Ideas in Progress

Paper Number 9

Technology Choice - game, set or match? *

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The series constitute ‘ideas in progress,’ after the notion described by I.J. Good in ‘The Scientist Speculates.’ Good also describes ideas about ideas as ‘partly baked ideas’ believing that “... it is often better to be stimulating and wrong than boring and right.” While the papers do not take this tenet as an excuse for licence at the expense of rigour, they are exploratory and the ideas may change as a theme is developed over time.

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Technology choice - game, set or match?

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Abstract:

How technologies are chosen for exploitation is of growing public concern. While that choice affects some technologies more than others, none are exempt. Traditionally ‘technology assessment’ has been thought of as the tool to base these decisions on, but its practice and rules are too narrowly defined and omit significant considerations for the present day. The notion of technology choice differs from that of technology assessment by making three influences explicit, namely the fitness-for-purpose, valuation and risk of alternative technologies. The paper develops these notions and indicates how they influence R&D activity, often unconsciously, and how their influence may become a feature of future R&D activity.

Keywords: Technology, Choice, Fitness-for-purpose, Valuation, Risk

Introduction

Technology has an important and sometimes paramount, influence on the development of organised society (the polity). Once the unchallenged prerogative of powerful individuals, the choice to exploit new technology, in products or processes, is now questioned ever more frequently and trenchantly. The result is an ambiguous and complicated set of circumstances, where the expectations of different stakeholders (employees; providers of capital; trade unions; pressure groups, such as Greenpeace; lobbyists; regulators and law enforcement officers; insurers; ethical assessors; tax authorities; and customers, clients, competitors and suppliers) are made known more effectively than ever before.

Anticipation of how technologies may influence the development of the polity, is now attempted more frequently than at any time in the past. Many ways of conducting these anticipatory inquiries have evolved, but few enable wide participation in the process of choosing the technologies that seem most likely to benefit the polity and of inhibiting the development of those that may not be beneficial. Technology assessment (TA) and environmental impact assessment (EIA) are amongst the more familiar processes that have evolved in an attempt to meet the needs of anticipatory inquiries, all of which have their roots in technology forecasting and systems analysis. These processes were influenced by the reductionism of the physical sciences, from which it may be difficult to escape. However, as the complexity of the polity grows, it is becoming important to shed the ‘old clothes’ of
assessment and to replace them with apparel that moves toward embracing the complexity of the polity. For this to happen, it may be helpful to discard the existing notions of assessment by recognising that anticipatory inquiries are concerned with technology choice.

It is suggested here that technology choice has three components, fitness-for-purpose, valuation and risk; their nexus embraces the economic questions of efficiency and equity, and the social, moral and aesthetic questions of concern to the polity. For example, in the recent UK Foresight programme, two important parameters explored in the Delphi survey were the capability of a technology to create wealth and to influence the quality of life. Both parameters are difficult to define, but where opinion indicates both to be mutually supportive the technology concerned is likely to be attractive to the polity. Both of these parameters relate to technology choice, with the implication that the technologies have the appropriate fitness-for-purpose, valuation and risk profiles for beneficial exploitation.

The stakeholders involved in technology choice have different motives and methods for choosing new technology. These differing motives and methods lead to tensions. Stakeholders often fail to share mutual appreciation of the technology, its in use consequences and of its embodiment in products, because the boundaries within which this is done may be drawn differently or be too constrained. Consequently, stakeholders need to be able to examine anticipatorily, and on as equal a footing as possible, the effects of introducing new technologies. The foregoing situation is not an accident and it is appropriate to review briefly how it has come about.

**Background**

Technology has developed two pervasive and interconnected characteristics, complexity and globalisation. Complexity, which subsumes globalisation, is a systemic property, a “.... new way of thinking about .... collective behaviour ....” and is the “.... study of the behaviour of macroscopic collections of .... units that are endowed with the potential to evolve in time.” Complexity implies that the system’s behaviour pattern cannot be formulated or perceived, but will emerge; this remark may seem so vague as to be useless, but reflection shows that not to be the case. It can be made clearer by using Perrow’s notions of linear and complex interactions; the former are “.... expected and familiar sequences, including those that are
visible though unplanned.” By contrast, complex interactions are “.... made up of either unfamiliar or unplanned and unexpected sequences that are either not visible or are not immediately comprehensible.” Systems that exhibit complexity also have a further property, stemming from theories of non-linear or self-organising systems, of exhibiting chaotic behaviour interspersed with ‘islands’ of stability, as the system is driven harder. Systems that exhibit complexity have both structural and dynamic components, including flows of information, that may be only partially apprehended and understood. Complexity also implies that systems are composed of highly interconnected elements, but conversely those that are linear in Perrow's terms, may be highly interconnected without exhibiting complexity. A particularly troublesome aspect of highly interconnected systems is their tendency to become unstable [5]; many new technologies have led to or are leading towards, higher connectivity between elements of the system, with consequences for stability in the polity. The world stock market crash of October 1987 is a good illustration of the instability resulting from the high connectedness resulting from the introduction of computer based communications globally.

The polity exhibits complexity; the choice of technologies by companies and service providers is one of its elements. However, there has been a persistent and tacit assumption, that the adoption of new technologies has always benefited the polity, and will always do so, and has been necessary for the creation of a competitive economy. Questioning of these premises led to the evolution, first in the USA and later more widely, of technology assessment (TA), which was formalised in the USA in 1972, through an act creating the Office of Technology Assessment (OTA) as part of the Congressional support system. However, OTA was disbanded in 1995 for “political” reasons. The history of TA has been reviewed by Janes [6], who confirmed that TA has been blighted by its early history, when missionary zeal led many people to equate TA with technology arrestment or technology harassment. The tacit association of assessment with restraint, control and taxation is inappropriate to describe an activity that is widespread, creative and purposive within the polity, and was initiated partly as a response to the central problem technology choice.

Technology choice, when expressed in terms of fitness-for-purpose, valuation and risk, is a general, but not uniquely defined process. The three components are often used, at least in part and often tacitly, by industry, investors and financial institutions in deciding whether a new or emerging technology\(^5\) will be of benefit to a business. If the likely outcome is believed
to favour adoption of the technology, this implies that a *tacit* bargain has been, will be or is expected to be struck between all the stakeholders, including end-users who apply their own version of the three components. The balance of the necessary trade-offs is then expected by all stakeholders to be favourable to the polity’s well-being. It is this tacit assumption that is no longer viable. The polity has become better informed and is less willing to accept the imposition of judgements originating from *experts*, wherever they originate from. The polity now recognises that the adoption of new technology involves complexity and uncertainty, producing not only the desired outcome, but many unintended by-products that may have unwelcome characteristics [9], if they are understood at all. An example is the production of certain plastics, that are widely used, but involve the use of molecules that behave as pseudo oestrogen; these enter the human food chain and water as residues, possibly causing a lowering of male fertility. The possibility of xenotransplantation surgery is a second example of complexity introducing unexpected outcomes. The foregoing are examples of an old phenomenon, but the complexity of new technology is now recognised to have influence on a far larger scale than previously experienced.

Janes review revealed the lack of definition of TA and the lack of political support that its protagonists sought. By comparison environmental impact assessment (EIA), a close relation to TA, has both the credibility and political support that has eluded TA’s protagonists. The requirement for EIA is enshrined in US law [2] and in a European Union Directive [3]. While the activity is circumscribed in both of these legal instruments, in Europe at least, discussions are proceeding to create a wide ranging regulatory tool from EIA [4], though both TA and EIA have technical shortcomings, particularly relating to risk.

Technology choice is influenced by many fields of knowledge, including (the list is not exhaustive);

- innovation studies
- risk assessment and management
- human judgement theory and practice
- the nature of expertise and expert knowledge
- investment decision making
- corporate venturing and entrepreneuring
- market research
- preference analysis and prioritisation
- theories concerning the nature of science and technology, and of knowledge (both codified and uncodified)
forecasting and foresight
the growth of pressure groups and the politicisation of science and technology
political theory
the development of regulation and regulatory bodies
accident investigation
conflict resolution and
changes in the underlying philosophical mode of thought in the polity, generally referred to as the (hotly debated) shift away from modernity toward post-modernity.

The last area is important and warrants a few additional comments.

**Need for participation**

The perceived need for widespread participation in technology choice, grew from a number of highly visible technologies that could be sensationalised easily as being harmful to either the polity or the natural environment or to both. The technologies included nuclear power, gene therapy, genetic modification, the health aspects of long persistence agricultural chemicals and, most recently, the BSE/CJD episode and the effects of pseudo oestrogens on male fertility [10]. To quote Nelkin [9] controversies, of which the foregoing are examples, “ ..... represent a decline in public trust. Critics question the ability of representative institutions to serve their interests. They resent the concentration of authority over technology in bureaucracies .....”

Trust, danger and risk are tightly interconnected as Giddens sets out clearly. It is also important to note that Giddens believes the antitheses of trust to be angst or dread, two terms that reflect the attitudes of many people toward the influence technology has had or may have on their lives. Both terms also reflect the concept of anomie, as defined by McClosky and Schaar [8], though it is suggested that anomie is the passive component of angst or dread.

The decline of trust has led to the demand for wider participation in technology choice, particularly for technologies that are now having a pervasive and long-term influence on the development of the polity; for example computer mediated communication and genetic science. The need for an independent and unbiased way of presenting these matters, is derived from the notion that widespread participation in the choosing of technologies is a legitimate goal. The decline in trust, suggested by Giddens and Nelkin, is one of the features of post-modernity that has permeated the polity more widely than is realised. Giddens also suggests that expert systems, which he defines as “.... systems of technical accomplishment or professional expertise that organise large areas of material and social environments .....
“today,” are only accessible through access points or persons and require trust in their competence, and the authenticity of their expert knowledge. The latter is an important issue that can be connected directly to Perrow’s notions of interactive complexity, but which come from an entirely different field.

Many processes have emerged in an effort to stem the decline in trust. Some have barely departed from tradition and remain buried within the bureaucratic processes of institutions and government (e.g. Committees to investigate issues such as xenotransplantation in surgery and exemplified by the current BSE/CJD episode). These solutions continue to suffer from the decline in trust accorded to any form of expert opinion and the capability of bureaucracy. Other approaches, that verge on the traditional bureaucracy, include TA and EIA. Here, the independence of the assessors a pernicious and inescapable question that is complicated by the need for expert judgement. Public inquiries and consensus conferences\textsuperscript{10} are endeavours to achieve greater public participation in technology choice. After technologies have been implemented, regulation, law and market forces have much influence on the survival of a particular technology and of the products or services and organisations that depend upon it. Product Liability, and Health and Safety law, bring their own implications for companies that ensure their survival by creating products and services embodying “perceived attractiveness” that sets them apart from those of their competitors.

**Technology choice and its components**

Technology choice can be circumscribed by three interrelated notions; fitness-for-purpose, valuation and risk. These three notions lie at the core of choosing to use a technology in creating a product or service or company and are used by those who may wish to acquire these products or services; they also lie at the centre of the tensions created by the introduction of new technology. In addition, the introduction of a new technology is much influenced by the concept of *interactivism* as an approach to social problem solving\textsuperscript{11}. Interactivism is participative and concerned with creating a desirable outcome rather than living with one created by someone else.

It is hypothesised that technology choice emerges from the intersection of three sets representing fitness-for-purpose, valuation and risk. Each of these sets contains a number of
subsets or elements, many of which lie in the intersections of the three major sets. The three major sets are:

**Fitness-for-purpose:** The property of an artefact (interpreted as either a product or a service or an organisation) that imparts to it a perceived attractiveness such that it produces a high degree of satisfaction, but only rarely complete satisfaction. If the artefact does not do so it fails. Fitness-for-purpose has subsets and elements that may include:

- The current and emerging needs of individuals and how these aggregate into trends within the polity; the more exhaustive, behaviourally based forms of market and occupational research are included here.
- The artefact design processes in their entirety; artefact quality, safety, integrity, appearance, in-service life, function and life-cycle are included here, as are the principles of dematerialisation, cost/price and life-cycle-analysis, including costing and minimisation of the artefact's energy content, whether the artefact is a product, service or organisation; for the latter artefact design will include organisational design.
- The artefact production process; artefact material, labour and knowledge content are included here, together with specific principles of production process design for safety and integrity, and to meet regulatory requirements. For organisations the artefact production process is thought of in terms of company formation and death according to the valuations placed on them by the polity.
- Subsets and elements containing or expressing in-use regulation and emerging trends in regulation (e.g. the emergence of product liability legislation, under a European Union Directive, over the decade from 1976-86), and law governing the conduct of business and relationships between organisations.

**Valuation:** The value placed on an artefact by all its stakeholders including any or all of the following: employees and their dependants; owners, including individual and institutional shareholders; investment analysts, brokers and financial institutions, including stock markets, banks and credit rating agencies; trade unions; pressure groups and lobbyists; regulators and law enforcement officers; insurers; ethical assessors; tax authorities; suppliers; and customers, clients and competitors.

- *Valuation* involves quantifiable factors and psychological (unquantifiable) influences that modify quantifiable factors subjectively and not according to any well-established pattern. For artefacts that are products, whether they are
goods or services, the value placed upon them emerges from the tension between the purchasers perceived attractiveness and the suppliers perceived worth of the artefact. The resolution of this tension is one among the mixture of quantifiable and psychological factors that influence the value placed on the supplying organisation by others. In the foregoing, ‘others’ includes individual and institutional shareholders, investment analysts, brokers and financial institutions, including stock markets, banks and credit rating agencies.

- **Valuation** also includes all the conventional measures of economic viability of a product or service as practised in investment appraisal in industry, commerce and by all other stakeholders.
- By contrast, artefacts may have a non-monetary value placed on them, by pressure groups, environmental agencies and others, because of their role in the polity and in the local, national or global ecology. These subjective judgements may be supported by quantifiable or quasi-quantifiable factors that, in combination, have influences reflected in the financial valuations of artefacts.

**Risk:** Is composed of the quantifiable measures and non-quantifiable subjective judgements that characterise the anticipated dangers the chosen technology may pose to the polity socio-politically, the economy, ecologically and morally via cultural and personal values.

- **Risk** then involves trust in those aspects of a system exhibiting complexity that is amenable to measurement by procedures that relate to future potential risk; this may build on actual experience involving individual components of the system or may necessarily be speculations based on incomplete understanding of the system.
- Because the polity exhibits complexity, judgements relating to risk need to be made holistically (acknowledging Popper’s criticism of the notion of holism[15]), as far as that is possible. Aggregation of individual components is likely to be misleading, through ignoring such interactions as can be identified. Alternatively, boundaries will need to be set to the system and clearly identified, acknowledging the arbitrariness of all boundary setting procedures.
- Judgements relating to risk ought not to be made on fail-safe assumptions, since the complexity of the polity invalidates these assumptions.
- **Risk** will also involve the psychological perception of the dangers a new technology may bring into the polity; this will be neither measurable by conventional processes nor necessarily susceptible to reasoned argument.
- **Risk** will involve elements from all of the STEEPV fields including finance, stock market behaviour, market failure, ecological components, political interventions, social upheavals, shifts in personal values and technological failures themselves.

There is much evidence that all stakeholders now wish to be involved in anticipating the introduction of new technology. **Self-interest** of specific individuals, interest groups and
organisations tends to drive this desire for consultation and participation. However, large scale indifference in the polity often legitimises many new technical developments by default. The eventuation of every new technology or speculative anticipation of such an event, cannot be subjected to a formal process of the kind typified by technology assessment. Pervasive generic technologies, those that underpin many individual implementations, do attract the attention of concerned individuals and interest groups. However, it is the specific implementation of new technical developments, in an artefact or by an artefact (including organisations), or anticipation of that event, that focus’s attention. Examples include the recent introduction, by Monsanto, of genetically modified Soya beans that are herbicide resistant and the prospect of ‘electronic money.’

The arrival of ‘media science’ and the onset of tensions

There has been a growing trend in recent years, toward media programmes and publications that skilfully (and sometimes sensationaly) combine entertainment with explanation of many complicated advances in science and technology. These events have managed or are managing to convey, concisely and in a popular fashion, a view of what new technologies mean for the polity. One might term this the development of media science. The intention is to raise awareness of issues, not necessarily to create understanding of science and technology. Media science is also practised by a range of organisations that either promote or denigrate science and technology.

Media science attracts attention to the actual or possible future individual implementations of generic technologies, creating tensions in the polity and attracting the attention of stakeholders, in a way that leads to examination of their fitness-for-purpose, valuation and risk.

Tensions can then arise from several causes including:

- Incomplete understanding of phenomena and the problems of presenting such information in a way that creates trust and not angst or dread or anomie.
- The influence of media science, where the quality of explanation and presentation of uncertain information, has to be tempered by the need for the presentation to be ‘entertaining.’
- Communication of incomplete understanding of the situation caused by incorporating new technology in an artefact or by an artefact, together with
uncertain or simplistic indications of the future potential situations that may arise.

- The need for commercial secrecy that either makes informed judgements more hazardous or reactive, and only possible *after* the technology has been embodied in an artefact or by an artefact.
- The different interpretations of known information by ‘experts’ representing adversarial groups and the accentuation of this propensity when speculations are required into possible alternative future situations.
- Serious financial loss or gain by some stakeholders or its possibility in the future, arising from the perceptions of stakeholders, promoted by financial analysts, investment advisors and other stakeholders able to influence the financial perceptions of the polity.
- The perceptions of the risks and benefits involved in the use of the new technology, as created by physical risk analysis.
- How the outcome of risk analysis is managed, particularly the communication of risks and benefits to the polity, to create trust and to avoid creating *anomie*, *angst* or *dread*.
- The influence of government, regulators and political ideologies or parties on the creation of trust and acceptability of specific applications of new technology and their future influences.
- Single issue, special interest or other similar group's activities, that are either reactive or interactive[^15], in response to actual or possible future outcomes of application(s) of a new technology.

**Tensions and some possibilities for their resolution**

All these sources of tension focus on the artefact, whether that is an organisation, a product, an organisation or regulation. The tension’s influence is independent of either the size of the organisation (where that is the artefact) or to its financial strength, but relates to perceptions, created by advocacy by different stakeholders within the polity, through processes that either legitimise or bar the progress of adoption of the artefacts that embody the new technology.

Valuation of new technology falls into two broad classes; quantitative and qualitative/psychological. Investment appraisal characterises the first class, which is typified by financial appraisal of capital investment relating to the production of an artefact. These processes are well known and were developed in accountancy[^16]. However, investment appraisal is either partial, representing only those matters that can be quantified, or is underpinned by qualitative assumptions to which values have been attached judgementally. Since all these methods relate to the *future* performance of an artefact, assumptions have to be made about future interest rates, inflation and other factors, including the complicated matter...
of boundary setting\textsuperscript{17}. The principles needed are essentially ecological, but have to be applied to social, technological, economic, political and value systems.

The foregoing matters are relatively well developed by comparison with the complication’s of judging the values of markets and of companies themselves, where the psychology of markets, their susceptibility to tensions and to the influence of single issue groups, regulation and mass psychology, come into play\textsuperscript{18}. Integration and quantification of these factors, to allow their influence to be expressed, depends on judgements in ways that have not been formalised. Life-cycle-analysis\textsuperscript{19} may offer opportunities to begin this process.

New technology choices can create tensions between a company and all its stakeholders, including stock markets. An example of this concern, one of many that now occur, is the pair of conflicting statements reported, by the Financial Times on May 3, following a recent review for analysts by Glaxo Wellcome. One analyst commented “Glaxo is so big that it needs a lot of products so you expect to be impressed, and its hard not to be impressed in the face of such good science” while another criticised Glaxo’s propensity to attack its competitors products in its presentation, commenting that “Perhaps that’s the way to sell to doctors. Other companies would be less negative.” Share prices represent an external valuation of companies, but they hide a multitude of influences, that are included implicitly in the decisions taken minute-by-minute in stock markets. The behaviour of the market then depends as much on nearly instant reactions to information and misinformation by market-makers, as on more thoughtful, but still judgmental information, prepared by analysts. The susceptibility of company valuations, to pressure from single issue groups, is now becoming more apparent, as the recent action fostered by Greenpeace, in preventing the deep water disposal of Shell’s Brent Spar oil storage cum transfer platform, shows; this has become a cause célébrè.

Structured examination of actual or proposed implementations of new science and technology, when it includes their psycho-social and political implications for the polity, requires separation from actions in the political sphere\textsuperscript{20}. Logical and rational presentation of information rarely displaces psycho-social perceptions once these have become established in the polity. Structured examination, using the notions of technology choice, is an extension of the processes used in TA and EIA; is iterative and makes use of the STEEPV guidelines\textsuperscript{21} to develop a holistic\textsuperscript{22} picture of the technology, embodying the notions of fitness for purpose,
valuation and risk. Particular skills are needed at the point where the outcome of the examination is introduced into the polity; there different forms of feedback loops occur (some open loops are also likely to occur) through consultative processes that at present might include public hearings, consensus conferences and widespread consultation through information technology processes, perhaps including interactive television. The skills needed are those of an integrator\(^{23}\) enabling a bridge to be built between the scientific and technical domain and the open domain of the polity, where debate and rhetoric will shape political and regulatory actions.

Any rational examination is itself open to a number of criticisms from the political domain. Since it will be based on the perceptions of the investigators, these will be prone to influences from many sources. The problem of creating an acceptable group of investigators is itself fraught with controversy and extreme difficulties. These concerns are evident, most acutely, at the point of transferring the outcome of the examination, from the relatively closed sphere of the investigators, into the public domain. There is acute conflict, between the need for widespread consultation by the investigators and the need for expertise in depth in synthesising future possibilities, in a way that will maintain the cohesion of the polity.

**Implications for Research and Development**

The time scales of the polity and of research and development differ markedly. In the polity, long term trends in social organisation depend on an interplay with values, technology and ecology. By contrast, these trends are punctuated by shifts in political ideology that, in modern democracies, accompany successive elections. The result is often a headlong rush for the application of the technical fix in good currency at the time, particularly if these appear to be supported by economic notions. Only rarely is there continuity of government intention through these ideological shifts, despite continuity in the public service. As a result, the polity’s development takes place through, and sometimes in spite of, a series of issue-attention cycles, where old issues return to be in good currency and are occasionally augmented by a genuinely new issue. However, as became apparent in the early 1970’s, for example through work of the Meadows\(^{24}\) and many others, the long term trends the world faces, and which research and development are expected to influence, are not amenable to technical fixes; to meet the lack of ‘fit’ between these long term trends and contributions from research and development “.... democracy itself must be endowed with new tools in education, in
participation, in communication and in management ... An individual who does not protect himself and his family by insuring against contingencies is regarded as irresponsible: on the national scale .... such foresight has too seldom been expected.”

National foresight programmes, as practised in many OECD countries, are not sufficient in themselves to guide research and development activity, unless their outcomes are set in the wider context of the polity and the narrower context of product development. Research and development activity underlain by the notions of fitness-for-purpose, valuation and risk, whether implicitly or explicitly, faces more arduous inquiry than might otherwise be the case. The choice to embark on the activity will be influenced by internal and external perceptions of its likely outcome and of its desirability. Each component of the triad should, perhaps, be regarded as an interface rather than a completely specifiable and quantifiable entity. As interfaces, fitness-for-purpose, valuation and risk will indicate protocols that are likely to result in handshaking between the providers product, process or service and the end-user. The extent to which the handshaking is perceived to be successful (or unsuccessful) will also be observed by other interested players, who can influence the successful continuity (or incipient decline) of the provider. The range of players involved will extend well beyond the conventional ones, as has already been illustrated. Providers of capital, financial analysts, stock markets and investors of all kinds have their say, but others, such as single issue groups, whose interests stretch from environmental protection to broad ethical and moral matters, relating to all living organisms, have now to be taken into account. At present there is no clear way in which even relatively few products, processes or services can face the full panoply of scrutiny by a wide variety of players, in advance of market exposure, so that for most providers the outcome of the handshaking process lies in market success or failure.

For research and development programmes, the notions of fitness-for-purpose, valuation and risk as interfaces, between the provider and the end-user and other players in the polity, introduce the complexity of the polity as an inexorable factor. As a result, there are likely to be many secondary and higher order outcomes beyond the conventional need for outcomes that create products or services, that are marketable and can be created by processes that are efficient, and economically viable. The secondary and higher order outcomes will not be recognised easily, if they can be recognised at all, as the programme begins and may well be concerned with direct action that can take bewildering forms. It is not that the range of
‘stakeholders’ has suddenly widened, which it has, but rather that all stakeholders have become more vocal and more familiar with the issues that surround the introduction of technical advances. Direct action in the world’s stock markets can be devastatingly quick in its effect on a company’s future, whether it results from resounding technical success, typified by Glaxo’s anti-ulcer drug Zantac\textsuperscript{26}, or disastrous failure as happened with Boots congestive heart failure treatment drug Manoplax\textsuperscript{27}. In a social context, direct action by a known or a hitherto unknown single issue group, by disrupting a company’s research and development programme, can be a difficult public issue requiring skilled management. Shifts in regulations are a further hazard, as has happened with the evolution of the European Product Liability directive\textsuperscript{28}.

The underlying processes involved in technology choice, involving its components of fitness-for-purpose, valuation and risk, with their extensive checklists of points requiring thought and response, place research and development in the context of the polity. Acknowledgement of the wider issues that now thrust themselves on any science and technology programme is forced upon management. For success these programmes now to adopt the interactive philosophy described by Ackoff\textsuperscript{29}, if they are not to be negated later by unforeseen development trends in the polity. Perhaps the most least familiar notion that research and development programmes now face is that of sustainability in all its guises. The notion of sustainability is encapsulated in the Bruntland\textsuperscript{30} definition “Humanity has the ability to make development sustainable — to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs.” Deceptively simple to state, this definition is both broad and deep in its content. It sets new rules for the research and development game that must be matched. For technology choice, sustainability is game, set or match.

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The discussion of how sustainability can be defined is not a new one. It was initiated by the Bruntland Commission, a group assigned to create a “global agenda for change” by the General Assembly of the United Nations in 1983. The commission’s definition of sustainability has been referred to by diverse bodies as a foundation for policies and practices that support a society that is economically, ecologically, and culturally sustainable. This statement is at the heart of sustainability, and leaves open for discussion how humans can achieve this goal.


STEEPV is an acronym for Social, Technological, Economic, Ecological, Politics and (Human) Values, the six dimensions of analysis and synthesis used in futures thinking and scenario building (Loveridge, D. “Scenarios,” Open University Business School, Course B885 “The Challenge of the External Environment,” Supplementary reading Book 2, 1992). The STEEPV dimensions were developed originally by Peter Schwartz, then at SRI International in 1974. Philip Holroyd and I deemed it necessary to add the ecological dimension, where ecology takes its true meaning and should not be confused with ‘environmental’ matters, as these are a more limited set of notions.

As described by Brock⁴, Wafer⁷, Kastrinos & Loveridge⁵ in “Definition of the overall framework for development, dissemination and teaching of TA course modules,” European Commission DG XIII/D2, “Value Programme Interfaces,” January 1995. ⁴ UNECIA Ltd. ⁵ CIRCA. ⁶ PREST. UNECIA and CIRCA held an administrative contract; the technical work was carried out by PREST.

For example “The Limits to Growth,” published by Earth Island Press in 1972 and authored by Meadows et al. This was a ground breaking work, much maligned at the time, but since recognised as a pointer to other modelling work during the 1970’s.

In the 1970’s, Lord Kennet led a team drawn from throughout Europe to study the desirability of creating an institute, within the EC framework, to provide early warning of important events and trends that would influence the development of the EEC, as it then was. The team reported in December 1975. The teams work was subsequently published as “The futures of Europe,” 1976, Cambridge University Press, for the Commission of the European Communities.

Zantac made very considerable contributions to Glaxo’s profits while it was protected by patents. The acquisition of Wellcome by Glaxo occurred at about the time that the primary patents on Zantac were due to expire.

Manoplax was withdrawn after a trial involving some 3,000 patients in North America and Scandinavia, revealed increased mortality under some circumstances. The immediate effect was a rise in Boots share price, because of the ending of the uncertainty over the future of Manoplax. However, this simultaneously raised questions over the future of Boots pharmaceutical division, many analysts stating that they believed the division could not survive in its then present state. Despite Boots making claims to the opposite the analysts turned out to be correct in their surmise.

The European directive on product liability was at least ten years in the making and in its final form was far more benign than in its original form. Strong industrial lobbying was needed to achieve modifications of clauses that would have placed European industry, and possibly Europe as a whole, at a major disadvantage to its competitors.

Ackoff’s definitions have already been referred to.

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