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TECHNOLOGICAL INNOVATION

1. INTRODUCTION

1.1 General

Shoshana Zuboff[1] in her book,"The Age of the Smart Machine", included the following quotation 'we don't know what will be happening to us in the future, modern technology is taking over, what will be our place?'. This statement was an expression of concern from workers interviewed on the introduction of new technologies. They feared that 'todays working assumptions could not be relied upon to carry them through, that the future would not resemble the past or present'.

More frightening still was the sense of 'a future moving out of reach so rapidly that there was little opportunity to plan or make choices'. Were we 'not heading towards calamity ...... the more regrettable for having been something of an accident'.

Certain questions emerge as a result of this and many other studies on new technologies. Some of the questions raised below will be addressed in this paper. It is however the intention to stimulate discussion during and after the symposium, as none of these questions have definitive answers and themselves generate further questions and further discussion. The main questions raised by Zuboff[1] are as follows:

Should the advent of the smart machine be taken as an invitation to relax the demands upon human comprehension and critical judgement? Does the massive diffusion of computer technology throughout our workplace necessarily entail an equally dramatic loss of meaningful employment opportunities? Must the new electronic milieu engender a world in which individuals have lost control over their daily work lives? Do these visions of the future represent the price of economic success or might they signal an industrial legacy that must be overcome if intelligent technology is to yield its full value? Will new information technology represent an opportunity for the rejuvenation of competitiveness, productive vitality, and organisational ingenuity? Which aspects of the future of working life can we predict, and which will depend upon the choices we make today?

Flowing from these questions the aim of the paper is to consider the issues arising from the interaction between people, robots and other automated devices and the challenge that this presents to robot users, researchers, developers and policy makers, both industrial and political. The challenges faced by the individual user cannot be divorced from the society that seeks to direct technological development and has the political capability to do so. The real revolution is in the way A & R needs to be harnessed and exploited to serve our needs. Robots and computer integrated manufacturing systems aim to promote manufacturing flexibility and innovations such as touch and voice input will revolutionise machine and human interaction. While the concept of a workerless factory is already with us the concept of a workerless construction site is more difficult to imagine.

We must accept or make acceptable the new mental and physical effort required of those individuals who are required to work with A & R. This means addressing the social and organisational consequences. Social acceptance is likely to be influenced by the amount of education the workforce has received, especially in the understanding of technology. A well educated workforce will find it easy to use new technologies to their best advantage. Educated managers may be able to identify those small improvements that can make technology more effective. Many people feel that the introduction of robotics will relax the demands upon human comprehension and critical judgement and that this may mean a dramatic loss of meaningful employment opportunities. This factor is addressed later in the paper.

2. THE EUROPEAN SCENE

The increasing sophistication of technology and the co-commitment rising costs of implementation are making international collaboration more and more necessary. International political re-alignments are intensifying the debate on the right proportion of expenditure on R & D between the civil and defence sectors. This is an absorbing problem for the UK because of its traditionally much higher expenditure on defence R & D than any other western country apart from the USA. Although this balance appears to be shifting, the UK still spends some 45% of its R & D budget in this field.

The culture antipathy to rapid economic change is extremely strong and within it there is an underlying lack of interest in technology. All the measures which have been proposed to improve technological competence can only be superficially effective unless this antipathy can be surmounted. Practitioners in science and technology have to an extent built their own mystique as a defence barrier, thus exasperating the problem. Technological subjects are regarded as inherently difficult to comprehend which has an adverse effect on young people in terms of their contemplation of future careers. The financial rewards are small compared with other professions, few technologists penetrate the political network, and when they do they rarely admit to their origins. It may be that the dawning realisation that economic decline may be related to a lack of technological innovation and that higher standards of living pertain in technology appreciative countries, will highlight the importance of technological competence and show that support for technological development is not simply desirable but essential to survival.

In Europe generally, technological innovation has now been awarded the accolade of dedicated manifestos by each of the main nations and their ruling political parties. It has been accepted that there is clearly a dynamic interdependence of investment, training and technical change and that these factors can be identified as the key influences on the ability to sustain economic growth.

3. AUTOMATION & INFORMATING - THE HUMAN FACTOR

Throughout history humans have designed mechanisms to reproduce and extend the capacity of the human body as an instrument of work. We are now in a situation when machines can substitute for and amplify the abilities of the human body, because machines are mute and precise and repetitive (the tireless worker) they can be controlled according to a set of rational principles in a way that human bodies cannot.

New technologies can of course be applied to automating operations according to a logic that hardly differs from that of the 19th century ie replace the human body with a technology that enables the same processes to be performed with more continuity and more control. On the other hand the same technologies simultaneously generate information about the underlying process ie a building or component. The suggestion is then that activities, events and objects are translated into and made visible by information when a technology 'informates' as well as automates. The informating power of intelligent technology can be seen in the manufacturing environment where micro processor based devices are used to translate three dimensional production process into digitised data. The programmable controller not only tells the machine what to do - imposing information that guides operating equipment - but what the machine has done - translating the production process and making it visible.

As long as the technology is treated narrowly in its automating function it perpetuates the logic of the industrial machine that over the course of this century has made it possible to rationalise work while decreasing the dependence on human skills. However, when the technology also informates the processes to which it is applied it increases the explicit information content of tasks, and sets into motion a series of dynamics that will ultimately reconfigure the nature of work and the social responsibilities that produce productive activity. A manager can choose to exploit the emergent informating capacity and explore the organisational innovations required to sustain and develop it. Alternatively they can choose to ignore or suppress the informating process, clearly the informating capacity for automation can bring about radical change as it alters the intrinsic value of work.

We are in a sense talking about leadership and the ability of leaders to recognise the new choices that are presented, will they find ways to create the organisational conditions in which visions, new concepts and new language of work place relationship emerges, will they be able to create organisations that can exploit the unique capacities of automation and robotics and in this way mobilise the organisations productive potential to meet the heightened rigours of global competition. Will there be leaders who understand the crucial role that human beings from each organisational strata can claim in adding value to the production of goods and services. If not, we will be stranded in a new world with old solutions because we have failed to understand the new technology and how it differs from what came before. By neglecting the unique informating capacities of advanced robotics and ignoring the need for a new vision of work and organisation we will have forfeited the dramatic business benefits it can provide.

4. THE INNOVATION PROCESS

Georghiov, Metcalfe et al suggest that "The innovation process is so complex some attempts at simplification are necessary ..... the process involves several discrete activities related sequentially to one another. These include research, development, engineering for production, marketing and sales".

By definition technological innovation involves introducing a technical idea into an area of industrial activity where the idea has not previously been used in the expectation of some commercial advantage. Innovations which are unsuccessful from an economic view point may nevertheless be of great significance if they identify a worthwhile area of investigation.

However, it must be accepted that the technological competitiveness of firms and industries is determined not by the rate at which significant innovations are developed but by the extent to which they are applied to commercial operations. Evidence of resistance to the utilisation of demonstrably effective technological advances tends to discourage managerial commitment to risky and costly efforts seeking additional advances. Research (McDonald et al[2]) indicates that many innovations are adopted not in the hope of increasing profitability but in order to minimise reductions in profitability threatened by competitors advances.

Innovation has often been perceived as a discreet event made possible by a prior invention and drawn into economic significance by a prior process of diffusion - Freeman[3]. The focus being primarily on the hardware aspects of innovation. This approach has two significant short comings i) it fails to recognise that innovations are rarely fully developed when they are first introduced and ii) their full economic significance depends upon the continued development of the original innovations following their introduction into the market place. It is necessary therefore to find ways of identifying the nature of the continuity engendered by post innovation improvement. This is considered to be of fundamental importance to the understanding of industrial growth.

Clearly management and researchers will all benefit from the development of a progressively more effective basis for systematic examination and appraisal of the effects of technological innovations as well as different patterns, rates and levels of diffusion.

It is all to easy to criticise construction management for delays in adopting seemingly relevant technological innovations. It is of fundamental importance to recognise that virtually all innovations involve technological and economic risks at all stages of diffusion and that decisions to reject may accordingly be entirely justifiable at any stage. The fact that the construction industry has been slow to consider the potential of R & A and its acute awareness of the risks involved and the lack of careful and systematic ways or evaluating risks are understandable if shortsighted.

Evidence suggests that the innovation process is not totally a 'technology push' phenomenon, it is closely related to the clear understanding of customer requirements and that these are at least as important as technology in stimulating technological innovation. Again research indicates that the success or delay of an innovation is dependant upon the continuous coupling of technological opportunity and market need.

Once it is accepted that the interaction of technological opportunity and market need constitute a time dependant evolving process, it is easier to see that success and failure is less about the conditions for innovation than about ongoing performance of the organisation. From the point of view of the firm, successful innovation is about choosing technologies which embody the potential of a sequence of developments that meet market possibilities as the product or process diffuses into the commercial environment. As successful innovation is linked to the ability of an organisation to provide a succession of post innovation improvements, so too the diffusion process must be enlarged to include in addition to demand factors, those factors that make it worthwhile for firms to embark on a particular path of innovation and technological development in the first place. It is likely that during the process of innovation the firm will experience not only the growth but also the retardation effects inherent in a period of transition.

5. ORGANISATIONAL BEHAVIOUR

The development of adequate social control over technology ranks among the most urgent of contemporary problems. Narrow economic criteria based on short term financial returns can produce social and economic disasters. Fascination with technical problem solving regardless of the human factors can also have lethal connotations eg advance weapon systems. Vital ethical and environmental questions can only be addressed by an approach to technology which concerns itself with the relation between purpose, design and outcomes. The precise meaning of technological literacy is debateable, perhaps the best definition is that suggested by John Matthews ' A capacity on the part of citizens to comprehend the essentials of technological design motives and change'.

Perhaps the most compelling reality that drives managers to a narrowly conceived viewpoint on automation is the web of economic logic in which they are forced to operate. Frequently new expenditure on technology can be justified only as a capital substitution for labour. New technology is often used as lever to reduce staffing, the question however could be asked can we keep the person, and achieve even higher levels of productivity and production. As management uses A & R to escape their dependency on workers unique skills, both managers and workers alike become more dependent on the A & R device.

In a detailed study of the history of numerical control machines David Noble[4] documents the series of technological choices that favoured forms of automation which concentrated knowledge and control in a managerial domain. In Nobles view 'management preoccupation with control over the physical and human contingency of production reflects an on-going class struggle in which technology is used as another means of enlarging authority, secure in prerogatives of power.

Why then would management wish to support the introduction of automation and robotics. Evidence from manufacturing suggests that the choices that managers and workers have already made would seem to imply certain irreversible consequences, at least in the near future. Technology has injected a new ambiguity into the rationale for imperative control. Many managers, particularly those in the most vulnerable middle ranks seek ways to use technology to reduce those experiences that help justify unilateral authority - a repetition of the past? Clearly the choices that are made will shape relations with authority in the work place. What will be the position of managers who insist on the prerogatives of command and seek methods that protect the hierarchical distance that distinguishes them from their subordinates?

New technology transformation engenders a new approach to organisational behaviour. One in which relationships are more intricate, collaborative and bound by the mutual responsibilities of colleagues. As the new technology acts as an integrating factor across time and space managers and workers could overcome their narrow functional perspectives and create new roles that are better suited to enhancing value added activities. As the quality of skills in each organisational level becomes similar, authority comes to depend more upon an appropriate fit between knowledge and responsibility than upon the ranking rules of the traditional organisational pyramid. Used constructively the new technological mallei becomes a resource from which are fashioned innovative methods of showing social change.

6. ECONOMIC GROWTH

In the 1950's and 1960's when economists produced mathematical models of economic growth, they discovered that increases in capital and the supply of labour accounted for only a small part of the total growth of production. The remainder was attributed to technical change. This latter factor was itself a combination of technical organisational and social innovations. These early growth models can be criticised for the somewhat artificial separation of what are in fact completely interdependent phenomenon - technical changes are embodied in new capital investment and in the changing skills of labour - but the results did highlight the extraordinary imports of technical and institutional change. It is the improvements in the productivity of both labour and capital which are the key to economic growth, not simply an increase in the quality of capital or labour. When the complimentaries in the process of economic growth are analysed - the interdependence of investment, training, company organisation and technical change, then it is clear that the nature of these interdependencies must change with every major change in technology.

The 25 years after the second world war produced the most rapid period of economic growth the world has ever experienced. This applied not only to Western Europe and North America, but also Japan, Eastern Europe and a few third world countries (the so called newly industrialising economies). Rates of growth averaged about 4% of the G.N.P. plan. These achievements were based on the rapid diffusion of materials and flow production technologies using cheap and abundant energy - mainly oil and gas - and vast quantities of steel and the newer synthetic materials based on petro-chemicals. The ending of the cold war creates for the first time a serious possibility of realising new public research and development priorities - a shift from massive military R & D spending to an emphasis on the natural and built environment.

The very success of mass production brought into question the ability to sustain continued growth. This problem came into prominence in the early 1970's. The best known model was based on the work of J Forester[5] Limits to Growth, at MIT. These and similar models suggested that the world economy and population would collapse early in the 21st century if growth continued, due to the exhaustion of materials and energy supply, pollution and food shortages due to insufficient agricultural land. The critics argued that technical and social changes were either neglected or under represented in the MIT models. If they were included then a pattern of sustainable growth or at least of a more prolonged period of world economic growth could be envisaged in the 21st century.

Economic growth occurs because countries are able to produce more valuable output from the same quantity of labour and capital or develop alternatives to labour such as A & R. The manufacturing industries have been revolutionised in this respect. Another good example of this can be seen in agriculture. The potential for a labour intensive industry such as the Construction industry, where comparison can be drawn with both manufacturing in terms of the process and agriculture in terms of its former dependence on labour is enormous.

7. DE-SKILLING AND RE-SKILLING

Whilst greater wealth and opportunity to the greater part of society is a possible outcome of the A & R revolution, the changes inevitably entail wide ranging upheaval, in which benefits and disadvantages construct an often tenuous and unacceptable balance eg high levels of unemployment, de-skilling (sometimes re-skilling). Re-skilling can often provide greater responsibilities and a more challenging and fulfilling goal for people making them more effective.

Experienced based knowledge has its weaknesses, when it comes to improving work methods or adapting them to new techniques and business conditions; the practical know-how of the traditional craftsman could be limiting. Men like Taylor and Gilbraith who were firmly committed to raising the total level of worker output by easing the arduousness of physical tasks look both to new equipment and to new principles of work organisation in order to accomplish their goal. For example after a meticulous study on brick laying, Gilbraith introduced an adjustable scaffold for piling up bricks. This invention eliminated the need for workers to bend over and lift the equivalent of body weight often a thousand times a day, and increased the workers output from 1,000 to 2,700 bricks a day. Gilbraith claimed that workers typically responded to these innovations with gratitude as their jobs were made easier. As the logic of Taylorism took hold, the substitution of machine power for human labour became the obvious method of increasing the speed and volume of production.

In the main, production in the Construction industry has depended on what the body could accomplish with strength and skill. Will the introduction of automation and robotics continue to diminish physical effort but allow the retention of experienced based skills or will effort and skill be wiped out altogether? It could be true to say that automation and robotics will naturally displace the human body and its know-how (de-skill), while the informating power of the technology simultaneously creates pressure for a profound re-skilling. How are these new skills to be understood, what are the implications for the differences that separate workers from managers, difference that have, in an important way depended upon the need for human labour and skill.

Many managers are not optimistic about the ability of experienced workers to trade their embodied knowledge for more explicit scientific inference. Workers must now develop a new kind of learning of which they are often frightened, not wanting to appear foolish and incompetent.

8. THE INTERNATIONAL SCENE - A EUROPEAN PERSPECTIVE

In the years following the second world war the countries of Europe grew much faster than the United States and then Japan grew faster still. The answer lies in part to the spread of technologies from the United States to Europe and later to Japan. By adopting technological advances that have been established elsewhere, a country can increase its productive potential. As new investment typically embodies the new technology there are advantages of being a follower rather than a leader i.e. the follower may be able to install plant that has been debugged by the innovator.

Transferring technologies from one country to another has become increasingly rapid, with new ideas moving swiftly around the world transferred by multi-national companies carrying innovations from one country to their investments in another. As the transfer of new ideas gathers pace so product innovation will become tougher. Companies will only have a few years or even a few months to make profits from new products before they are evaluated (and improved on) by rivals. As a result innovation in the production process will become more important than innovation in product design. If countries and individual organisations are not receptive to new ideas they will find it increasingly difficult to keep pace. The importance of technology as a component of growth has another equalising effect - it is no longer essential or even important for a country to be rich in natural resources in order to flourish eg Singapore, Hong Kong. In fact there is a question as to whether plentiful natural resources may in some way handicap economic growth rather than promote it.

The aim in Western Europe is to achieve greater efficiency in the use of materials and energy. In construction this can be achieved through better design and production control systems aimed at reducing rejects and waste. There is evidence of a slowing down in productivity in the richer countries. Since 1973 the growth of productivity in the USA has slowed dramatically, productivity growth in the UK and West Germany which outpaced America in the 1960's has also declined. Even Japan is now showing signs of deceleration. This is despite the fact that the pace of technological advances continued as companies increasingly see this as a way to establish market share. It is extremely difficult to explain the different degrees of success with which individual countries adopt new technologies. Perhaps the most significant factor is education accounting for the emphasis placed on improvements in education generally.

The tendency in Europe has been to build a strong research base in robotics rather than to worry about the development programme. The feeling was that there was more added value to be had from providing the know-how to a large number of users, than from having one or two large companies developing robots. This was probably the right decision in the early 80's. Progress in the use of robotics in the UK failed miserably because the companies who made the decision to use first generation industrial robots did so for the wrong reasons. The accepted view was "automate or liquidate".

Although the technology exists and the European market is definitely there, there is little knowledge relating to the value of the new market for second generation robots. The problem was and still is the relatively small amount of investment in R & D in this field.

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