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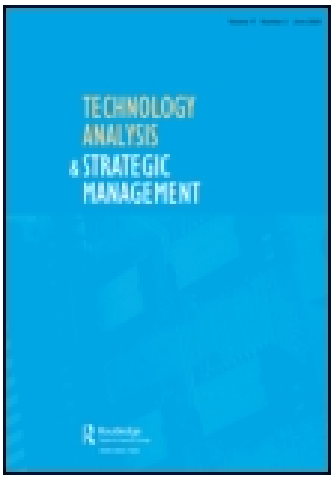

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Ignorance and uncertainty: influences on future-oriented technology analysis

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Future-oriented Technology Analysis (FTA) deals in phenomenological ignorance of three kinds (known unknowns, unknown knowns and unknown unknowns) that give rise to its basis in subjective opinion. These invade both the qualitative and quantitative information co-joined to create outcomes for policy and management in all the STEEPV (Social, Technological, Economic, Ecology, Politics and Values and Norms) themes. FTA then becomes an imaginative projection of current knowledge in which formal methods/techniques play a subsidiary role following Wittgenstein's dictum that 'methods pass the problem by'. These contentious matters form a platform for discussion, concluding that FTA's practical outcomes are underlain by human behaviour, subsumed under subjective opinion in many dimensions and will be more so as FTA becomes involved with technologies of great social and commercial complexity.

Keywords: future-oriented technology analysis; ignorance; uncertainty; qualitative; quantitative, methods

Any sufficiently advanced technology is indistinguishable from magic
(Arthur C. Clarke)

1. Introduction

Is there something phoney about foresight, a major part of Future-oriented Technology Analysis (FTA) or does it really tell us something about the future? What the future holds for the Earth is well understood if the physics of cosmology is to be believed. What about nearer home? What can or does FTA hint may be in store for all the denizens of planet Earth? Or even closer home what may be in store for humanity however weakly that may be intimated? Much depends on the conflict between modernity, with its strong attachment to science, and post-modernity with its questioning of much that modernity accepts. Staton (2006) drew out the poverty of foresight if Derrida's claim that foresight does not say much about the future is accepted. These are not empty arguments but get to the root of what foresight, as the outcome of anticipation, appreciation and learning, can say about something that does not exist. Just as the future of the Earth can be computed and imagined from the physics of the Cosmos, a future that does not exist, can lesser

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matters be similarly imagined (anticipation), appreciated (behavioural pattern and numeracy) and learned about through imaginative assessment of substantive knowledge of what is? Are these the characteristics of foresight, the institutional practice, now in vogue? In the present context, with its emphasis on science and technology, is foresight embedded in *diminuendo* in its corresponding social and commercial expectations? The essence of what follows is to *rediscover* the interdependence, and sometimes interlocking, role of ignorance (Roberts and Armitage 2008; Roberts 2012) and uncertainty in underpinning quantitative and qualitative thought in FTA. There is an evident paradox in characterising, if indeed that has any meaning, the 'future', something that does not exist even conceptually or perceptually, as much is shrouded in various forms of ignorance, especially the unknown unknowns[1] form (Rumsfeld 2002). The paper sets out to pay much attention to the situations that may confront FTA practitioners, typified in Section 2, in the future, which emphasises the need for extensive learning: this is expanded in Section 3. Section 4 introduces some important issues that are referred to infrequently in FTA, while *conventional* methodological matters are deliberately placed in *diminuendo in* Section 5. An example is given of how subjective opinion, a core activity in FTA, can be elicited (Section 6) in a way that supports quantitative expression: this relates to the three forms of ignorance referred to. The paper concludes (Sections 7 and 8) with a further discussion of situations that FTA is likely to face in the future.

2. Getting a feeling for the range of FTA

Can the notion of the future as a 'black hole' be contested? Does ignorance preclude any escaping light of anticipation? The responses are ambiguous. In many branches of science, the future is a 'grey hole' in which some of the matter is quantitative and some qualitative. The co-joining of quantitative and qualitative information is exemplified by the Tōhoku earthquake and tsunami on 11 March 2011 north east of Japan. To quote 'The earthquake occurred where the Pacific Plate subducts under the plate beneath northern Honshu.' The boundaries of the tectonic plates and the understanding of the process of subduction are reasonably well elucidated distinguishing two processes differing in terms of their tendency to follow 'stiction' or 'lubrication'. It was supposed, from history, that the plate movement north east of Japan was predominately lubrication: movement would follow a pattern of 'small' steps at relatively low Richter scales, well below 9 that actually occurred (generally a stiction pattern event). The Pacific plate moves at a rate of 8–9 cm per year dipping under Honshu's underlying plate: this motion pulls the upper plate down until the stress builds up enough to cause a seismic event releasing a large amount of energy. The break caused the sea floor to rise by several metres creating a sea bed rupture about 480 km long The earthquake consisted of three events, subduction, creating a highly stressed region on the sea bed; rupture, releasing enormous amounts of energy and the consequent tsunami. The precautionary principle might have questioned the assumption that a Richter scale 9 event might occur (a low probability event) and FTA might have had something to say about the location of the Fukushima nuclear power station and its design, but did either notion come into play? What contribution ought FTA to have made to planning and building of the Fukushima plant? Did that happen? Even in hindsight, the responses to these questions remain unclear. For the debate in this paper, there was no 'black hole'. The location of the fault line was 'known' as was the rate of movement of the plates, which had tended to categorise the subduction in a particular way. The General Electric boiling water reactors (BWRs) generated a total of 4.7 GW, making Fukushima one of the largest nuclear power stations in the world. The BWR was probably the best known at the time and stability in a known earthquake zone would have been very much in mind. And yet …Was it one of the three categories of ignorance, an extreme case of the combination of an

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unusually severe earthquake and tsunami, one of very low probability of occurrence but of extreme importance in its occurrence? The occurrence was not what Taleb (2007) has picturesquely called a Black Swan event as Richter scale 9 earthquakes were known events, though there had been only four more powerful ones in human history. Suppose again that an FTA had been requested during the planning of the Fukushima power station where would the expertise have come from to conduct the study? How would that expertise have been tested to give it the necessary credibility in the public domain? How would the study have been conducted to bring together the subjective, qualitative opinion and the quantitative information including all its uncertainties? How would the risk of disaster and the need for disaster management have been assessed? How would the possible social and political consequences have been assessed?

Similarly, any business has a certain momentum that will ensure its continuity for an uncertain time into the future in the absence of some new and rejuvenating feature to its business endeavour and sphere. Rejuvenation creates the need for new artefacts to sell into existing or new markets; for mergers and acquisitions to increase market power; but above all else to ensure successful continuity of the business based on securing future profits and a strong share price. FTA has a strong role to play in businesses achieving successful continuity through offensive and defensive activities. Again particular kinds of expertise are needed based on the three components of foresight that run throughout the business's activities, including the network of companies with which the business has either strong or weak interdependencies or interlocking arrangements of a quite different character (Cagnin and Loveridge 2012).

Retracing ones steps to Derrida's criticism, real foresight (Loveridge 2001), perhaps more so than its institutional practice, can have much to say about the future recognising that ultimately the future is a 'black hole'. Attempts to look inside the 'black hole' will be unsuccessful as characteristically it contains unknown unknown forms of ignorance. The important issue then becomes the understanding of how ideas do emerge, in a random manner and sometimes fleetingly, from the fuzzy boundary between the unknown and the barely appreciated. These ideas, and more broadly artefacts, can blend together across the entire STEEPV (Social, Technological, Economic, Ecology, Politics and Values and Norms) set to begin to offer risky insights into what is possible in all the STEEPV themes and their probabilities for the future. If foresight or its institutional counterpart say nothing about the future, as Derrida claims, then it is because part of the future is akin to a 'black hole' from which nothing escapes. However, the analogy cannot be taken too far as the future eventually yields some of its secrets as ideas emerge across its fuzzy boundary. It is a major part of FTA to reveal or capture the presence, however brief, of these 'secrets' as they cross the fuzzy boundary of *unknown unknowns* and in doing so to initiate the three embodiments of real foresight: this role for FTA is discussed further in the next section.

3. Characteristics of FTA as an umbrella activity

FTA focuses on the need and potential to address disruptive transformations in response to grand societal challenges. It follows that disruptive change is a prime focus for FTA, a highly contentious statement since many of the most disruptive changes in the Earths' and human history have happened with FTA nowhere to be seen. The immense disruption caused by the change from an oxygen poor to an oxygen rich atmosphere is one example. Disruptions of consequence in a lower league, but huge nevertheless, abound. Exemplars are the recent shifting of parts of Japan by some 3 m, an alteration in the tilt of the Earths' axis and in the speed of rotation, a matter of importance to satellite communication, following the 2011 earthquake. No doubt it will be

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argued that this is not what FTA is about, but when there is talk of 'managing the Earth' for this or that 'grand challenge' (all of which are interconnected and interdependent) then there seems to be some hypocritical or sophisticated (in English sophistication means/involves deception) discussion taking place. Perhaps, it is better to settle for a discussion of lower order, a route that will be taken in what follows.

FTA is said to provide a common umbrella for foresight, forecasting and technology assessment research techniques of and for their respective communities. Futures studies are omitted. Derrida's comment, as described by Staton (2006), creates the impression that the umbrella is for immediate protection from inclement situations rather than trying to see beyond them into 'what comes next'. The direct reference to 'research techniques' accentuates the impression that FTA is approached through an enforced search for techniques to fit perceptions of the work in hand. However, Wittgenstein's dictum that 'methods pass the problem by' needs to be constantly in mind to prevent any FTA becoming simply an exercise in technique manipulation that prevents any useful outcome. Practically, FTA needs to be a multi-themed hybrid, accommodating whatever principles and mind-sets are needed by the work in hand; it is suggested that this happens already but by default.

FTA's future orientation means that it deals with matters characterised by uncertainty and ignorance: that is the kernel of this paper's introduction. To embrace these characteristics, FTA's premises and principles ought to draw on those fields. Instead FTA seems to draw extensively on what are commonly believed to be the metaphors from foresight, forecasting and technology assessment: all have a long history and an equally long and growing catalogue of techniques to use: these are the subject of an extensive literature. As an aside, these agreed metaphors are often construed as theory while a parallel search for a philosophical cum theoretical basis for FTA is pursued outside the cohort of practitioners. None of these feature overtly in the evolution of FTA where every application makes assumptions about the underlying validity of the processes used. Indeed, it is questionable whether any purpose is served, in practice, by deferring to notions of philosophy and theory in a field where practical outcomes, based on learning; investigative thought and numeracy, are what matter. M'Pherson (1974) put the matter differently but essentially in the same terms when attempting to rebut Popper's (1957) criticism of holism. However, the practical outcomes are themselves underlain by complex matters relating to human behaviour, uncertainty and ignorance that are generally subsumed under the title of subjective opinion in many dimensions.

It is not the intention to debate the merits of the methods and techniques listed and described elsewhere, but to look into the darker corners of the FTA world. The first of these relates to TA, which is expected to identify first, second, third and higher order effects systemically. The knowledge and investigative capabilities needed to achieve this are broad and may be referred to as 'specialization in breadth and depth', a rare combination in a single individual or small group. Whatever the formal brief, it will be the personal interpretation of it that will shape the work that is done and its boundaries. Personal behavioural patterns (Loveridge 1977) will influence the information sought, including data before its transformation and its integration, via learning, appreciation and anticipation, into a systemic outcome. All of this will be derived from known quantitative and qualitative information including the known unknowns: the outcome will not include unknown (to the individual or group) knowns or unknown unknowns. Hopefully, it will include statements of known unknowns in recognition of the uncertainty of the outcome. The outcome is then a version of the long-time notion of the future as a present appreciation of current knowledge projected to some future horizon. All this may or may not involve formal processes for bringing together quantitative and qualitative information that goes beyond the

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conventional 'synthesis report'. The latter may, or may not, recognise the nature of the expertise and uncertainties involved revealed in the next section.

4. FTA and subjective behaviour: methodological issues and metaphors

FTA assumes that its processes have an innate capability to deal with dynamic situations made up of many interconnected themes, each of which is characterised by behavioural traits, uncertain opinions and ignorance. How individual subjective opinions invade many aspects of FTA needs some clarification. Savage (1954) distinguishes between three different interpretations of probability: objectivistic (frequentist), personalistic (with regard to propositions expressing opinion) and necessary (measurement of the extent that a set of propositions 'of necessity' confirms the truth of another). The latter is perhaps less often encountered in FTA than the first two. Frequentist probability does not require explanation: if it occurs in FTA, it may take the form of the frequency distribution of an adverse drug reaction or something of that kind. The second (subjective opinion) can be either individual or group depending on the situation involved. Cooke (1991), Lipinski and Loveridge (1982) and Amara and Lipinski (1983) have all described similar processes for eliciting expert (subjective) opinion from either individuals or small groups. The difference between group elicitations (reminiscent of a small scale Delphi without the consensus seeking element) is its 'corporate' nature. When individual opinions are sought and later combined, the formulation is thought to be nearer to the advisory situations prevalent in companies contemplating market sensitive moves.

An individual expert's opinion on the situation in question takes the form of a probability distribution of Savage's second type: recognising that is an important step as it prevents the notion that the advice offered is absolute, which in the real world it never is. If several experts are consulted individually, the individual probability distributions can be joined (there are technical difficulties) using the procedure set out by Lipinski and Loveridge (1982). However important as these matters are, the discussion during the elicitation unearths how the expert's thinking proceeds. How that responds to seeding his or her thinking with unusual ideas stemming from over the horizon scanning relating to the various forms of ignorance is important. In this way, a relationship between an expert's thinking processes and their representation as a subjective probability distribution can be built by creating a wider appreciation of the situation involved in the FTA. There is a secondary process: that arises from the unknown knowns in the FTA team's distribution of knowledge and the depth of it. Every field of expertise tends to have its own language: the success of expert elicitation will then depend crucially on the mental 'handshaking' between the interviewee and interviewer, an aspect that can spread beyond the elicitation of opinion into appreciation of the brief itself. There is another aspect to the language involved. For example, FTA is likely to become involved in synthetic biology; nano-science, nanotechnology and nano-artefacts and their social acceptance; stem cells and what they offer and their social dimensions. These new fields have commercial cum socio-political implications not in individual silos but interdependently and globally. These are immense challenges in themselves and to the notion of expertise in breadth and depth that facilitates appreciation. Each new field has its own language to be learnt. There is spill over into the fast moving fields of investment and money, where invention and innovation move at an alarming pace. The contrast to the inexorable, but slower pace of ecological change is stark, and can be devastatingly disruptive while occurring over decades or centuries, bringing life changing events where an appreciation of existence alone will bring the situation into a liveable perspective.

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Throughout FTA, there can be confusion over the use of the words possibility, plausibility and reality in relation to subjective opinion. When thought is transferred from conceptual to perceptual space, it becomes possible as a mental construct. It may have negligible probability of embodiment as an artefact in physical space for an indeterminate period of time: this is the basic condition that underlies the notions of 'over-the-horizon scanning', a necessary precursor to any FTA to achieve its future orientation. Plausibility is a matter of belief that has its own frequency distribution assessed through probability. Reality is the creation of the artefact or event in physical space, and will be preceded by its scientific possibility and/or technological feasibility, even if the former is not recognised until after the event. For example, engineers often create a working artefact before its theoretical underpinning (science) is fully understood: that is simply an example of a known unknown in science.

Scenarios are often used to present the quantitative and qualitative output of FTA. Bearing in mind that a scenario is the skeleton of a play and that the number of plays written is huge, it becomes clear that any scenario has a very low probability of occurrence among the total number of plays written. So, it is for scenarios describing the outcome of an FTA. The number of scenarios actually presented is infinitesimally small compared to the entire set. Consequently, the probability of any one scenario actually occurring is negligibly small as it is for each of the remaining set not presented. All scenarios then have an equal but negligibly small probability of occurrence, implying that a probability of occurrence ought not to be attached to any single scenario. Managerially, this does not prevent a scenario from performing its two primary roles of integrating ideas in a way aimed to shift entrenched managerial behaviour.

Historically, the focus of FTA has been on technology. Its purpose now is to set technology in the context of socio-economic matters, ecology, politics and human values/norms of the STEEPV set. Casti (2010) is only the most recent person to question the frequent assumption that science and technology are the prime movers in disruptive change: here, it is assumed that they are not and nor should they be considered as such. Transformation of quantitative data from science, technology and pseudo-science into information then plays a role, in conjunction with the STEEPV constituents, in framing the context of any FTA. Questioning quantitative data to understand its genesis needs to occupy a prime place in FTA. How often the nature of measurements is dissected according to the NUSAP[2] system (Funtowicz and Ravetz 1990), a form of quantitative 'due diligence,' is often shrouded in mystery. For example, the location and nature of measuring instruments can have important implications for the data reported. Similarly, how and why a particular survey question (or group of questions) was constructed can influence the outcome markedly. Many of the perceived 'uncertainties' of quantitative information arise from these sources and from the nature of expert opinion: the latter needs to embrace each experts substantive knowledge, assessing ability (which enables substantive knowledge to be 'interpreted' into the future), and imagination; these are all matters related to an individual's behavioural pattern. The literature relating to the methods used in FTA will not be reviewed but the next section necessarily sets out briefly their relation to the purpose of the paper, namely the influence of ignorance and uncertainty on FTA.

5. Quantitative and qualitative methods in FTA

In a sense, FTA is related to operations management. It was in that field that Meredith et al. (1989) developed the two-dimensional framework shown in Figure 1.

Meredith's notions can help FTA practitioners' position methods to guide their role and use. Figure 1 sets out compactly the influence of knowledge, and conversely of ignorance, on the

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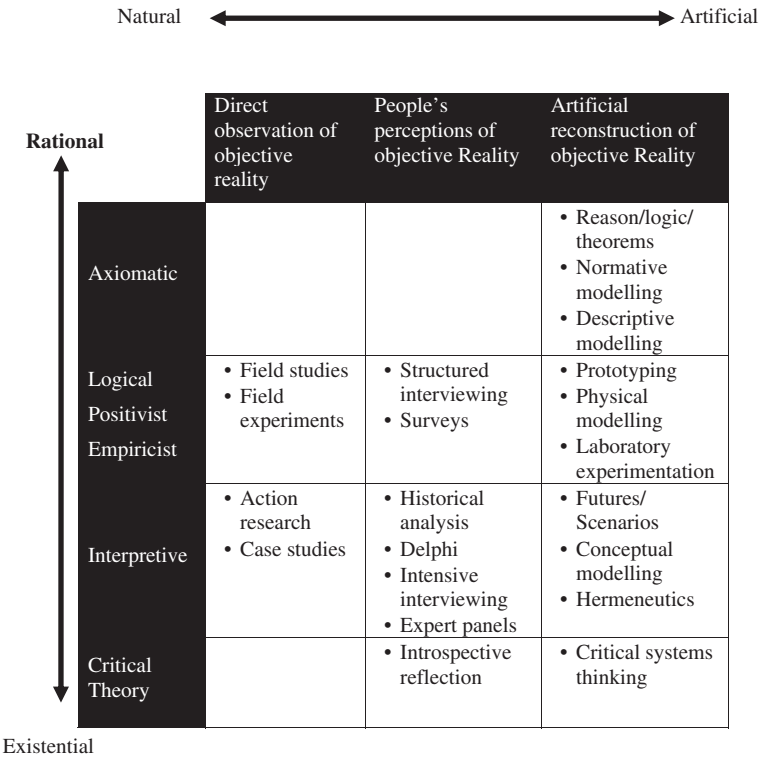

Figure 1. A framework for research methods (adapted from Meredith et al. 1989, 139).

selection of methods used in FTA indicating the nature of the knowledge (ignorance) each assumes to be present along the two axes.

On the *vertical axis* at the *rational pole* knowledge tends to be deductive, more formally structured, with a formal degree of objectivity and with a methodological proscription all of which are influenced by the individual's behavioural pattern. In contrast at the *existential pole*, knowledge is more inductive, less structured, typically subjective, and requires more interaction with the environment.

In detail the

- *axiomatic* perspective represents the theorem–proof world of research. A high degree of knowledge is assumed, *a priori*, about the goals and the socio-technical structure of the situation
- *logical positivist/empiricist* assumes that a situation can be isolated from the context in which it occurs. Facts or observations are independent of the laws and theories used to explain them: this is the basis for most survey research
- *interpretive perspective* includes the context of the phenomenon as part of the object of study. Interpretive FTA studies people rather than objects
- *critical theory* attempts to synthesise the positivist and interpretive perspectives and to get past their dichotomy by placing knowledge in a broader context of its contribution to social evolution

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The *horizontal axis* concerns the source and kind of information used. Empiricism lies at the *natural pole* (deriving explanation from concrete, objective data), while subjectivism (deriving explanation from interpretation and artificial reconstruction of reality) lies at the *artificial pole*. The individual's behavioural pattern creates three categories: *object reality, people's perceptions of object reality* and *artificial reconstruction of object reality.*

In detail

- *object reality* refers to direct observation of the situation and assumes that there *is* an objective reality that can be detected
- *people's perceptions of object reality* relates to surveys, interviews or many laboratory experiments: the primary concern is with the perception or abstract representation of reality by *individuals* exposed to the situation. These are second source methods, but may be the only efficient or effective way to obtain information about the situation
- *artificial reconstruction of object reality* is attempted in almost all modelling and systems analytic approaches recasting the object reality, as determined from one of the above two categories, into a form that is more appropriate for testing and experimentation, such as analytical models, computer simulations or information constructs

Meredith chose a number of measures to describe the poles of the horizontal dimension.
At the *artificial pole*, FTA

- uses highly abstracted and simplified models such as linear representations
- tends to yield conclusions with high reliability and internal consistency
- is often characterised by a significant separation of the phenomenon from the researcher, as with an abstract representation
- is highly controlled since the researcher uses *a priori* constructs or models to specify the information to be collected
- process is highly efficient since aberrations (classified as 'noise') do not have any causal source

At the *natural pole*, FTA is

- concerned with real phenomena
- less concerned with reliability and more with externally generalisable validity
- closer to reality
- less controllable and less efficient.

The critical issue here is the balance between reliability and external validity (e.g. surveys provide reliable data distributions but their validity in actually measuring constructs is suspect). Clearly, the most valid information is obtained by direct involvement with the phenomenon.

The references to 'truth' in the matrix are not relevant as FTA depends on subjective opinion, expressed probabilistically, which is heavily influenced by the notions of ignorance.

The matrix that emerged from Meredith et al.'s philosophical review described methods useful in operations management. It is appealing, because of its practical compactness, for use in the different conditions applying in FTA: these have already been indicated above. Meredith et al.'s matrix is a subset of a much larger set (Popper 2008). Consequently, it enables judgements to be made on the mix of methods to be used. In selecting methods, these judgements place less

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emphasis on philosophical matters and more on practical ones of concern in FTA, to help to take the study forward.

The first step in the practical use of the framework is to understand that FTA strives to identify:

- Actionable future visions
- Timely mitigation of negative impacts or adaptation to new situations and exploitation of positive outcomes
- Guidance and support for the policy process identifying impacts on society and implications for policy, and particular stakeholders, and sectors of society probabilistically to express their relevant uncertainties
- How to deepen dialogue with society
- How to improve governance

Because of the dominant role of subjective opinion, FTA knowledge is:

- Not verifiable experimentally in the scientific mode
- Highly uncertain and complex, particularly relating to the existence of causal relationships
- Able to create the basis for visions of the future based on common ground among participants
- Action oriented in terms of identifying threats, challenges and opportunities and the relevance of knowledge for a particular situation
- More than future-oriented research
- Normative combining socio-techno-economic feasibility and scientific possibility to yield desirable outcomes
- Multi-disciplinary by definition

FTA develops understanding of systems and situations in time and space through people's perceptions (a basis for opinions); suggests methodological approaches that assist in capturing the essence of systems and their contexts; improves practices with conceptual modelling; helps to formulate policies and puts them into practice to influence situations in desirable directions. In its context, FTA helps to develop hypotheses as to how present situations may evolve into the future, often by using scenarios and conceptual modelling, that may include prioritising important areas of intervention, though prioritisation is an underdeveloped art. The next section illustrates how knowledge relevant to FTA can be elicited showing the practical implications of many of the issues raised above.

6. Combining quantitative and qualitative information – an example of elicitation

The events involved in the 2011 earthquake north east of Japan illustrate the importance of the STEEPV set and within it, the broad range of sciences and technologies that any FTA has to be able to cope with: it also illustrates the uncertainties and the kinds of ignorance involved. The need for capabilities and knowledge in breadth and depth is clearly established. Figure 2 (Loveridge 2009) illustrates a scheme for undertaking the essential learning processes.

Elicitation of opinions and combining them is a central feature in FTA. The following example illustrates how this can be done. For the sake of simplicity, only one example is presented to illustrate many of the matters discussed in the preceding sections. In this example, it is the content of the methodology that is important and not its context, though that was the more important aspect

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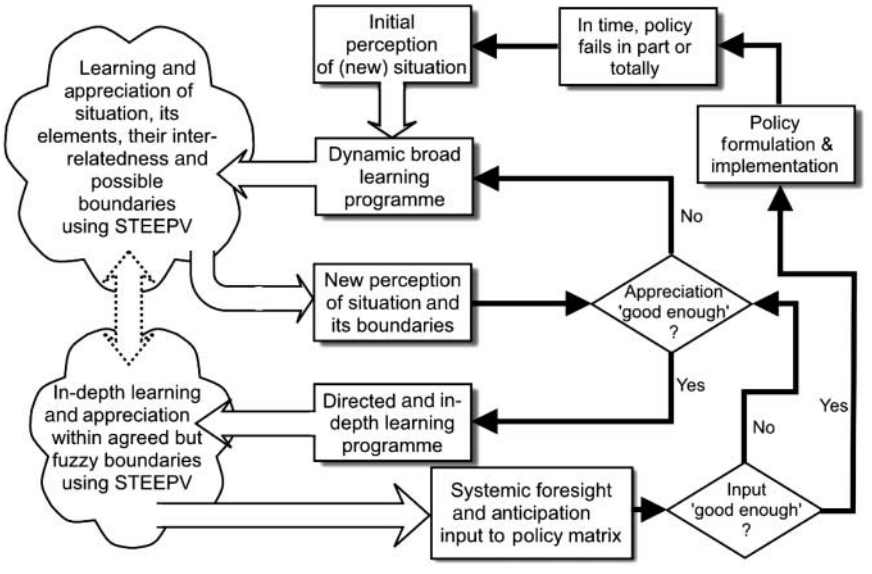

Figure 2. Learning scheme (reproduced from Loveridge (2009) by courtesy of Routledge).

of the study. The full methodological description of the study has been referenced (Lipinski and Loveridge 1982) as it can only be summarised here.

In 1977–1978, the Institute for the Future (IFTF) carried out a study of the future of the UK, which was regarded then as the 'sick man of Europe'. The full outcome of the study remains confidential to this day, but its sponsors (16 major companies and a UK Government department) agreed to publication of the methods used. The study took as its basis a tree structure, based on 10 variables chosen (here the variables are less important than the methods used) to describe the future situation of the UK. Scenario style photographs portrayed the UK at two time slots, 1985 and 1995.

Interviews are used so often to obtain opinion that the procedure is regarded as mundane, but it is not. Elicitation of expert opinion is a deep and arduous process. It was invoked in the IFTFs study to gather information for the main parts of the study that later involved scenario generation. The elicitation process used facilitated the later combination of quantitative and qualitative information that lay at the heart of the study. Three kinds of people were invited to take part in the elicitation programme: *generalists*, *people of thought* and *people of present and future action*. *Generalist's* had a wide spread of interests; a high level of perception and awareness of the relevant components of the situation. *Persons of thought* were the conventional experts who had deep knowledge of matters relating to a particular component of the situation or of a tightly related set of components. *People of present and/or future action* were those people whose present or possible future position meant that they were then able to affect the amelioration of a situation or were likely to become able to do so at some time in the future. Seeking subjective opinion about a situation and its future from these three types of expert had to be tailored carefully to each and the elicitations carried out sensitively, but within the general principles that apply to elicitation procedures.

The first step was identification of a sufficient number of people in each of the three categories who were willing to be interviewed: this raised the subsidiary question of their individual levels

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of expertise and how it could be assessed in advance. Recognising an 'expert' and coming to some understanding of how expert the individual was, was an underlying concern. Finding experts was done through recommendations followed by simple due diligence: once invited, the experts were asked to use a set of five 'self-ranking' criteria (described in full in Lipinski and Loveridge (1982)) that permitted an understanding of their level of expertise. The headings of the self-assessment criteria were:

(1) *Unfamiliar* with the subject.
(2) *Casually* acquainted with the subject.
(3) *Familiar* with the subject.
(4) *Quite familiar* or *knowledgeable* about the subject.
(5) *Expert* because you are in the community of people who *currently study, work on and dedicate themselves to the subject.*

The outcome of self-ranking can provide weighting factors for each 'expert' (Amara and Lipinski 1983).

The next step in the elicitation explained the kinds of information being sought: these were *substantive knowledge*, *assessing ability* and *imagination. Substantive knowledge* was the base from which the expert's responses, in the elicitation, would be made; *assessing ability* was the way and skill with which the expert was able to interpret his knowledge into the future and imagination was free thinking ability. Next, the elicitation moved to an *assessing ability test* in which the interviewee was asked to respond to 10 questions, drawn from the Guinness Book of Records, in a probabilistic way: this was used to alert the interviewees to the need to think probabilistically about their responses during the next phase of the elicitation.

The next phase of the elicitation was the most arduous: in it, the interviewees were asked to respond to a set of questions in his/her topic field the responses to which would enable a probability distribution to be constructed representing their opinion regarding the topic of the interview. The interviewee was asked to *think out loud* (generally recording was not acceptable to the interviewees) during this part of the elicitation. In this way, the interviewers gained insights into the interviewees thinking processes leading to questionnaire responses, creating subjective, technical impressions of the kind of information described earlier relating to the Japanese earthquake. Verbal equivalents to different probability levels (Alpert and Raiffa 1982) were used during this part of the elicitation to seed the interviewee's thinking processes.

Finally, the assessing ability test was repeated this time using questions drawn from the interviewees' field of expertise.

The final step in elicitation was the combining of the distributions of opinions from several interviewees into a single joint set for later use in constructing scenarios. The scores from the second *assessing ability* test were a form of calibration of each interviewees assessing ability. Calibration allowed 'correction' of each probability distribution to a common basis that enabled combination of the individual opinions.

The elicitation procedure used in the IFTF study illustrates how *known knowns, known unknowns and unknown knowns* enter into the practical steps of elicitation of subjective opinions on which the success or otherwise of FTA rests. It also indicates how very different kinds of information from throughout the STEEPV set can emerge from elicitation procedures and be combined into a coherent outcome. These matters are likely to become ever more important as FTA moves into the complex situations discussed in the next section.

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7. Future influences on FTA

All the foregoing has lain within the conventional boundaries of FTA and how it makes use of quantitative and qualitative information in unison. So far, FTA has stuck to familiar approaches to what it does and its intentions. Whether these can be sustained as 'fit for purpose' is another matter. There is perhaps a new tier to be built on and above the current edifice that centres on the unknown knowns and known unknowns forms of ignorance. Current FTA components of foresight, forecasting and TA are simply not able to cope with the welter of information now available to anyone with the wit to look for it nor is FTA able to cope with the increasing complexity of the tasks it faces, often with very significant political interventions and implications. A current example may help to clarify the situation. In a recent UK newspaper article, George Monibot, a well-known environmental campaigner, claims that 'The unpalatable truth is that the anti-nuclear lobby has misled us all' over the effects of nuclear radiation on the human body measured by the number of deaths and illnesses arising from the Chernobyl disaster. Monibot goes on to claim that much of the information used by the anti-nuclear lobby is not supported by peer reviewed research but comes from press articles and books of unrestrained opinion that rely heavily on 'gut' reaction. FTA is heavily dependent on opinion and the use of quantitative data that needs verification and due diligence (e.g. following the lines of NUSAP (Funtowicz and Ravetz 1990)) to establish its veracity. These are 'straightforward' matters but do they remain so in the face of the political and social worlds' demands for immediacy that underlie the mode of living of modern society? The latter is made possible by access to 'infinite' sources of 'information' of unknown quality and veracity.

Increasing computer power may have some wide and unconventional influences on FTA. In 1983, Loveridge was only the then latest person to raise questions along the following lines:

> 'Computers and you' is no longer the mildly bizarre idea that it was in 1977 or earlier, but whether society fits into the concept of 'computers and you' or 'computers or you' is a matter of social concern that is unlikely to be resolved by the turn of the century, while the outcome will persist for very much longer

Data mining of very large (and open) databases including blogs; the myriad of social networks; public broadcasting (both TV and radio); e-mails and others yet to be created alongside the conventional (and sometimes less than conventional) databases arising from academia; business government and elsewhere, is already possible but limited by human and search engine factors. Data mining is far from a new idea, the possibilities of which far exceed those of the 1960s or 1970s. Kurzweil (2005) is only one among many to claim that the 'singularity', when computer 'intelligence' or at least computer power, may exceed the capabilities of the human brain, is now 'within reach'. More advanced search engines and massively fast computers, with architectures not unlike the human brain, are likely to change data mining out of all recognition possibly specifying how FTA should be conducted. The role of algorithms in these processes will be crucial and largely unseen but will require deep understanding if the phenomenon described by George Monibot above is to be avoided.

As the complexity of systems involving synthetic biology, genetics and artificial life, nano-artefacts and other developing themes merge, the 'learning the language' aspect of FTA will become correspondingly arduous but essential. The role of computation and of algorithms will become accentuated. Skills in understanding what algorithms do in producing FTA outcomes becomes essential for presentation to the polity for discussion and acceptance, bringing

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a new social role for computation and computers. Perhaps, this implies the need to extend computer-based translation beyond natural languages and into the languages that lie within the themes of the STEEPV acronym. At the same time, the ever decreasing dimensional scale of artefacts means that FTA will become involved in knowledge of measurements and their meaning at scales and with methods that are unimaginable at the present time except to a few scientists. Framing legislation appropriate to these situations to enable public acceptance of these types of artefacts, is another aspect that FTA may be expected legitimately to fulfil.

Finally in this brief look, not into the unknown future, but into what is already coming about with much more to follow in every dimension of the STEEPV acronym, is the notion of 'grand challenges'. In a sense, these are a throwback to the 1970's debates about the world *problematique* but seem now to be seen as a series of silos rather than as a global phenomenon. However, 'naïve' the modelling processes used then may have seemed to some people at that time they were brave attempts to draw attention to the existence and nature of global situations. Whether Kurzweil and others of a similar frame of mind are right in their beliefs in what raw computer power will be able to achieve in improving our understanding of complex, interactive global systems remains to be seen. The interdependence of the silos of 'grand challenges' adds dimensions that were appreciated in the 1970's but seem to be less so today despite Lovelock's Gaia theory and extensive work on the notions of limits from different disciplines. For that appreciation to return the current global circulation climate models (GCM's) may need to be seen as simply a module in a much bigger global model. At a different scale, the evolution of personalised medicine will need high throughput diagnostics of great power: these too will depend on computer power and algorithms that will need to be understood in the courts if malpractice suits are filed. FTA is already confronted by technological convergence, not at the historic macro scale, but at the nanometre cum atomic scale, where phenomena are unfamiliar and the territory suffused by quantum phenomena, but artefacts are commercialised at the macro scale. Throughout publications about or adjacent to the nano-artefact, biotechnology, information technology and cognitive science quartet (NBIC), there is a continual introduction of ideas, processes and artefacts that are now firmly in the social frame where FTA might be expected to be concerned. Underlying convergence in the NBIC frame are matters relating to modelling and simulation, which in turn means algorithm construction and computation.

Advanced algorithms and enhanced computer power are very likely to become features of every aspect of life, human and non-human, and will face FTA with a new world of expectations of a form of social control of technology.

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8. Epilogue

In conclusion, the following observations are offered:

(1) FTA's greatest obstacle is ignorance. The best that the three components of FTA can do is to identify the 'known unknowns' and the 'unknown knowns'. Nothing could have identified the 'unknown unknowns' that were present in the recent Japanese earthquake. In that sense, Derrida's argument is unassailable: foresight does not and cannot say anything about the future
(2) The presence of ignorance in all its manifestations needs to be constantly in mind enabling any FTA to be framed and managed in its perceived context bounded by the fuzzy boundary between what can be known and that which cannot be at the time

(3) FTA needs to embrace not the notions of knowledge but of ignorance, its dynamic boundary and the ecological safe-fail principle that is a manifestation of ignorance, placing the current emphasis on what is known in *diminuendo* in favour of 'messier' matters from behavioural and cognitive sciences because all analysis is heavily influenced by opinion and all models and surveys are, to an extent, representations of the opinions and beliefs of their designers
(4) The commonly believed metaphors of foresight, forecasting and technology assessment are often construed as theory. To search for a philosophical cum theoretical basis to underlie FTA seems to be of limited value. Each FTA project makes assumptions about the underlying validity of the processes used: deferring to notions of philosophy and theory seems inadvisable when practical outcomes, based on learning, thought and numeracy are what matter (M'Pherson 1974), though underlain by complex matters relating to human behaviour, uncertainty and ignorance
(5) Pursued on the basis of knowledge applied through due diligence investigations' FTA assumes that its processes have an innate capability to deal with dynamic situations made up of many interconnected themes, each of which is characterised by behavioural traits, uncertain opinions and ignorance. Consequently, FTA needs to dwell more on the nature of individual expertise that enables some individuals to stretch out their appreciation of a situation, in all its STEEPV components, towards that fuzzy 'event horizon' beyond which lie the unknown unknowns
(6) The quantitative data that features in FTA do not escape from behavioural influences in its transformation into information so that its 'certainties' are fraught with the uncertainties of expertise
(7) There is the temptation to believe that hugely increased computational power will take FTA into a Kurzwellian era in which FTA may be conducted by means that 'fence' with unknown unknowns, the known unknown category having been banished by algorithmic searches through immense unstructured but interconnected sets of databases. All will then depend on who created the algorithms and their behavioural patterns (Loveridge 1977) whether human or machine.

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Notes

1. These are referred to often in project engineering as 'unk-unks' and are similar to the ecological 'safe-fail' principle, whereas the more common 'fail-safe' principle is akin to the other two forms of ignorance
2. The NUSAP system examines quantitative data as follows: N for correctness of the number: U similarly for the units: S for simple statistical spread: A for confidence levels and P for the pedigree of the number, that is, where and how was it generated and who was responsible for doing so.

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