates that a Technology, without the pull of the Market, has minimal effect on Policy. This skepticism concerning the actual use of expert systems is supported by a recent (October 12, 1987), generally optimistic article in Fortune magazine. It included the following comments (Kupfer 1987).

> "Though expert systems are now in the mainstream computer world, they are not yet fully established. While American Express is proud enough of its expert system to have featured it in its last annual report, company officials are discomfited by the difficulty they are having in assimilating the new technology. People still regard expert systems as clever, industrious immigrants who wear funny clothes and can't quite be trusted."

I now relax the assumption of non-penetration. Expert systems do in fact perform remarkably well on very particular types of problems. The use of ES's on these applications can indeed save large amounts of money, and provide the benefits outlined earlier in this paper. Examples of major companies that have developed expert systems for repair of engines and generators, credit evaluation, and the manufacture of automobile and airplane parts are impressive. These tasks are typically "diagnosis type" tasks though other problem types (monitoring or scheduling for example) are conceivable. Commonly the expert system is designed to replicate the performance of skilled, experienced (human) technicians, thereby allowing the task to be performed by less skilled, less experienced (human) technicians, in conjunction with the system. The expert technicians are then free for other (hopefully more interesting) tasks. (The task may in fact involve enhancing the knowledge of the system.) With this in mind, the following scenario is proposed.

Scenario 2: In All Areas, ES's Will Contribute to, and Accelerate the Impact Already Observed As Part of AMT's.

While expert sytems are structurally and in many ways functionally, different than AMT's, I argue (by analogy) that expert systems fit, in several fundamental ways with respect to their impact, into the type of dynamic environment described at the head of this section, and introduced here under the rubric of AMT's.

> Skill upgrading. Workers with lower skills take on jobs previously done by higher skilled individuals. As noted above, this is a policy decision. Workers, with varying skill levels, may or may not be afforded the time, incentives and resources to think about process improvement. See comment below regarding intellectual content.

Flexibility. Training time is shorter; novices can quickly gain skill by working with the system. Further, "old hands" who have worked on another task for some period of time (remember the broad job specifications with AMT) can fairly easily return to their previous work with the help of the system.

Possibility of intellectual content. ES's are typically "living and breathing" systems - that is, they need to be updated frequently. Users can be part of the process. Clearly they are likely to be in a good position to find deficiencies and suggest improvements in the system because they work with it. However, it will also require that they develop a sound understanding of the process in question. This understanding must therefore be provided through thoughtful design of the ES. Zuboff (1985) refers to this as "informating" as opposed to "automating" and makes the argument that informating a process as opposed to automating it, is a policy decision. Some expert systems for maintenance of large systems (i.e., power plants) and those based on first principles tend to implicitly support user comprehension.

Interdependence. In a large organization, the development, diffusion and updating process will require networking and effective communication across scattered (both functionally and geographically) areas of the organization. Expert systems may enhance knowledge and information management, a crucial function in the turbulent environment of the post-industrial organization.

Increased capital cost per worker.

These observations are supported by current research (Weitz and De Meyer 1988), studying the development and diffusion of a large scale expert system for computer board diagnosis. The system is designed for use by a multinational company across multiple sites throughout Europe.

Note that both these scenarios rest heavily on an attempt to understand the technology itself, the market for the technology, some general sense of values, and then the policy decisions likely to result.

VII. Observations and Questions

"Cheshire Puss," she [Alice] began, "Would you tell me, please, which way I ought to go from here?"

"That depends a good deal on where you want to get to," said the Cat.

Lewis Carroll
(as cited in Armstrong 1985)

In this paper I have provided two scenarios for the likely impact of expert systems on the nature of work and the structure of the organization over the medium term time horizon. Moreover, a general framework was developed for the process of assessing the future impact of a technology. This framework may be summarized by the following four guidelines.

Any forecast of the diffusion and/or impact of a technology should stress the market for the technology and not the technology itself.

Forecasts made by those "in the business" - in the case of expert systems, software and hardware developers and salespeople - should be viewed with deep suspicion. They are likely optimistic.

All forecasts should explicitly state the assumptions upon which they rest, and better yet, should evaluate the stability of those assumptions, and the sensitivity of the forecasts to possible variations from those assumptions.

The impact of a technology is a function of policies regarding how the technology is to be used. These policy choices are a function of the business environment, the culture in which the technology is introduced, and indeed the technology itself.

The first of these guidelines suggests that appropriate further work in impact assessment for expert systems should include fundamental market research. While the characteristics of a problem which make it amenable to expert system solution have been isolated, (see Dym 1987, Bobrow et al. 1986 and Weitz and De Meyer 1988), the purpose of this market research should be to realistically determine the number of organizations with these problems, and whether the costs, benefits and potential strategic advantage afforded by an ES solution support or discourage the likelihood that ES technology will be applied.

Future research in the area of technology impact should be directed towards a means of measuring and quantifying the factors in the technology matrix. This would provide both a sounder understanding of the factors in the matrix and how they interact, as well as moving the matrix in the direction of a substantive model with predictive validity. With such a model, the following types of questions could be addressed. First, which options resulting from new technologies are inescapable (if any), and when do they become so? Economic, political and social pressure may force certain utilizations of new technologies to be, to one degree or another, more desirable than others. How are these pressures created, and by whom? Second, when the Market and Values conflict, for example when participatory management is not more effective than a Taylorized system, under what circumstances does one mediating factor take precedence over the other in directing the Policies governing the acceptance and use of a Technology? Further work exploring the nature of the interactions between the factors Technology, Market, Values and Policies is needed, not only to better forecast the impact of technology, but also to help more coherently direct that impact.

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