Science, Technology and Innovation Studies

Ian Miles
Ozcan Saritas
Alexander Sokolov

Foresight for Science, Technology and Innovation

Springer

Science, Technology and Innovation Studies

Science, technology and innovation (STI) studies are interrelated, as are STI policies and policy studies. This series of books aims to contribute to improved understanding of these interrelations. Their importance has become more widely recognized, as the role of innovation in driving economic development and fostering societal welfare has become almost conventional wisdom. Interdisciplinary in coverage, the series focuses on the links between STI, business, and the broader economy and society. The series includes conceptual and empirical contributions, which aim to extend our theoretical grasp while offering practical relevance. Relevant topics include the economic and social impacts of STI, STI policy design and implementation, technology and innovation management, entrepreneurship (and related policies), foresight studies, and analysis of emerging technologies. The series is addressed to professionals in research and teaching, consultancies and industry, government and international organizations.

More information about this series at http://www.springer.com/series/13398

Ian Miles • Ozcan Saritas •
Alexander Sokolov

Foresight for Science, Technology and Innovation

Springer

Ian Miles
Higher School of Economics
National Research University
Moscow, Russia

Ozcan Saritas
Higher School of Economics
National Research University
Moscow, Russia

Alexander Sokolov
Higher School of Economics
National Research University
Moscow, Russia

ISBN 978-3-319-32572-9 ISBN 978-3-319-32574-3 (eBook)
DOI 10.1007/978-3-319-32574-3

Library of Congress Control Number: 2016950616

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG Switzerland

Acknowledgments

This book was prepared within the framework of the Basic Research Program at the National Research University Higher School of Economics (HSE) and supported within the framework of the subsidy granted to the HSE by the Government of the Russian Federation for the implementation of the Global Competitiveness Program.

Contents

Authors

Ian Miles is head of the Laboratory for the Economics of Innovation, Higher School of Economics, Moscow, and Professor of Technological Innovation and Social Change at The Manchester Business School, University of Manchester, UK. He has a BSc (Psychology) and a DSocSci (service innovation) from the University of Manchester. Most of his working life has been spent at Sussex University (SPRU—Science Policy Research Unit) and Manchester (MIoIR—the Manchester Institute of Innovation Research, and its predecessor organizations PREST and CRIC). He has numerous journal articles, book chapters, and contributions to reports, in addition to edited and authored books. His first book, *The Poverty of Prediction*, was in the ForSTI area, as have been several subsequent books and many other publications; more generally, a "futures" orientation is apparent in many of his other works on innovation, emerging technologies, indicators, and knowledge-intensive business services. He is a well-known lecturer and teacher in this area.

Ozcan Saritas is a Professor of Innovation and Strategy at the National Research University, Higher School of Economics, Moscow; a Senior Research Fellow at the Manchester Institute of Innovation Research, University of Manchester; and editor-in-chief of "Foresight"—the journal of future studies, strategic thinking and policy. His research focuses upon innovation and policy research with particular emphasis on socioeconomic and technological Foresight. With a Ph.D. from the "Foresight and Prospective Studies Programme," he introduced the "Systemic Foresight Methodology" and has produced a number of publications on the topic. He has extensive work experience with the international organizations including United Nations (UNIDO and UNCTAD), OECD, and the European Commission. He has been involved in large scale national, multinational, and corporate research and consultancy projects such as Research and Innovation Foresight for Europe 2030 (RIF2030); Russian S&T Foresight 2040; European Commission Anticipatory Governance Systems; and Scanning for Emerging Science, Technology and Innovation issues (SESTI) and a Horizon Scanning project for the Rockefeller Foundation on the future of developmental issues. He designs and delivers executive education courses on Foresight and STI Policy. He also delivers lectures on Foresight and Strategic Planning, Technology and Innovation Management, and STI policy and supervises Ph.D. and Masters students.

Alexander Sokolov is Deputy Director of National Research University Higher School of Economics (HSE) Institute for Statistical Studies and Economics of Knowledge and Director of HSE International Foresight Centre. His main professional interests are related to Foresight and S&T and innovation priorities, indicators, and policies. He is a tenure professor at HSE. He teaches Foresight for undergraduate and postgraduate students. He has authored over 120 publications in Russia and internationally and managed many Foresight projects, including Russian S&T Foresight: 2030, Foresight for Russian ICT sector (2012), Innovation Priorities for the Sector of Natural Resources (2008–2010), Russian S&T Delphi Study: 2025 (2007–2008), Russian Critical Technologies (2009), etc. He is a member of several high-level working groups at OECD and other international organizations and serves for advisory boards at several international conferences and journals.

1 Introduction

1.1 Why This Book?

Not long ago, many serious people would dismiss studies of the long-term future. This is not altogether surprising, given that many popular books and films that claim to tell us about what will happen are indeed easy to dismiss. Those that are not simply establishing an environment for adventure stories, almost always represent partial and one-sided views. They are aimed mainly at arguing for a particular goal—or arguing for the credibility of one futures guru or another. More serious pieces of work are often thrown out with the bathwater, dismissed as not really worth much attention for one or more reason.

Sometimes the argument has been that efforts to inform current activities by insights based upon such studies smacked of old-fashioned long-range planning. Such planning has surely now rendered obsolete by the triumph of free markets and neoconservative politics. *The future can take care of itself*.

Another argument made the case against basing decisions on ultimately untestable judgements about people's actions, or about scientific discoveries, that lie over the immediate horizon. *The future is inherently unknowable*.

A different line of argument warned against the risk of imposing rigid thinking, or unexamined assumptions reflecting dominant ideologies, closing off many potentially valuable lines of development when seeking to shape affairs with the long-term in mind. *The future is not ours to colonise*.

Views such as these were very influential during an upsurge of futures studies in the 1960s and 1970s, perhaps best-known through The Limits to Growth (1972)—which succeeded in putting environmental concerns firmly onto the agenda.[1] Though many activists were mobilised around concerns about the long-term

[1]Futures studies have a long lineage, of course, and the tools and techniques now employed in ForSTI often date back many years, with much intensive development in the 1950s and '60s. See Miles (2008).

I. Miles et al., *Foresight for Science, Technology and Innovation*, Science, Technology and Innovation Studies, DOI 10.1007/978-3-319-32574-3_1

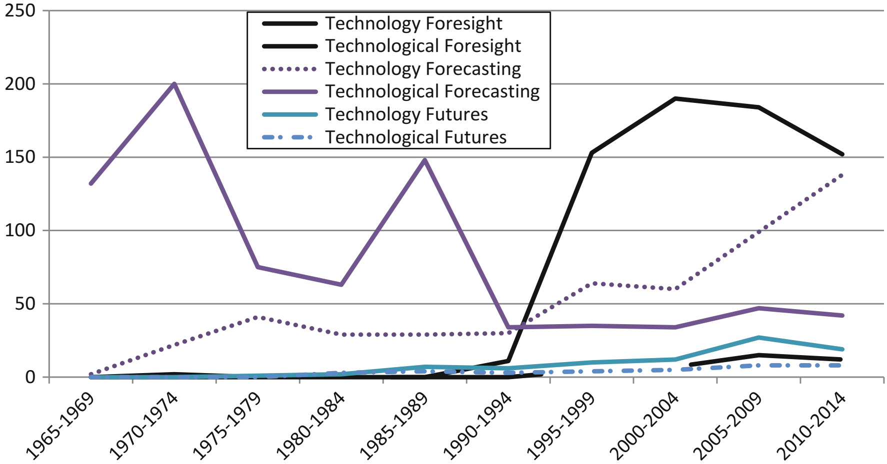


Fig. 1.1 Publications featuring key words in their titles, 1965–2014. *Note*: The data points capture the number of times both words appear in the title of a publication, regardless of order or proximity. *Source*: data produced using Harzing's "*Publish or Perish*" (accessed on: 04/02/2016)

implications of, for example, climate change, most decision-makers were concerned with much shorter-term issues. Those who had to make decisions affecting the long term (such as investments in power plants and infrastructure) usually took these decisions from a "business as usual" perspective. Their attention tended to be narrowly focused on the immediate concerns of their industry or government department. Limits had been very controversial, but as scientific consensus around dangers of climate change became established in later decades, increasing pressure was exerted on business and political leadership to take the threats into account.

The last decades of the twentieth century saw a remarkable revival of futures activities (Fig. 1.1). There were many manifestations of this, for example "Twenty First Century Studies" and a body of work concerned with the UN's Millennium Goals. The approaches that have most informed the discussions of this book were the large-scale Technology Foresight Programmes being launched in a great many countries (henceforth, TF = Technology Foresight and TFP = Technology Foresight Programme). (For a detailed account, see Georghiou et al. 2008). Some of these TFPs proved very influential, for example playing major roles in the restructuring of national and regional STI (Science, Technology and Innovation) activities; others were less so. The wave of (mainly government-funded) TF activities has continued to expand. Some countries have been through several rounds of TF, while others are taking the activity up for the first time. Meanwhile, the general principles of Foresight exercises have been widely disseminated, beyond narrow understandings of STI. Countries, regions, firms and voluntary organisations have launched activities with diverse foci. Technology remains a major preoccupation, but we also see activities with more of a focus on, for example, health and demographic issues, ecological and climate change issues, social and political development, and so on.

Foresight approaches, then, have become more “respectable”. Foresight has moved from being a fringe activity, dismissed as wild futurology, to becoming a body of widely adopted practices, used in significant ways by a wide range of decision-makers. Substantial amounts of experience and documentation have accumulated, and the community of practitioners has expanded; there is much more explication of the tools, techniques and practices involved than was previously the case. (Indeed, another common, and not altogether unjust, criticism of the futures field was that it was too reliant on the wisdom of talented individuals and consequently too dependent on fashions, celebrity, and opaque methods. *The future was the preserve of gurus*.) Not everything in the garden is rosy. As the term “Foresight” became recognised as conferring a certain legitimacy upon futures work, so many less systematic and lower quality activities were marketed as Foresight.

This book sets out to draw out the key lessons from the experience of the last few decades. It will focus particularly on Foresight dealing with Science, Technology and Innovation (ForSTI—Foresight for STI). The meaning of these terms will need to be spelled out in more detail, but at this point we shall note that the STI field is one where longer-term analyses are of considerable importance for stakeholders of all kinds. The aim of this book is to help provide guidance to practitioners, would-be practitioners, and users of ForSTI, as to how activities may be planned, implemented, interpreted, and applied.

1.2 foresight, Foresight—and Foresight for STI

We use the term “Foresight” in a particular way in this book, which is why we capitalise the “F”. It is this sense of Foresight that we embed in the term ForSTI. We will explain just why we are introducing this new acronym in a few paragraphs. First we further clarify the meaning of Foresight.

Dictionary definitions of *foresight* usually refer to one or both of two complementary capabilities. The first capability is *insight* into possible future affairs, being adept at drawing conclusions about possible implications of current trends and contingencies. The second capability is *prudence*, being prepared for the substantial responses that challenging implications may require. The combination of these capabilities lends “foresight” positive connotations lacking from terms such as, say, prediction, prophecy, and planning. However, the capabilities are typically seen as the preserve of gifted individuals possessed of intuition or other mysterious talents—rather than as involving skills that can be (more or less easily) cultivated and practices that can be (more or less effectively) enacted.

Of course, ForSTI activities may well be most successful if they can enlist really capable and charismatic practitioners. This is true for all but the most routine human enterprises. People vary in how capable they are as analysts and communicators, narrators and visionaries. They also differ in their expertise (or lack of it) in one or other specialism, and a few are "T-shaped" professionals who can span multiple disciplines. Some skills can be learned, but recruitment of talented people is important.

Moving away from individual gifts, when we talk about Foresight—with a capital "F"—we are referring mainly to what Loveridge (2009) has described as institutional Foresight.[2] This involves some serious, structured effort to develop, gather and organise evidence-based insights concerning future challenges and opportunities, and to apply these as strategic intelligence for decision-making. This is much more than an exercise in prediction, one that seeks to establish what *will* happen. Likewise, it is more than an effort of planning, aimed at saying what should happen in order to solve specific problems or implement specific solutions.

As we shall spell out in more detail in the next chapter, ForSTI (and Foresight more generally) involves a participative process in which evidence is assessed, possibilities articulated, and actions proposed. It is liable to be related to decision-making. Equally, it is liable to engage a range of stakeholders that is sufficient for two purposes. First, since relevant knowledge is unevenly distributed across many people and institutions, reflecting the wide spectrum of experience that can be brought to bear on most STI activities. Thus, the range of stakeholders should be sufficient to access critical varieties of knowledge. Second, if action is to be effective, insight into the rationale for, and potential outcomes of, particular courses of action may need to be widely shared among those responsible for and affected by the actions. This is a matter both of democracy and legitimacy, and of more instrumental purposes—i.e. understanding of the rationale for action may be essential if action is to be implemented as intended. Again, achieving this requires engaging a sufficient range of stakeholders.

This notion of Foresight has much in common with the work of the "prospectives" school in France. Much of the pioneering work in this tradition, from de Jouvenel, Godet and others, has tended to focus on strategic issues confronting firms and regions, rather than the sorts of ForSTI that has formed the core of many national governmental (and intergovernmental) TFPs, and the typical methods used in its toolkit include some rarely used in TFPs. But much of the core philosophy is shared between the approaches.

"Foresight" has been a remarkably successful piece of terminology. It was rarely used before the 1990s, less frequently than formulations such as futures studies, futurology, and forecasting (the list could go on: prospectives, prognostics, futuribles, futuristics...). Figure 1.1 depicts the remarkable rise of this term. Foresight has effectively displaced many of these terms, being used on an increasing scale since the 1990s (as documented by Miles, 2010). This is no doubt because of the success and successful diffusion of TFPs around the world from the early 1990s on. Sometimes this use is misleading, with quite narrow desk-based activities being labelled Foresight. So not everything that is now labelled Foresight is really

[2] The term 'institutional' here refers to "an aggregate of individual perceptions negotiated into some agreed form that becomes a property of the institution" (Loveridge 2009).

any advance on traditional forecasting and futures analysis. Likewise, not all Foresight is labelled as such. Recent years have also seen the new terminology, such as FLA (Forward Looking Activities), and FTA (Future-oriented Technology Analysis), and recently "Horizon Scanning" seems to have been used rather frequently to refer to a spectrum of activities extending well beyond the more technical meaning of the term. Variations in terminology seem in part to reflect particular individuals and organisations seeking to differentiate themselves (sometimes misleadingly), in part to stress specific activities such as Technology Assessment or computer simulation.

Why introduce yet another acronym—ForSTI—into this already-crowded field? First, in order to indicate that Foresight practices including participatory and policy activities, as well as prospective analyses, are involved. The activities are not simply forecasting, though examination of trends and possible futures are integral to ForSTI. Prospective analyses and associated efforts to elicit wide participation and influence policy agendas have been particularly honed in the context of STI activity and decisions. But often this is labelled as Technology Foresight (TF). ForSTI indicates that we are looking beyond TF as narrowly understood in terms of the features and capabilities of emerging technologies. ForSTI encompasses a wider range of activities—including "upstream" developments in science and research, and "downstream" developments in terms of innovations and innovation processes and their outcomes, and more contextual phenomena such as the evolving structure of innovation systems. Many TF exercises (especially more recent ones) have been ForSTI in this sense. It is not uncommon for TF exercises to drop the "Technology" prefix and simply been labelled as Foresight. We have not followed in this usage, because we are focussing in this book on Foresight applied to the STI field, and the specificities that this involves.

Using This Book

We frame ForSTI as a process involving a number of activities. These activities, while overlapping and subject to several iterations, can be viewed in terms of a succession of stages. This book, after introducing the subject and its background in more depth (Chap. 2), will be organised in terms of this somewhat idealised succession of stages.

We shall examine the issues confronted at the outset, in terms of determining just what sort of activity is being undertaken, what objectives are pursued, what methods are used, what participants enlisted, and what management frameworks are adopted and decisions made (Chap. 3). We shall consider how the work is to be structured, and how key participants are identified and encouraged to be engaged in the process (Chap. 4). We outline some of the main methods applied to scan horizons and gather intelligence for ForSTI (Chap. 5). We then examine ways of eliciting and analysing expert opinions, which remain important sources of evidence about possible futures (Chap. 6). Methods for exploring alternative futures, explicating the range of contingencies that may be confronted, are the next topic (Chap. 7). We consider how we can elaborate our understanding of how things are related to each other as systems, through modelling approaches of various kinds

(Chap. 8). Following the appraisals of future prospects, we turn our attention to how strategies to create desirable futures may be developed and assessed (Chap. 9). Finally, the book explores ways in which ForSTI can be used to help establish priorities and provide more recommendations for action, how it can be followed up by efforts to disseminate and apply these results, and how we can assess and evaluate the ForSTI process itself (Chap. 10)—and hopefully embed it further into decision-making (Chap. 11). In all of these cases, we combine discussions of the key ideas and principles involved, with case studies drawn from various exercises and countries, and dealing with a range of STI issues.

The case studies are sometimes part of a continuous text, but we will present some more extended cases in the form of Boxes that can be read separately, if desired. Each chapter is structured in such a way that the reader can quickly see which sections deal with general orientation, with specific concepts and principles, with explication of tools and methods, and with case studies.

These structural features are intended to make this book useful for a range of readers interested in ForSTI ideas and approaches. It is especially aimed at those interested in how these ideas and approaches can be applied in practice. The book can be read as a single narrative, but particular topics can be easily located via the table of contents (and the index) and thus rapidly accessed when required.

An Overview of the Structure of This Book

More specifically, the following chapter will continue to elaborate the case, sketched in above, for considering Foresight and in particular ForSTI to be increasingly important activities, ones that need to be addressed in serious and systematic ways. Following this, Chap. 3 will discuss the initiation of such activities—how we need to scope and manage them. Since, as we shall argue, interaction with stakeholders and sources of knowledge is a key element of ForSTI processes, Chap. 4 discusses the issues that arise in this respect.

The next set of chapters deal with the main methods typically applied in ForSTI activities. Though we present them in an order that reflects a common and systematic way of going about the process (as outlined in Chap. 2, in fact), they do not need to be read in this order. Furthermore, many of the methods may be applied at multiple stages of the ForSTI process, and various different ways of designing and implementing the tools involved can be brought to bear.

Chapter 5 examines Horizon Scanning and the gathering of intelligence for a ForSTI exercise: this is normally a very early step in the process, but it is also something that needs to be attended to more continually. Chapter 6 goes on to consider ways in which this intelligence may be further gathered, and inputs synthesised so as to appraise possible futures, by methods such as Delphi. Delphi tools are in reality rather flexible, and some designs allow for their application to other tasks such as priority setting. Chapter 7 introduces scenario analysis, which involves imagination and integrates various partial appraisals of possible developments into more coherent accounts of prospects and choices. Chapter 8 concerns the informal and more quantitative models that underpin our analyses and appraisals.

Chapter 9 discusses methods for integrating and interpreting these appraisals, so as to help guide action through strategies. The chapter outlines Critical Technology Analysis and other approaches to priority setting as well as techniques that form roadmapping. Next, Chap. 10 first considers a variety of outputs and outcomes generated through ForSTI, and their reporting and dissemination. The chapter involves a discussion of the impact of ForSTI, and how to go about evaluating ForSTI exercises.

A round-up of conclusions that emerge from the overviews of numerous aspects of ForSTI in the course of this book will be presented in Chap. 11.

2 Foresight for STI: What and Why

2.1 The Nature of Foresight and ForSTI

The term Foresight has long been applied to futures work, not least in H.G. Wells' call for "Professor of Foresight" in the 1930s, and in studies for the US government (involving Joseph Coates among others).[1] But as the previous chapter noted, "Foresight" has become prevalent as a description of futures-related activities only in the last couple of decades. Consultancies, University courses, research programmes, and all kinds of institutional activities are now badged as being Foresight activities. The rise of "Foresight" to prominence stems from the pioneering studies of John Irvine and Ben Martin in the 1980s.

Irvine and Martin were working in the Science Policy Research Unit (SPRU), University of Sussex (under the leadership at the time of Chris Freeman, who himself authored several important studies of STI and the long-term future.) SPRU was a pioneering institution that combined innovation studies with futures studies. (Indeed, in the 1980s it was still rather rare to find a university-based group of any size working on either of these areas.) Often the same researchers were engaged in both streams of work, and Irvine and Martin played an important bridging role. Their analyses of what they labelled Foresight[2] were initially presented in two substantial and influential books, the first (1984) entitled *Foresight in Science*, the second (1989) *Research Foresight*. Their approach was to examine how governments around the world were addressing long-term decision-making in STI (science, technology and innovation) areas, and as the books' titles indicate. "Foresight" was the label attached by these authors to the task. Martin (2010) provides a helpful retrospective on this work, explaining that they had been inspired

[1]The evolving application of the term, and the confusions consequent upon this, is traced out in some detail in Miles (2010).

[2]See Irvine and Martin (1984), and Martin and Irvine (1989).

I. Miles et al., *Foresight for Science, Technology and Innovation*, Science, Technology and Innovation Studies, DOI 10.1007/978-3-319-32574-3_2

by the use of "Hindsight" to describe efforts to determine the origins of new technologies in R&D and other activities.

These two path-breaking studies were systematic overviews of the area, of what practices various agencies were adopting, with what success. They were funded by UK and Dutch government agencies responsible for determining "promising areas of science", of establishing provision for strategic research. The studies are thus not ForSTI research themselves, but as studies *of* ForSTI.

Irvine and Martin saw Technology Foresight as primarily about informing research priorities, a major concern of their studies' sponsors. In explaining its importance, they saw it as being:

> . . . the only plausible response . . . to resolving conflicts over priority-setting caused by escalating experimental costs, limited resources, complexity in scientific decision-making and pressures to achieve 'value for money' and socio-economic relevance. . . . Foresight provides, at least in principle, a systematic mechanism for coping with complexity and interdependence as it affects long-term decisions on research, in particular facilitating policy-making where integration of activities across several fields is vital.
>
> Martin and Irvine (1989, p. 3)

Their work informed the Technology Foresight Programmes (TFPs) in the UK, the Netherlands, and elsewhere, during the 1990s and onwards. This large scale of institutional activity gave the term considerably legitimacy and cachet. The result is that the term has now come to be applied to all sorts of futures activities, some of which lack the systematic approaches, the policy links, and the participative orientation of the best of these TFPs. The notion of "fully-fledged foresight" was introduced to differentiate these latter practices from more limited, less participative forms of futures study, carried out often as pure (and often desk) research with little link to decision-making. It should go without saying that desk research, scientific modelling, citizen debates, and many other activities can result in important breakthroughs, deeper insights, wider understanding. They may well contribute to ForSTI activities. But they feature different ambitions and scope, and ForSTI has contributions to make to decision-making and collective intelligence that reflect the elements of fully-fledged Foresight.

Many of the futures studies that have achieved most public visibility are not closely tied to particular decision-making processes. Sometimes they are the result of academic exercises; sometimes they are "wake up" calls from pressure groups. Such studies—when implemented with some degree of rigour, systematic appraisal, and open-mindedness—can be useful aids to planning, decision-making, and thinking about the future. They can be helpful inputs to exercises that are more appropriately termed Foresight. (Forecasting studies can also, of course, draw on reports and data produced in the course of Foresight activities!). Many of these traditional futures studies had been carried out by researchers and/or activists with very specific sets of concerns, anxious that these be properly attended to by decision makers. Often their efforts took place outside of the timetables and apparatus of policymaking. For this reason their impact was frequently limited or took much time to be realised. Efforts to promote the work as extensively as was the case for

The Limits to Growth, whose sponsors (the Club of Rome) organised media attention and governmental briefings around the world—and thus fed an emerging environmental movement—are rare indeed. ForSTI, in contrast, will typically be generated in response to policy concerns, and to be linked to policy cycles of one sort or another.

The (typically national) TFPs that took off from the mid-1990s differ from much other technology-oriented futures work in several ways. Typically they involve a configuration of three elements, though the precise emphases and methods vary considerably, and we see these elements as featuring to greater or lesser extents in ForSTI:

1. **Prospective**. As befits "futures studies" they put considerable effort into applying systematic methods to developing appraisals of longer-term developments. The larger TFPs examined a wide range of trends and possibilities, of challenges and opportunities, concerning STI.
2. **Policy-related**. Many of the early TFPs were intended to help establish priorities in funding research, and to orient related technology policies, such as training and regulatory development. They were often explicitly intended to inform major policy pronouncements, and timed so as to fit into the rhythms of policymaking. They were sponsored by influential policy actors, rather than being ivory tower or outsider analyses.
3. **Participative**. They usually set out to access knowledge and elicit opinions from a much wider pool of knowledgeable stakeholders than "the usual suspects".

Figure 2.1 captures the essence of the "Fully-Fledged Foresight" that combines these three elements of policy-relevant, participative, and prospective activity. Not all TFPs were so thoroughgoing, not least because there was a kind of bandwagon effect, and not a few countries launched pale imitations of one or other aspect of TFPs seen elsewhere. Serious policy learning is more than this sort of imitation: it requires understanding the underlying principles that lie behind specific policy instruments, and determining how to tune and implement a policy mix that is adapted to local circumstances and objectives.

Foresight, then, should not be confused with forecasting, though it should take into account the results of serious forecasting exercises, and such exercises may be part of a Foresight process. Forecasters often aspire for precision in an attempt to predict how the world might look at some point in the future, often using techniques like trend extrapolation, computer modelling, etc. By contrast, Foresight does not seek to predict: instead, it is a process that seeks to create shared "visions" of the future, appraisals that stakeholders are willing to endorse by the actions they choose to take today. It is focussed on *influencing the development of the future;* some commentators portray this as *creating the future*. We are inclined to see "creating" as too grand a claim, since many factors and actors play a role in this, and not all are mobilised in the Foresight process. Perhaps we can best see ForSTI as helping to *shape* the future.

One of the definitions in the literature captures key elements of this:

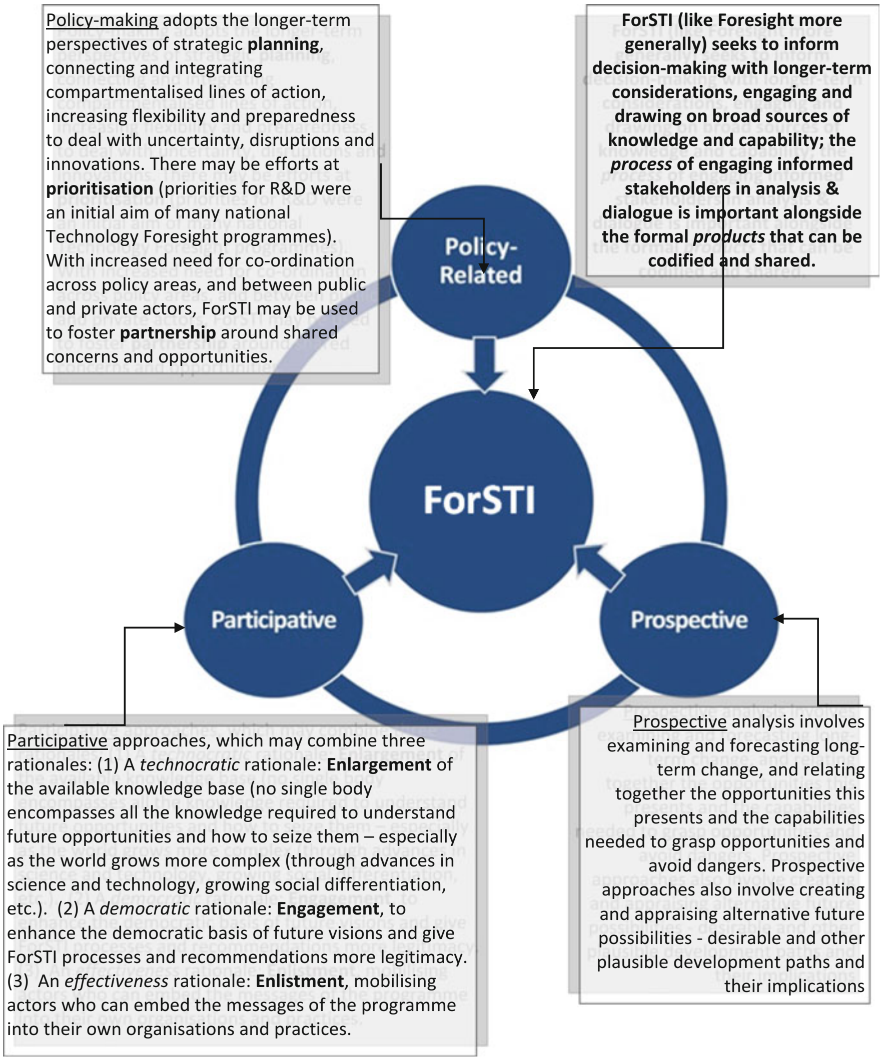


Fig. 2.1 Three components of Fully-Fledged Foresight (ForSTI). *Source*: loosely based on Keenan et al. (2003)

Foresight is "*the application of 'systematic,' 'participatory,' 'future-intelligence-gathering and medium-to-long-term vision building process' to 'informing present-day decisions and mobilising joint actions'*" (Miles and Keenan 2002).

So, typically, Foresight (and when it is applied to issues of STI, ForSTI)

1. considers multiple futures, which may include possible, plausible and desirable futures
2. is a participative process
3. is action-oriented

ForSTI does not replace technological forecasting, technology assessment, futures studies, or strategic planning of R&D. Each activity has its role, and in many instances these can be mutually supportive. However, these latter activities are sometimes conducted in a fashion that closes off debate and considerably limits the scope of the alternative futures and paths of action that are considered.

Many efforts to inform decision-making about longer-term implications of the issues and actions in question are relatively top-down affairs, oriented towards producing reports or other forms of intelligence to support policymakers or corporate strategists. Sometimes they are intended to sway the opinion of the public, or of a particularly important constituency. Two major varieties of such forward-looking activities are:

- **Expert Judgement**, where a gifted individual or a small expert panel weighs available evidence and generates an appraisal of the future (e.g. the scientific or technological achievements that can be gained, the dangers that need to be confronted, a list of priorities for research funding. . .). The panel may commission new studies or mainly draw on the expertise of its members. These members are often what in England are known as "the great and the good"—people that have established reputations in related fields, and who have credibility with the intended audiences and users of the work. While the renown of the experts will partly determine the impact of the work, there are cases where it may be dismissed as the product of special interests. It will be alleged that these are the "usual suspects" with limited inclination to propose radical alternatives; other experts, it will be alleged, could be found to give other views (Thus the dismissive acronym BOGSAT is sometimes applied to this approach—it is criticised as being just a "Bunch Of Guys Sat Around a Table"). Such an approach has often been employed to gather evidence and reach conclusions as to "critical technologies" or priorities for research in particular scientific fields. Variations on this, such as committees of enquiry and more participative "citizen juries" are sometimes engaged in other sorts of decision-making as to regards STI, especially where matters of regulation are concerned.
- **Technique**, where future prospects are appraised via more or less technically sophisticated procedures such as computer simulation and modelling, or some specific tool such as Cost-Benefit Analysis. Sometimes such approaches dominate the debate. Large and complex models—for example those used to forecast climate change, or some of the more ambitious attempts to explore world energy futures—may consume a great proportion of the funds required for a project. They can become the main element into which data and analysis are fed, and around which appraisals are constructed. Their legitimacy will partly rest on the techniques and approaches employed—often computer simulation has been treated with some degree of awe. But there is increasing awareness that simulations depend on assumptions about the object of study—and that these assumptions may be contested ("Garbage in, Garbage Out" is a mantra used to

indicate that the results of modelling are only as good as the underpinning assumptions and data). Models may well require expertise for informed interpretation of their results (and to mount credible challenges to these results). Since models are rarely able to deal with qualitative phenomena and structural changes, extending the study, beyond the narrow parameters that can be properly addressed by the model, may require other forms of expertise.

2.2 The Origins of ForSTI

The mid-1990s saw a substantial blossoming of ForSTI, in the form of TF programmes (TFPs), in Europe. These approaches in Europe were the result of policy learning, especially from the Japanese technology *forecasting* programme, as it was then known (the ongoing Japanese programme was soon rebranded as Foresight). Irvine and Martin (1984) were particularly impressed by the Japanese model of "research forecasting" that had developed in the decade prior to their review of approaches to STI; they recommended borrowing its guiding ideas. The Japanese framework, that had been underway since the 1970s, itself had drawn on earlier US initiatives. Techniques such as Delphi studies had been adapted to the Japanese context, for example.

In the 1980s and early 1990s, Japan was seen as, in many ways, offering a model of a national economy using STI to achieve rapid growth, catching up with and (in some areas) hauling ahead of European rivals. In one of the key studies developing the "national systems of innovation" approach, Freeman (1987) portrayed Japan as having a particularly effective innovation system (e.g. by allowing innovation efforts to be directed towards areas where capabilities in research and production meshed with opportunities to enter or create markets. This was not just a matter of Japan's growing economic and STI prominence. If Japan had been a struggling country, Irvine and Martin might have paid it less regard—but they were clearly impressed by the systematic nature of the Japanese programme. They noted that Japanese ForSTI has multiple aspects, going beyond sophisticated deployment of tools like Delphi. They stressed that the Japanese activities were not just a matter of forecasts and reports, priority lists and investment opportunities. Japanese ForSTI exercises featured significant "process" attributes—bringing people together to construct and share appraisals of current circumstances and future possibilities. They were impressed by the combination of bottom-up inputs, systematic analysis of trends, and efforts to apply a broad range of new approaches to decision-making and prioritisation in STI.

The reason for undertaking this review of ForSTI approaches round the world stems from STI policy challenges being confronted in the UK and Europe more widely. European countries had been becoming increasingly aware of several STI-related challenges in the last quarter of the twentieth century. Traditional science policy faced difficulties in choosing which of numerous competing lines of R&D to fund—some established areas were becoming extremely expensive, new areas were emerging. There were growing concerns about technology gaps with the

US and Japan, and about Europe's late reactions to developments in Information Technology (IT) and other fields. There was evidence of ongoing public concern about the implications of some large areas of STI such as nuclear power, and about hazards associated with food safety in a world of transformed agriculture and food industries. Media coverage of new IT often featured alarming forecasts of large-scale unemployment and job polarisation, and concerns were growing about reproductive technologies and bioscience more generally. Established tools for STI policy were seen to be struggling to deal with such challenges, and ForSTI might be at least a partial solution.[3]

Thus, several leading European counties launched TFPs in the early and mid-1990s—these included not only the Netherlands and the UK who had funded the Irvine/Martin studies, but also Germany and France and numerous other followed in short order. Approaches varied, with the first French and German exercises largely recycling a Japanese Delphi study, rather than adapting the Japanese principles to their own context. (This led to extremely poor consequences in the French case, where there was considerable resistance to what was seen as an alien tool, even as one which might give Japanese strategic insights into the French innovation system. [4]) As the idea picked up momentum, with TFPs launched in other Northern European countries during the 1990s, the European Commission got behind the approach. It supported ForSTI exercises of its own, and encouraged countries seeking EU membership to undertake their own TFPs as part of modernisation of their STI systems. International organisations such as UNIDO also began promoting the approach, funding training programmes and ForSTI exercises.

The UK TFP experience was particularly influential in the later 1990s.[5] (Indeed, the notion of "Fully Fledged Foresight", as set out above, was very much informed by the experience.) Launched in 1994, it had a very tight timetable, since it was intended to inform major science policies planned for introduction and implementation in the next year. It succeeded in doing this, and while the scale of the impact was a matter of some debate, practically all observers agreed that it was substantial. "Technology" was dropped from the title after a while, as it was seen to deter potential participants in less technology-intensive sectors of the economy. The TFP became known as the UK Foresight Programme, and a Foresight Office has been based in the UK government ever since. (Its exact institutional location has varied over the course of time.)

The UK TFP was explicitly developed round the recognition that the tools that had been effective in Japan should not simply be transplanted to other countries

[3]The introduction of research evaluation techniques, and efforts to reorganize links between public research and private industry, were also part of this effort.

[4]Conflict among two French ministries as to whom should be leading in foresight and prioritisation did not help here, either. An alternative Critical Technologies approach was more securely established.

[5]For a detailed account of the background and origins of the exercise see Martin (2010).

without modification. The tools had been designed and configured within a particular social environment, in which they meshed into social networks and institutions—the Japanese innovation system, to be precise. The UK's innovation system, in comparison to that of Japan, featured relatively poor linkages between the scientific research base and industry; the TFP would need to address the problem. Thus not only Delphi, but also extensive networking via Panels and other meetings, were built into the Programme. Such stress on the participative nature of the programme, as compared to more traditional consultancy studies and expert panel reports, was also a theme in the Dutch and several other national programmes in EU countries in the mid-1990s. If anything, subsequent developments, such as the high levels of public concern around risks and ethics associated with biotechnology (and around other issues in food and agriculture, and in environmental affairs), coupled with emerging concerns about topics such as artificial intelligence, automation, and surveillance, have reinforced the case for widening participation. This has extended the scope of the notion of ForSTI stakeholders—they include not only narrowly conceived users and suppliers in the innovation system, but also the much wider communities seeking solutions to social challenges and/or being liable to experience the results of STI efforts.

ForSTI in the EU is in many respects quite distinct from activities in the USA. Contemporary US activity rarely involves the stress on broad participation that is prominent in much European work—especially when participation involves more than a matter of enlisting experts into Delphi surveys. Forecasting and other futures approaches are, of course, applied in the US context—numerous consultancies provide services ranging from trend-watching and computer simulation to scenario analysis and running futures workshops. The Japanese ForSTI model itself involved "Japanisation" of tools largely developed in the USA in the 1950s and 1960s, where the evolution of methods such as Delphi and scenario analysis was largely driven by the stimulus of military and space programmes. The complex problems addressed by these programmes led their leaders to reason that systematic marshalling of expertise was required in order to grasp future possibilities: quantitative extrapolation and the forms of modelling then available could not readily deal with qualitative change, the coevolution of strategies across actors and domains, and the like.

Japan faced complex challenges too, in terms of moving beyond "catching up" to becoming an industrial leader. Japanese practitioners acquired methods in the US and made them their own, and then people in other countries sought to emulate Japanese methods (This was also the case for methods of industrial modernisation such as quality control and just-in-time). Arguably, the Delphi method as used in Japan can be seen to have been structured so as to emphasise and promote consensus.[6] Many commentators have seen this as a prominent and enduring feature of Japanese society (though other commentators propose more nuanced views). The effort could be seen as one of developing appraisals of future prospects

[6]E.g. the way in which results were aggregated in providing feedback to respondents tended to stress majority opinions, rather than explore the outliers.

that are relatively widely shared, and that can serve as guidance for cooperating policy, industrial and research partners can be viewed in the same way.

Europe, of course, already had its own tradition of futures work, so it is not as if Japan's model of ForSTI was presenting a completely new set of approaches. Though the futures movement of the 1960s was strongest in the US, several European countries had been fertile ground for futures studies (on the whole, interestingly, the UK had been less engaged than most[7]). The futures movement claimed and aimed to be more holistic than traditional forecasting exercises, which feeds into a key element of contemporary ForSTI. The sorts of problems that ForSTI deals with involve highly complex phenomena and overlapping policy domains. Grasping the future was not just a matter of modelling or extrapolating a narrow set of trends. Such forecasts can be useful if examined critically, but analysis of a broader set of factors may indicate developments that undermine a trend or its drivers. And in a complex world, with numerous agents developing and pursuing their own strategies, futurists seek to envisage alternative futures—rather than simply to predict the future.

This particular element of the philosophy was strongly voiced by many European futurists, who were often explicitly motivated by the desire to find alternative futures to the visions proffered by the USA and USSR. This probably lies behind the attention given to scenario analysis (both multiple and normative[8] scenario development) in European ForSTI. Such attention has more recently been echoed in Japanese activities (which show, in several respects, signs of reciprocal policy learning back from Europe).

The initial broad aim of many TFPs was to identify those emerging generic technologies that would be likely to yield the greatest economic and social benefits, but ForSTI more generally covers multiple activities and purposes. Therefore, for the sake of clarity, it is important to stress not only what is common to TF activities but also the ways in which they differ. In terms of purpose, various goals for ForSTI may include:

- ***Exploring future opportunities so as to set priorities for investment in science and innovation activities***. The degree to which priorities can emerge from ForSTI varies from "critical technologies" exercises, where the whole discourse is focussed on a priority list, through more general programmes from which priorities are derived, to targeted Foresight where the priorities are in effect set before Foresight begins.

[7]Cf. Miles (2008). The UK was host to one of the leading journals in the field—*Futures*—but lacked the sorts of large scale enquiry into the Year 2000 that appeared in other countries. It is interesting, too, to compare the lively Science Fiction scenes of the era in the UK and other countries—British SF featured "cosy catastrophes" that can be seen as reflections upon imperial decline. (see Aldiss and Wingrove 1986; Greenland 1983) *The Entropy Exhibition: Michael Moorcock and the British 'New Wave' in Science Fiction*. London: Routledge & Keegan, 1983.

[8]We discuss the exploratory-normative distinction in the next chapter.

- ***Reorienting the STI System***. This goal goes further than priority setting, to shape the structure of the system that sets priorities and undertakes initiatives in STI. For example, there may have been a preliminary diagnosis that the science and innovation system does not match the needs of the country. This was a common perception in parts of Central and Eastern Europe in the immediate post-Communist period when, apart from severe resource difficulties, capabilities reflected an industrial system that no longer existed. In this context it has been proposed that ForSTI can be used as a tool to re-orientate away from more traditional fields of STI (e.g. some classic forms of materials research) and towards emerging fields (e.g. nanotechnology, life sciences); and it can be used to explore new institutional structures (e.g. the institutional location of R&D across Universities, government laboratories, private and third sector research organisations).
- ***Raising the Profile of the Science and Innovation System***. In this context ForSTI becomes a "shop window" to demonstrate the technological opportunities that are available and to assess the capability of science and industry to fulfil that promise. Sometimes the emphasis will be on developments in a particular field, such as Information Technology, where ForSTI is used to generate appraisals of the modernisation of a region, country, or social organisation through the application and further development of the knowledge involved. While this sort of effort can come dangerously close to Public Relations exercises, and is often undertaken by firms interested in developing markets or regulatory frameworks that advance their own interests, it is possible for such efforts to be employed so as to promote and provoke wider debate and engage wider sets of stakeholders in the appraisal process.
- ***Bringing new actors into the strategic debate***. A growing tendency is the use of ForSTI as an instrument to broaden the range of actors engaged in science and innovation policy (This builds on the last points of the preceding bullet). One example is the inclusion of major stakeholders, such as particular professional communities, or even sections of the general public such as youth. It is particularly relevant where established social institutions are confronting major challenges in terms of demand, supply and expectations—as is the case in public health services in many advanced industrial societies, where changes in demographics, technology, and approaches to service delivery are all creating considerable uncertainty. New ethical challenges—often involving bioethics around, for example, genetic modification of human beings, but also in fields as diverse as human enhancement through pharmacology and prosthetics, and the evolving balance between security, surveillance, privacy and civil liberties—are also topics where ForSTI can help to shift discussion away from immediate controversies to longer-term challenges.
- ***Building new networks and linkages across fields, sectors & markets or around problems***. A ForSTI activity may be explicitly aimed at creating new networks and/or clusters that break out of long-standing disciplinary, departmental or sectoral ties. For instance, people concerned with nutrition, sports, social

marketing, and health may all have (unexplored common) interests in developments in related life sciences.

2.3 ForSTI as a Process

ForSTI is an activity that usually takes place over an extended period of time, measured in months and often years. It is helpful to view this in terms of a series of phases, as depicted in Fig. 2.2. Here we merge two slightly different depictions of the cycle, drawing on Miles (2012) and Saritas (2013). These phases do not constitute a rigid schema; we do not intend to suggest that ForSTI has to be pursued in a specific sequence of steps. There can well be reiterations of specific phases, and the sequence may need to be very flexible (Consider some examples Ongoing Intelligence is required throughout the process, scanning for emerging phenomena that need to be taken into account. Decision makers may request advice from the ForSTI—here placed in the Intervention phase—at earlier stages in the process—even though final conclusions may not yet be available, provisional ones and useful insights may well be).

The phases are:

- **Initiation**: sometimes known as PreForesight, in this phase, the need for the activity is examined, and the scope and intended uses and users are established. This may start the whole process off, or follow on from an Impact phase of an

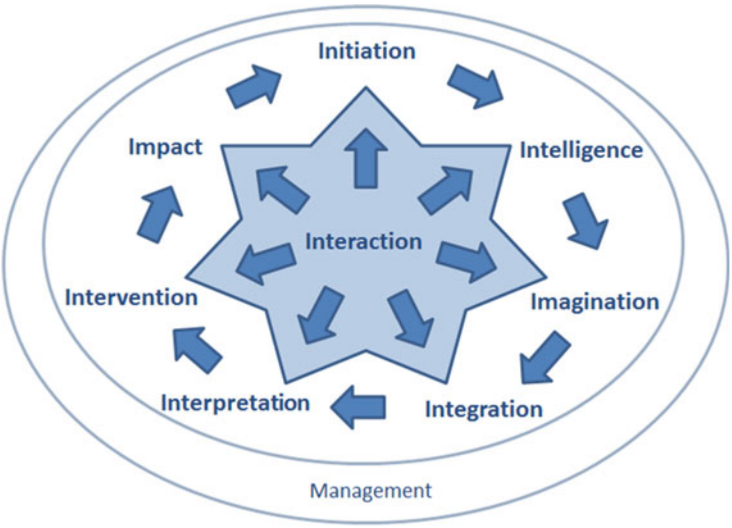


Fig. 2.2 Phases of ForSTI. *Note*: these are not to be taken as a strict sequence. There may well be both "snakes"—jumps back to "earlier" phases—and "ladders"—jumps forward to later phases—in practice

earlier ForSTI activity. In the Initiation phase, plans for the other phases need to be put in place.

- **Intelligence**: Scanning and surveying phase, establishing basic knowledge about trends, about the results of other studies and the views of major stakeholders, etc. While this is liable to be most intensive early on, some ongoing activity of this sort will be required through the exercise, since new developments may come into view. Indeed, the activities associated with all of the phases may be undertaken "out of sequence" as occasion demands.
- **Imagination**: Creativity and modelling phase, in which efforts are made to grasp the underlying dynamics of the focal object(s) of the ForSTI activity.
- **Integration**: Appraisal and visioning phase, in which the possible futures arising from the dynamics and developments that have been considered are delineated.
- **Interpretation**: Strategy and prioritisation phase, in which the implications of the preceding steps are examined, especially in terms of what these mean for achieving the major objectives of the sponsor and other stakeholders.
- **Intervention**: Action phase, where proposed strategies, priorities, and next steps are outlined and communicated to—or deliberated with—key actors.
- **Impact**: Evaluation and embedding phase, where the extent to which the ForSTI activity has been useful, and achieved its objectives, is assessed and specification for follow-up or extended activity is laid out.

In addition, and somewhat outside the cycle of the other phases, is:

- **Interaction**: this is not so much a specific phase as a continual activity that takes different forms across the exercise, for example it particularly involves Recruitment of stakeholders early on, and engaging their ongoing Participation later. It is put at the centre of the diagram because various forms of interaction are required at successive phases of the ForSTI process.
- The process also needs to be **managed** throughout; this is another form of interaction, but because of its pervasive nature it is represented here as enclosing the whole process.

The chapters of this book roughly follow this schema. Accordingly, the Initiation phase, in which the decision to undertake a ForSTI exercise is being taken, and its broad parameters established—what the objectives and topics are to be, what resources will be available, who is responsible for what—will be considered in the next chapter, when we will also touch upon some more general management issues that span the whole exercise. We then discuss some general methodological issues surrounding Interaction, especially matters connected with engagement and participation. Then, the following chapters each tackle a method, or a range of methods, associated with the later phases of the process—though many methods can be applied in more than one phase.

Initiation: Scoping and Managing ForSTI 3

3.1 Introduction

Given the pervasiveness of STI in most aspects of our lives, our cultures and societies, ForSTI of one sort or another may be relevant to many policymakers, and many decision-makers in business and third sector bodies. ForSTI may be undertaken at almost any level of decision-making, though it has been most prominent to date at the national level. It has been used by international organisations, such as the European Commission (EC) and UNIDO (e.g. in support of TF activities in Latin America). More recently, regional authorities and governments in many countries have carried out ForSTI exercises. However non-governmental actors, such as professional associations and industry federations, have also been active in ForSTI, with exercises on topics such as agriculture, the automotive and aerospace industries, and higher education, having taken place since the late-1990s.

"Scoping" refers to those processes of deliberation, discussion and research that contribute to the shape and timing of a given ForSTI activity. Some social actor or set of actors must determine that it requires some form of ForSTI. It will need to determine and just what sort of activity, organised in what way, is required. We shall describe this actor as the "sponsor", because often this party will be the main source of funding of the activity, or play a key role in leveraging that funding from elsewhere (Sometimes an external agency—perhaps a UN organisation—is the ultimate source of funds. There may be a consortium of clients, of some sort, coordinated by one or other agency). Whatever the case, there is typically one body responsible to commissioning the ForSTI activity and ensuring that relevant resources are sufficient—we refer to this as the sponsor for convenience.

Sometimes an exercise may be simply a matter of "me too" on the part of the sponsor—a government agency, for example, sees that its counterpart in another country has undertaken ForSTI and seeks to emulate this. This may involve trying to transplant the other party's exercise to the local context—bringing in the same consultants, for instance, and asking them to provide precisely the same set of

I. Miles et al., *Foresight for Science, Technology and Innovation*, Science, Technology and Innovation Studies, DOI 10.1007/978-3-319-32574-3_3

services. While this is liable to be misguided, a poorly-informed sponsor may think it is appropriate—and even resist the advice of the consultant that much more than minor customisation of the service is required.[1]

There is most often liable to be a dialogue of some sort, where the would-be sponsor refines its notions of just what it wants through sounding out practitioners, other users of ForSTI, or local experts of one sort or another. There may then be an initial Invitation to Tender circulated among potential suppliers of the ForSTI service; typically those who respond to the Invitation will propose their own ideas about how the exercise should be conducted, and these will influence the selection of service suppliers and quite possibly the final set of elements that are assigned to the exercise.

There may not always be competitive tendering for conduct of a ForSTI activity. The sponsor may have established strong links with a practitioner organisation, and simply goes to the latter with its thoughts about what is desired. This may be the case in environments where there has been little experience with ForSTI, and thus little development of practitioner skills. It may also be the case where there is one centre of expertise that has been established by the sponsor or some authoritative party, which is the "natural" body to go to, and is one that has some legitimacy and hopefully some track record. Another situation is where the sponsoring organisation has (or wishes to develop) its own in-house capability. This is often the case in countries whose governments have long worked on issues of STI policy, and also in environments where external sources of expertise are not trusted (for example, it may be feared that they may be hard to monitor in terms of their charging for work, or in terms of their failing to toe a particular political line). Often at least some parts of ForSTI will be contracted out, even in these cases, however. For example, a specialised survey research agency may be requested to implement a Delphi or other survey, a web design firm may be employed to run the online communications portal, and so on.

The extent to which new ForSTI practitioners are required also varies according to the type of project. For example, if a major new TFP is to be launched, there will be decisions to make about whether this is to be extremely wide-ranging or focused on one or more specific topics. If we have already accomplished one such Programme, then the issue may be whether to replicate it or extend it, or to take a new tack altogether. If we have an ongoing Programme, then we may be deciding what new topics to address with a stream of projects.

Whatever the precise arrangements, turning ForSTI from a vague idea to a concrete exercise has to start with an Initiation phase, and its associated Scoping activity. Practitioners (or would-be practitioners) will interact with sponsor(s) to design the programme—to clarify what it is for, what it should do, how it will do it, and so on.

ForSTI activities come in many shapes and sizes, reflecting the diverse issues that STI policy confronts. Scoping involves attempting to fit the intended ForSTI to

[1] For the implications of viewing Foresight as a service, see Miles (2013).

the context it is intended for. This requires thinking about and possibly piloting various ForSTI options to assess their strengths and shortcomings in terms of the context. This means assessing requirements (How long will this take? How much will it cost? What skills do we require?) against capabilities (What is the sponsor prepared to provide? Whom can we mobilise? What skills do we lack?). The plan that is generated typically requires some flexibility, so as to leave room for learning about what does and does not work, and to deal with contingencies that may arise.

3.2 Twelve Elements of Scoping

Scoping, then, means addressing a range of issues. In this chapter, we group and discuss these issues in terms of 12 "scoping elements" described by Miles and Keenan (2002),[2] and illustrated in Fig. 3.1. Those elements on the left, the "conditioners", are usually (though not always) and largely (though not entirely) predetermined. They represent the *Framework Conditions* under which the ForSTI exercise is to be carried out, including:

- the starting point of an exercise (national, supranational, sub-national, company, etc.);
- its desired outcomes (usually politically determined);
- the resources available for carrying out the exercise.

Those elements on the right are the "modulators". They feature much greater scope for choice (on the part of the ForSTI team) about the conduct of the exercise, including the specific methods to be used, the degree and style of participation, and the organisational structure of the process.

Element 1. Starting Point

The starting point for ForSTI tends to be largely determined by the nature of the sponsor and the particular circumstances they face—including their institutional setting (what level of territorial governance they operate at, what responsibilities they have for what domains, what relations they have with other institutions, etc.) they cover, define all institutions. Such factors 'position' the ForSTI activity, but there may well still be considerable room for choice in an exercise's focus. For example, a national health ministry may decide to use ForSTI as a policymaking tool. However it could decide to focus on a variety of areas; for example:

- particular health problems (e.g. infectious diseases, obesity),
- particular social groups (e.g. infants, elderly people),
- particular sites of service delivery (e.g. hospitals, mobile clinics, home-based care),

[2]See also Keenan and Miles (2008).

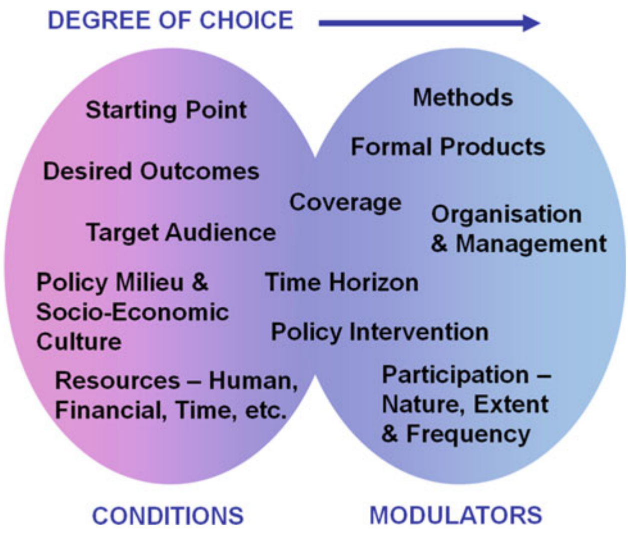


Fig. 3.1 Scoping ForSTI

- the implications of certain social or technological developments (e.g. drug use or sexual habits, nanotechnology or pharmacology).

It may also decide to collaborate with other health-related agencies and bodies (e.g. charities, medical industries, professional associations) in its own country, or internationally. The institutional positioning of ForSTI has a large effect on its scope and shape—a health ministry, for example, is unlikely to be launching ForSTI focusing on aerospace or marine ecology. But there is likely to be considerable room for choice in selecting the focus of a particular exercise, even when the exercise is in response to a current or looming crisis (such as the AIDS epidemic or the ageing population, to take a pair of topics of interest to a health ministry).

Many STI issues are the responsibility of national governments, so not surprisingly the larger-scale national ForSTI programmes and exercises tend to be largely funded by national governments; one or other ministry or government department or agency (such as the research funding body) will usually be the main sponsor. Table 3.1 outlines a number of examples here. From a mapping of over a thousand Foresight-related exercises, European Foresight Monitoring Network (EFMN) concluded that government sponsorship is dominant in all world regions (EFMN 2009). It is present in nearly all European and Latin American exercises, but is to some extent less dominant in North America (where business has a fairly large role, though government remains most important), Asia and Oceania (Since the governmental activities—probably with the exception of military and security exercises—are likely to be more often made available in the public realm, we may be underestimating the scale of private sector initiatives here).

Table 3.1 Examples of sponsors of national ForSTI exercises[a]

Exercise	Sponsor
Japanese Science and Technology Foresight	Ministry of Education, Culture, Sports, Science and Technology (http://www.nistep.go.jp/en/?page_id=56)
German BMBF Foresight	Federal Ministry of Education and Research (http://www.bmbf.de/en/18388.php)
UK Foresight projects	Government Office for Science (https://www.gov.uk/government/collections/foresight-projects)
Finnish Foresight 2030	The Prime Minister's Office (http://www.2030.fi/)
Russia 2030	Ministry of Education and Science (http://prognoz2030.hse.ru/)

[a]All web links on the table were active as of 25.09.2015

The leading role of government sponsors does not rule out the involvement of other sponsors, nor the use of funds from other sources. Industry federations and/or international development agencies have contributed substantially to a number of TFPs. Whoever the sponsor, it is often important to bring others on board, not least because their commitment to, and sense of ownership of, the activity may well be vital to its overall mission. The political competence to deal with the issues may reside outside the main sponsor—for example, a research funding agency has little control over what topics and levels of investment private companies may want to make in particular STI fields. Recruitment of key stakeholders and experts into the process may well depend on the goodwill of business or of academic professions. Other key players will be brought on board very early on, in order to access resources and to build bridges to critical centres of power and authority.

Element 2. Policy Milieu and Socio-economic Culture

ForSTI is, then, positioned within an institutional setting, and institutions themselves are situated in wider policy milieu and socioeconomic settings. A sense of social or political crisis, or the anticipation that break points are undermining established trends, often gives rise to demands for ForSTI. It makes matters a great deal simpler if there must be a good measure of shared agreement as to the nature of these challenges, and the responsibilities and capacities to tackling them, at the outset.

There may be wide agreement on the big challenges facing a society, or there may be much disagreement about these challenges and especially about the particular responses they may evoke. For example at the time of writing, there is much controversy within and between European countries as to the nature of the economic crisis that kicked in towards the end of the first decade of the twenty first century. The "austerity" solutions that some governments propose and pursue are seen by many opponents as in large part an opportunistic effort to reduce the role of the state and public services in line with neoliberal ideology. The level of disagreement among the stakeholders, and the degree to which they can find accommodation to work together on shared concerns, will impact on how an exercise needs to be managed. In areas of conflict, appropriate objectives could include:

- stretching perspectives into the future (if possible, beyond the reach of current disputes)
- developing mutual understanding of, and respect for, different positions
- laying the foundations for continuous long-term strategic conversations
- overcoming inter-organisational barriers on policy making

By contrast, where there is less disagreement, emphasis might be placed on:

- introducing new perspectives and/or data that call into question current assumptions
- instilling a sense of urgency (or even crisis) that demands immediate collective action

Other issues that might be considered when scoping ForSTI include:

- Cultures of collaboration—are there institutional settings where very different interests are used to setting aside differences to conduct mutual work
- The presence or otherwise of a forward-looking tradition—how far is thinking about the long-term seen as a legitimate and critical activity, rather than a luxury
- The presence of other policies and programmes that take (or profess to take) a strategic view of future developments and actions—how far is one liable to be treading on the toes of others, how committed are stakeholders to devoting their efforts to some other activity

The latter can be especially important—a stand-alone ForSTI exercise may not be an appropriate choice if strategic programmes of a related kind already exist. Instead, it may be possible and more effective to introduce ForSTI into these existing strategic processes.

Element 3. Target Audience

We devote Chap. 4, below, to issues of interaction, but a few words are in order here, since this is a major issue for Initiating ForSTI. Since a participatory process involves time and commitment from stakeholder representatives, one of the elements to design into the activity at the outset is assure participants that they are engaged in a worthwhile endeavour. Communications and conduct are professional, so that the activity looks well-resourced and well-managed. The process should also be clearly explained, transparent and involve the key stakeholders.

It can be supported by endorsement from leading figures (e.g. from government, industry and science), and by evidence that these figures are prepared to commit to the process and to pay serious attention to its outcomes. The case needs to be made that ForSTI can help to accomplish widely shared aims for STI better, perhaps by drawing attention to examples of other places or contexts where similar approaches have been successfully deployed. It can be helpful to document ForSTI "success stories" in organisations and/or areas characterised by similar problems and objectives (published Case Studies, presentations from those involved, joint workshops to examine areas of synergy, etc.). However, expectations require management—care must be taken not to promise too much, to too many stakeholders. For example, scientists or industrialists should not be encouraged to believe that their opinions will hold decisive sway, that their areas of activity and concern will achieve top priority.

It is often helpful to work together with specific intermediaries and sectors of activity (science academies, trade unions, research centres, industry associations, government ministries, etc.), whose aim is to encourage participation and promote a more active and knowledgeable involvement among their members or clients.

Different types of communication may be more or less focused on dissemination (of decisions that have been taken and results that have been achieved); on more active consultation as to ForSTI aims, approaches, and activities; on soliciting appraisals of future prospects; on gathering stakeholders' knowledge of predisposing and countervailing conditions. Methods of communication used to promote widespread appreciation of, and participation in, ForSTI activities, include:

- Publications and traditional media (TV and radio presentations, databases, newsletters, etc.) aimed at widespread promotion of the activities to be carried out; these should be targeted at stakeholders whose participation, or at least whose attention, is sought.
- Online presence: this can be used to disseminate information, to promote activities and outputs, to solicit information and opinions, to promote discussion and debate. Websites are being used to increasingly good effect in TF activities, and can provide an important way of reaching people remotely. Often we see tools such as Twitter, LinkedIn, Facebook, and blogs—the list grows all the time—used for further dissemination and to provide spaces for dialogue.
- Initiatives aimed at encouraging participation, such as conferences, workshops, and other meetings—typically face-to-face meetings involving physical presence are employed, and are believed to be most effective. But online meetings are possible, and it is not uncommon for one or more participants in a physical meeting to be "virtually" present through Skype or other computer networking means.

Element 4. Desired Outputs and Outcomes

The sponsor organisation(s) will play a major role in determining the intended and achieved outputs and outcomes for ForSTI, though participants in the process may seek to influence these (more often by adding to them than by seeking to rule out ideas initially specified). While there may be some evolution of objectives over time, it is good practice to set verifiable objectives for a programme—i.e. to specify planned outcomes of the work in such a way that it should be possible to estimate how far they have been met. This was not always the case for the first wave of TFPs, but now that much experience has been gained about ForSTI, sponsors and managers should be able to determine what their exercise is (and is not). Thus we return to the discussion of objectives started in Chap. 2, this time from a more practical orientation.

In the context of policy-making, some of the most important, and frequently encountered, objectives are to:

- Improve the decision-making process, informing it by more systematic appraisal of emerging developments, and making it more legitimate and accountable by providing an evidence base.
- Propose criteria for setting priorities, and to assess options in terms of these.
- Assess the likely impacts of current STI policies, and identify gaps or mismatches in the policy mix—which may extend into wider diagnosis of limitations in a national or sectoral innovation system, and proposals for reorienting it.
- Explicate new needs, new demands and new possibilities, new challenges and new solutions for problems; this may involve demonstrating the linkages between different elements of grand challenges and wicked problems, so as to raise awareness and foster cooperation among key stakeholders.
- Link critical stakeholders together in new ways, providing them with experience in working together on long-term appraisals (and hopefully finding common ground in so doing).
- Define desirable, and undesirable, futures—often this involves establishing a shared vision of what might be achieved if appropriate plans and efforts are undertaken, but there may also be elaboration of critical dangers to be avoided or mitigated.
- Start, and stimulate, processes of ongoing ForSTI, in recognition of the fact that a changing world, and changing knowledge bases, will mean continuous emergence of new problems and opportunities, and requires ongoing monitoring and discussion of strategic choices.

A single ForSTI activity will need to focus on a selection of these objectives (since it is impractical to devote considerable effort simultaneously to each one) at once (although some make the mistake of trying). (Various ways of integrating ForSTI methods to achieve goals and generate outputs and outcomes will be discussed in this book's methods chapters). There must be a clear focus on the specific objective of the process. In most regional and national ForSTI cases, the major target is to identify the most promising opportunities in STI and related topics like education, entrepreneurship, regional dynamics, etc. These issues are identified to assess the priorities that should receive additional support from governments (or from other stakeholders, like private companies and charities, who have resources and leverage). Such priority-setting was often specified as the primary objective of most early TFPs, which were motivated in part by the desire to set R&D funding on a more solid basis.

Setting priorities is a complicated affair, generally involving a mixture of systematic methodology (which may be as simple as asking experts about the likely benefits of investing on one or other area of STI, or may involve more sophisticated appraisals and modelling), interpretation of the results that the methods produce, and the ultimate decisions made by policymakers. Policymakers will often want to put their own stamp on the final decisions, even if their understanding of the detail is limited. They may respond to lobbying, follow their own prejudices about what constitutes, for example, “real growth” or sustainable development; they are liable to be many matters left undefined by a simple listing of priorities (e.g. should the R&D allocated to these areas be concentrated in a few establishment, or distributed across many of them? What fields should be brought into in interdisciplinary work? When should institutions to connect basic research and commercial innovation be set up?) Setting priorities involves not only selecting the winners, but also identifying “losers” (issues that will decrease in importance and therefore will be achieve less support, whether in absolute or relative terms). The results of a ForSTI exercise may be resisted by those committed to the “loser” subjects—which can be especially problematic if they have good access to decision-makers. Policy-makers may adopt a set of proposals fairly uncritically, and leave it for middle managers in government agencies to turn these into practical action plans; or they may intervene in the proposals at the outset. The managers of the exercise, and its participants, need to be aware that often the path between policy proposals and policy implementation is a protracted and winding one.

Some ForSTI activities are more result-oriented (e.g. aiming at producing an ordered list of priorities) and some are more process-oriented (e.g. aiming at building networks and common visions around critical STI developments). German Foresight activities can be considered as an example of process-orientation in ForSTI. After an early TFP largely based on a Delphi survey, a process orientation was determined to be a key feature of the activities of the “FUTUR” programme (1999–2007, and continuing with the on-going BMBF Foresight[3]). The overall aim is to provide engagement, mutual learning, collective visioning and further networking beyond the ForSTI exercise. The activities in Germany explored broader areas like education, ethics, demography, employment, education, human-technology interaction, and trans-disciplinary studies, among others; they considered technology-push along with demand-pull, and engaged stakeholders from industry and academia, as well as representatives of civil society and, of course, policy-makers. Tackling both societal and technological issues, and engaging numerous stakeholders required a mix of interactive and creative methods.

While the selection of exercises studied is not comprehensive, and will include Foresight exercises that are not oriented to STI issues, it is worth reproducing some results from EFMN (2009). This is the most systematic overview of relevant exercises that we are aware of, and around 200 specific objectives were identified, classified into the nine groups represented in Fig. 3.2. STI issues arise in at least two of these categories. While individual exercises had three to four specific objectives, spread across two or three of the families, the large national programmes (featuring several discrete exercises) typically covered all nine.

[3]http://www.bmbf.de/en/18388.php (Last visited on: 25.09.2015)

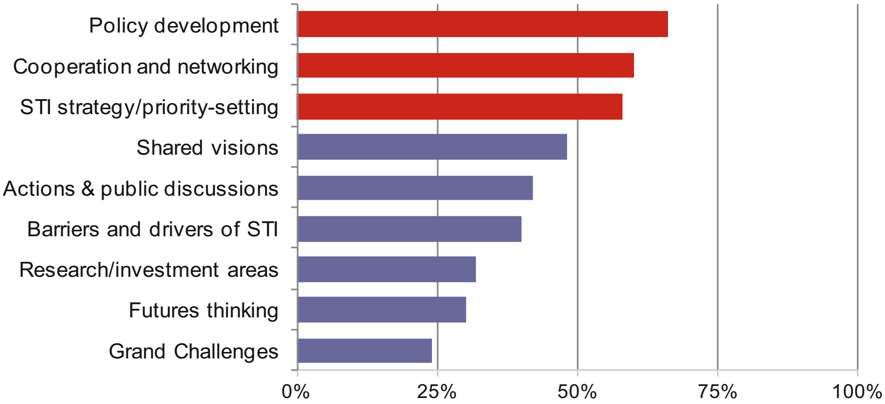


Fig. 3.2 Common objectives of foresight exercises. *Source*: EFMN (2009)

Element 5. Resources

Here we focus on financial resources, but it should be stressed that the resources needed for ForSTI also include people's time, political support, human resources, institutional infrastructures and the broader culture in which the exercise is embedded. These themes are addressed under other headings; for now, resources in terms of money will be the main topic.

"Official" sponsors can be from the public or private sectors, on a national or international basis (and regional and local bodies may have a role to play too). The "third" sector (e.g. charities, professional associations, trade unions, voluntary groups, etc.) are also sometimes sources of funding, especially where there are overlaps between an STI domain and the interests of that organisation (e.g. medical charities may be interested in some aspects of health-related STI). (We can imagine future exercises that might be supported by crowdfunding). It is not unheard of for ForSTI to be co-sponsored by all three. Core costs are usually borne by the main sponsor via a centralised unit. They are most likely to result from such elements as:

- The running of a project management team;
- The organisation of meetings and events, travel and subsistence of at least some of the participants.

The financial burden of ForSTI activities is typically borne by a wide range of players, not least by the participants themselves, who usually provide their thoughts and time at no charge. Some participants may be paid to give up their time for the exercise — this not usually the norm for most participants, who are hopefully funded by themselves or their employers to be engaged in the process. Employers may find the ForSTI a useful source of prestige, network-building or strategic intelligence for themselves; they may see it as a good way of building loyalty among professional staff to give them the opportunities to learn and network, or as a part of their pro bono mission of social responsibility (for example, Universities and charities may be motivated in this way). But in some occasions, such as when recruiting independent international experts, or employing someone to play facilitation as well as participation roles, some payment can be necessary.

Other costs include:

- IT costs (computers, servers, data entry, website design, etc.) for supporting interaction within the project teams and participants, and outreach and dissemination to wider communities via websites and the like;
- The organisation and operation of extensive consultation processes both face-to-face (public consultation meetings require premises, travel, etc.) and virtual (Delphi and other questionnaire surveys and more open-ended solicitation of information and opinion require both professional preparation and systematic analysis);
- The production and dissemination of publicity material—traditional printed publications and electronic publications in readily accessible formats—and other types of content such as podcasts, videos, interactive demonstrations (for example, offering opportunities to run a version of a simulation model);
- Other activities, both routine and one-off, associated with carrying out an exercise, in particular the costs of management, of premises, and of travel expenses.

The cost of a ForSTI exercise depends primarily upon its scale and duration. The shorter the exercise and the fewer people involved, the cheaper it is likely to be. Some tools may be relatively expensive to use, for example if a computer simulation model is being created from scratch; if state-of-the-art or international benchmarking reviews require much consultation with experts.

Element 6. Coverage: The "Focal Object of ForSTI"

As well as focusing on specific outcomes, a ForSTI exercise will need to choose particular themes and/or sectors to focus on. Any ForSTI activity has a focal object. Though some selective attention is inevitable, how such selection has been made is not always explained: it is as if the topic is the natural choice. In reality, there will often need to be some lengthy discussion in order to define what is being covered. Some topics may be "no go" areas—the future of national security or of nuclear power can be highly sensitive topics, where opening up strategic intelligence to a wide range of stakeholders is regarded with great caution. Some topics may be the subject of great and widespread concern, which is the case for some "grand challenges" such as those connected with demographic and climate change.

EFMN (2009) presents a classification of the objects of study of over 900 Foresight exercises. Many studies targeted a number of areas, for example considering aspects of social change (like demography) with one of more fields of science (e.g. medical science) and engineering (e.g. urban design). In Latin America social sciences tended to be present in a majority of studies, In Europe both social sciences and engineering and technology appeared in just under half; in North America engineering and technology appeared in about half the exercises, while social science topics were much less common. Asian countries placed more emphasis on engineering and technology, and almost half of their exercises involved medical sciences. Agricultural sciences appeared rarely, other than in Latin America. Arts and Humanities were rarely a focal object.

Difficult decisions may be required, when there is a sense of multiple challenges confronting the sponsor. There are practical limits to the range of themes and/or sectors that can be addressed simultaneously. While the general field of concern is likely to be a product of organisational responsibilities and a sense of emerging challenges, there may be influences from, for example, lobbying by interest groups, and imitating what other countries are doing. Many national ForSTI exercises have focused at least in part on Information Technologies, transport technology, biotechnology (primarily applied to healthcare and agriculture), nanotechnology, and energy systems.

Discussions with stakeholders can play a role in identifying themes of concern—and increasing the likelihood of commitment to later stages in the exercise. The UK Foresight Programme from 2002 to some point in the early 2010s adopted an interesting strategy here, in deciding what focal objects its exercises would choose. There were wide consultations as to hot issues and emerging challenges, with an effort to balance those representing technological developments (e.g. new uses of the electromagnetic spectrum, advances in cognitive engineering) and those reflecting socioeconomic challenges where STI could have a role to play in developing adequate responses (e.g. flooding, obesity). The range of people involved in consultation could be very wide—SF authors were involved in one brainstorming session, for example. But the go-ahead for a particular theme to be a focal object was only taken if and when a senior policymaker (e.g. a chief scientific officer, a government minister) could be found to commit to serious involvement in the work. This was seen as providing some guarantee that the ForSTI would be linked intimately to policy development.

Element 7. Time Horizon

Although ForSTI is principally concerned with increasing the time horizon of planning activities, this is not just a matter of "stretching" familiar planning and intelligence gathering into the longer term. Many current trends and emerging phenomena, although relatively unimportant to one's immediate circumstances, may have serious repercussions if they are not taken into account until the problems become clearly manifest. By then, effective responses may be far more costly than they would have been—and some opportunities may have been ruled out altogether. Consider, for example, the question of developing a skill base to cope with economic or technological change: this is often a matter that will require years to put into place. In practice, the time horizon of ForSTI activities will differ considerably, because what is thought of as the "long-term" varies considerably across different issues and different cultures. The average time horizon for national and regional ForSTI exercises seems to be around 10–20 years, although it may be as long as 30+ or as short as 5 years (Table 3.2 documents some cases; EFMN (2009) presents statistical evidence for a very large number of exercises mapped by

Table 3.2 Time horizons used in a selection of Foresight exercises[a]

Name of the exercise	Initiator	Date of initiation	Time horizon
The Future of Cybercrime	International Cyber Security Protection Alliance (ICSPA)	2014	2020
The Future of Families to 2030[b]	OECD	2011	2030
Aviation 2040[c]	Arup	2009	2040
Global Europe 2050[d]	European Commission	2012	2050
New Lens Scenarios (Energy)[e]	Shell	2013	2100

[a]All web links given in the footnotes were active as of 04.02.2015
[b]http://www.oecd-ilibrary.org/social-issues-migration-health/the-future-of-families-to-2030_9789264168367-en
[c]http://db.foresight.kr/sub03/research/filedown/main_category/eNortjK0UjJWsgZcMAkeAcs./id/680/field/file_saved_name
[d]http://ec.europa.eu/research/social-sciences/pdf/global-europe-2050-report_en.pdf
[e]http://s01.static-shell.com/content/dam/shell-new/local/corporate/Scenarios/Downloads/Scenarios_newdoc.pdf

EFMN—the period 10–30 years dominates, but around a quarter of European exercises deal with longer time horizons).

The time horizon that is chosen will depend upon the objectives and orientation of the ForSTI exercise.[4] An apparent paradox of ForSTI is that whilst a long time horizon provides the opportunity to develop a broad vision, most stakeholders' expectations are for short-term policy and/or investment responses. This is less paradoxical than it looks; ForSTI appraises possible futures, with a view to informing and improving what we do today—create organizations and societies that can be more capable and agile in dealing with, and shaping, their future.

Element 8. Methods

The main methods used in ForSTI exercises are summarised in later Chapters. Here we will consider the choice of methods, and the way in which they can be used together, both in parallel and in sequence, to constitute a coherent exercise. To do this effectively, it is important to think through the key steps in a ForSTI process, as outlined in Chap. 2, and to understand what inputs and outputs associated are expected from ForSTI methods applied at different steps in the process.

ForSTI methodology is not confined to approaches for thinking about the future, e.g. Delphi, scenarios, etc. It must also take into account the important tasks of organisation and management, coalition building, implementation, evaluation, etc.,

[4]The focal object is a major factor in choosing a time horizon. For example, ForSTI on the IT sector tends to have shorter time horizon (perhaps of 5–10 years) than on the Energy sector (which can be as long as 50 years).

and the methods that are employed here. Many of these methods are common features of project management in many types of activity, not just ForSTI; but this does not render them any less important; we discuss some of these issues in the next section.

Classifications of the methods used to create and assess appraisals of future prospects can take various forms, for example there are methods that are more or less quantitative and/or qualitative; methods that are more focused on "exploratory" questions (what if?), and those that are more "normative" (how to?), methods, typically employed in earlier and in later phases of the ForSTI process. Many approaches are rather hard to precisely capture in these terms, because they can be implemented in various ways. With this in mind, we produced a star-shaped framework for classifying ForSTI methods (ForSTAR).[5]

The ForSTAR framework illustrates the mapping of methods in line with the phases of the ForSTI activity. The precise location of the specific methods mapped here should not be regarded as definitive. Indeed, many methods can be deployed in quite different ways, and at the very least they should be regarded as having rather fuzzy locations. The framework is intended to illustrate a common pattern of practice, and to highlight our view that any sizeable ForSTI project should combine methods that range widely across the spectrum of approaches represented here.

ForSTAR can be used in various ways, for instance, to portray the activities involved in the ForSTI process (Fig. 3.3b), or to indicate qualitative (Fig. 3.3c), quantitative and semi-quantitative methods for ForSTI (Fig. 3.3d).

Some of the methods mentioned above are used more frequently than the others. For instance, expert panels, literature review, Delphi surveys, scenarios, roadmapping and trend extrapolation have been used widely. The variety of qualitative, quantitative and semi-quantitative methods has increased from 1 to 2 in the early 1990s to over 30 at present (Saritas and Burmaoglu 2015). Differences across regions were reported, too: futures workshops are much used in Europe and North America, less in Asia, Oceania and Latin America. Delphi is most often used in Latin America, Asia and Europe; less in North America. Perhaps reflecting industrial sponsorship of activities, technology roadmapping and key technologies emerged as two of the most popular methods in North America and Asia. Saritas and Burmaoglu (2015) investigate further the use of ForSTI methods across time, and the geographic and thematic factors affecting the use of methods in ForSTI.

Selection of methods is liable to be influenced by local concerns and experience, but will of course be influenced by the availability of expertise, time and financial resources. Some aspects of some methods have been rendered faster and cheaper to

[5]Compare with the Foresight Diamond (Popper 2008), which in turn builds on an earlier depiction of ForSTI tools as a triangle by Denis Loveridge (Originally presented in: Cameron et al. 1996 and also available in: Loveridge 1996).

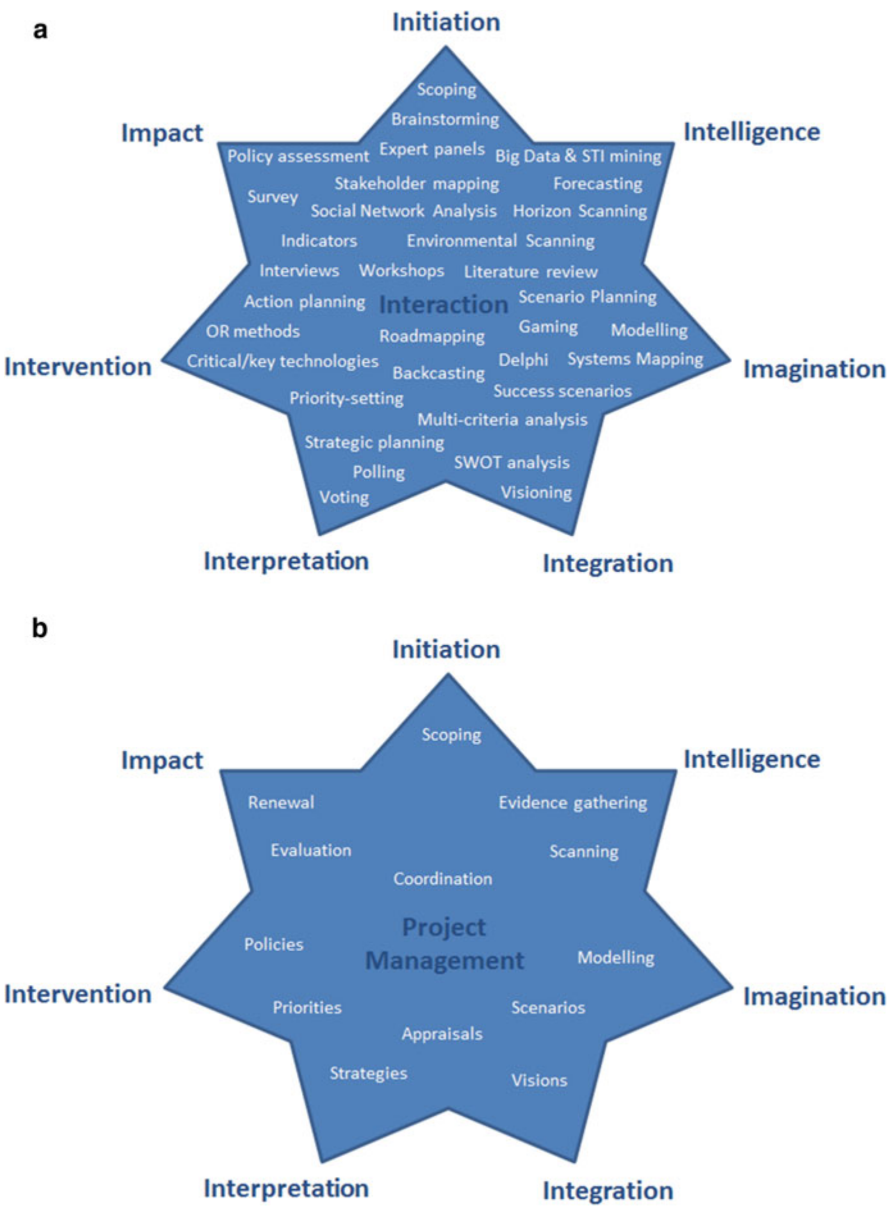


Fig. 3.3 (**a**) ForSTI methods Star (ForSTAR). (**b**) Activities in ForSTI. (**c**) Qualitative methods in ForSTI. (**d**) Quantitative and semi-quantitative methods in ForSTI

complete due to the increasing application of IT (e.g. online surveys, computer simulation). It should be remembered that methods are quite flexible tools. Some methods can play multiple functions; they may be used at different phases of the exercise; they (and their results) can be integrated in various ways. New methods

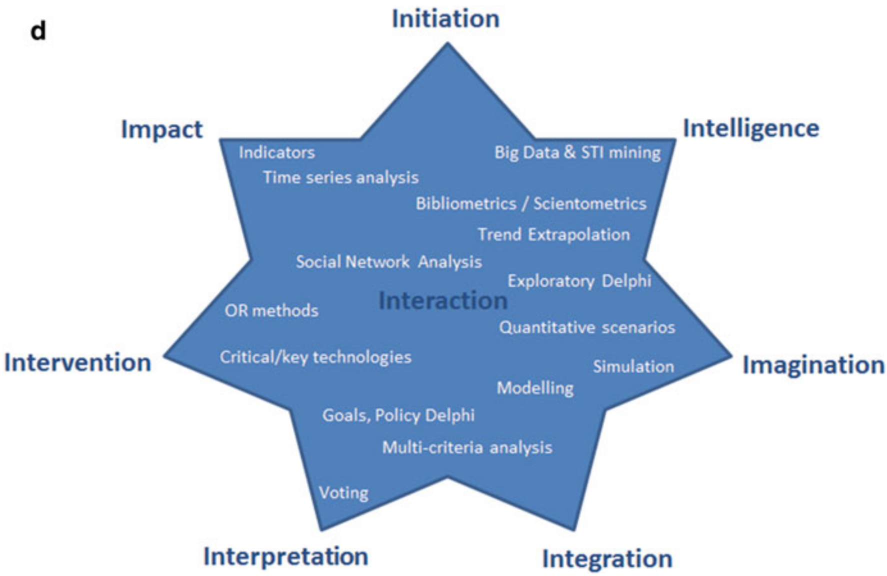


Fig. 3.3 (continued)

can also be created during the ForSTI exercise, which can even be designed so as to allow for methodological innovation and experimentation.

We should not identify ForSTI with a particular method like Delphi or scenarios. The methods need to be regarded as process and decision aids ('means'), not as the overall aim of the exercise in themselves ('ends'). They are tools to be used to explore ideas, acquire information, clarify situations, and negotiate solutions. Methods will be used, modified or tailored whenever needed: innovation in methods may help to handle the unique requirements of systems under investigation, though often we will find that someone has confronted a similar situation before and developed some relevant tools. Very often we will need to tailor and customise tools and techniques to fit the issue, the participants, the resources we have available, and the context more generally. It is worth locating any discussion of "dos" and "don'ts", and to pilot new approaches where possible, because just about any implementation of a tool will have some limitations.

As a methodological aid, practitioners may wish to map out their own intended processes using a blank version of the ForSTI frameworks above. What tools are selected, and how their results are integrated can be planned so as to take into account the phases and the context within which the ForSTI activity will take place (and, of course, the goals of the exercise). A spectrum of methods will typically be employed in any exercise of scale, ranging from divergent and more creative methods to convergent and (often) more quantitative ones, and all requiring some degree of information input, creativity, expertise and participation. The methods given in Fig. 3.3a are indicative; the list can be extended with other methods that fulfil the functions of different phases described above. Use of the methods will, as mentioned already, also be determined by available resources including expertise, skills, time and budget, and by views as to the level and type of participation required.

This is a convenient point at which to introduce one rather important distinction, often drawn to differentiate between stances to futures (and thus to ForSTI) approaches and methods. This is the distinction between what are most often referred to as exploratory and normative methods. While this distinction could be the subject of major essay in its own right, we shall just briefly summarise its bare bones here.

- Exploratory methods explore the implications of evident or potential developments—What does this trend mean? What would happen if this trend is reversed? etc.
- Normative methods are more focused on how to achieve a particular future (most often a desirable state of affairs, sometimes the avoidance of a particular threat).

We will use this terminology—especially in Chap. 7 and following chapters—because it is well-established. We conform to it, despite several reservations. If "normative" means "value-laden", then all ForSTI has normative elements. The decision to undertake an exercise and the choice of a particular focal object to examine are value-laden. Meanwhile normative approaches to developing, for example, roadmaps to achieving a particular future, involve identifying and exploring various unexpected contingencies. Any approach should be taken with serious consideration of alternative points of view, of data that may not be readily assimilated within one's worldview, and of the possible pitfalls stemming from the assumptions we use and the participants we engage.

The distinction between exploratory and normative approaches is not the same as that between more or less convergent and divergent approaches. Exploratory approaches may well arrive at a range of alternative scenarios, for example—but simple trend extrapolation or trend impact analysis are classic exploratory approaches that are not particularly divergent. Some normative approaches may generate quite different lines of future development, too. For example, tools like morphological analysis and relevance trees may generate multiple ways of achieving the same goals. Even applying a tool like Multiple Criteria Analysis—to identify the most effective way of reaching a goal—may indicate that different routes would be most relevant depending on the weighting given to various value criteria. Ultimately decisions about action require some convergence as to the most important options to pursue. Even so, eggs should rarely all be put into one basket. One way in which the implications of more divergent thinking can be taken into account, is via preparation of options to apply in the case of changing contingencies, and implementation of ways of assessing whether such changes are imminent (for example ongoing scanning for turning points and weak signals).

Element 9. Organisation and Management

A ForSTI activity may be a one-off project, or part of an ongoing activity organised by a single agency that is responsible for long-term strategic intelligence. Many countries have established such agencies for such functions as:

- Determining upon and running a succession of projects,
- Informing policymakers and responding to requests from them,
- Serving as repositories of knowledge and updating the results of exercises,
- Providing training and advice on ForSTI for users (such as government agencies, city-level decision makers, etc.).

A ForSTI Unit or Agency of this sort requires substantial commitment, and has to be staffed by people with real understanding of ForSTI. It may be overly dependent on a volatile source of funding, if its core mission is not written into law, and is more something that requires support from (changing) political leaders.

The organisation of a ForSTI activity assigns roles, tasks and responsibilities to working groups, panels, committees, trainers, etc. Often, a vital initial step involves establishing a steering committee and a project management team. As we discuss in Chap. 4, since many activities make use of expert and stakeholder groups or panels to focus on particular issues, establishing these groups is also critical. Their membership will influence the whole exercise, as will the management style applied to these groups will need to be defined. For example, how far does the project team define the details of activity (as opposed to just setting the ground-rules), how far are working groups given the freedom to make their own decisions about methodology, about dissemination of their results, etc.? Development of goals and timetables should be a matter of consultation rather than imposition, and it is also important to communicate these goals and timetables to new participants, and to refresh understanding of them among team members who may become preoccupied with day-to-day problems.

ROAME is an old, but reliable framework for planning and management of ForSTI.[6] ROAME consists of a set of statements, which specify:

- **R**ationale: Why is a ForSTI exercise being undertaken (the overall reasons)?
- **O**bjectives: what are the aims, what specifically is to be achieved?
- **A**ctivities: what are the lines of work to be undertaken, what should each achieve and how?
- **M**onitoring: what systems are put in place to ensure that (or assess whether) the lines of work are being undertaken according to schedule, outputs emerging as intended?
- **E**valuation: how we are determining whether, and how efficiently, the main objectives have been achieved?

The application of ROAME produces an action plan that can help orient a programme through its life. This systematic approach to ForSTI management will not be welcome in all organisations: some consider it to be too formal, as limiting efforts to introduce more experimental approaches, and impeding the learning that ForSTI should achieve. It should be possible to prepare ROAME statements so as to allow for flexibility, but this requires some imagination in its application. Even where there is no overt organisational rejection, the ROAME approach may be undermined in other ways. There may not have been sufficient commitment to following through its implications; changing political circumstances may lead to change in objectives (as is rather common for major policy initiatives in countries with regular changes in government), and so on.

Some approach such as ROAME, in any case, will help to guide and advance a ForSTI activity, and to think through the project management tools that are to be used. Establishment of systems to document ForSTI processes and outputs will not only help the process to work efficiently; it will make eventual evaluation much easier. Conventional project and organisational management tools can also be applied to management of the day-to-day and longer-term agenda of the process. Techniques such as PERT and GANTT charts, for example, explicate when activities are due to be initiated and completed, what resource flows are intended, etc. Such tools are increasingly computer-based, but pen and paper application is possible; the tools are generally regarded as useful—if not essential—for the management of large projects. They are important for co-ordination of the work and responsibilities of different members of the management team. Care should be taken not to apply them in heavy-handed ways that could alienate the voluntary participants in ForSTI. Excessive demands for reporting can easily backfire.

[6]The framework was introduced in the UK and widely used in STI policymaking—for a convenient account see Miles and Cunningham (2006).

Setting up simple tools that allow the project team to monitor the ForSTI exercise constitutes good practice in project management. Monitoring consists of continuously observing and ensuring that the resources foreseen for each step are used effectively as defined in a project blueprint; that work schedules are respected; and that outputs actually materialize. It will help the project team to control and focus the implementation of the project. On-going monitoring involves:

- Observing the activities undertaken during the implementation of each step in the project in order to compare them, in real time, against the targets set
- Continuously adapting the project plan to its environment. As new knowledge is gained and stakeholders are activated, the vision or process of the ForSTI exercise may need to be altered: ForSTI exercises are not expected to be rigid
- The monitoring methodology should involve a set of selected indicators that are designed to provide relevant actors with specific and topical data that allow them to follow the course of the project

Furthermore, evaluation skills and capabilities need to be developed outside of the sponsoring and management organisations. It is useful for independent evaluation capabilities to be developed, with evaluators who are not heavily beholden to or reliant on specific clients, and who are able to draw upon experience and good practice gained from evaluation of different sorts of programme. Even then there is a danger of "capture" of the evaluators. "Real time" evaluators become participant observers, often and legitimately involved in changing the processes they are observing—this is a contribution to organisational learning, but should be informed by the principles of action research. "Post hoc" evaluation should not be confused with "success story" analysis: they are independent and complementary activities.

Element 10. Participation

Chapter 4 will focus on this element, but several main points can be made now. As a key element of ForSTI, participation of experts and stakeholders improves the quality of ForSTI exercises through the engagement of both scientific and non-scientific knowledge, their values and perspectives. Experts and stakeholders come together to dialogue on alternative courses for the future from their own perspectives and determine the actions to reach the most desirable future. Their participation elicits knowledge and facilitates mutual understanding and learning and thus increases the legitimacy of ForSTI exercises.

Who participates in a ForSTI exercise depends upon other elements of ForSTI's scope, including objectives, orientation, the themes/sectors covered, and the intended audience. Some exercises are quite limited in their breadth of participation, both in terms of actual numbers and the types of actors engaged. However, others have set out to directly involve widely disparate groups, including citizens. There may well be challenges in recruiting some key participants—busy people may not have much time, non-experts may be worried about understanding experts, there may be doubts about the aims and applications of the ForSTI process itself. Some people may be eager to participate, but not to play the game—they want to lobby for their pressure group, firm or industry, or simply to get their own pet idea across, and are not interested in learning from others. Locating the right participants, and communicating with them to elicit support, can be a tough management task.

Element 11. Formal Products: Outputs and Outcomes of ForSTI

As already noted, ForSTI exercises may emphasise formal products or less formal processes, or seek to synthesise the two. **Product-oriented approaches** generally aim at achieving tangible outputs, such as reports embodying a scenario; a "critical list" hierarchy of priorities (e.g. areas for R&D expenditure) or of key technologies, a Delphi report, etc. Such approaches often involve small expert groups, and/or highly formalised methodologies for eliciting and combining expert opinion (most notably, Delphi). For example, the French and German national exercises have taken this form. Tangible outputs are often what some people refer to as "codified" knowledge, in that the knowledge generated through the process has been turned into information that can be circulated widely, without necessarily requiring face-to-face interaction.

Process-oriented approaches are more focused on achieving better networking and exchange of opinions among actors. The idea is that a shared focus on longer-term developments will help those involved to identify emerging issues and the carriers of relevant knowledge about these issues, to share understanding about each other's expectations and the strategies that are liable to be pursued, and to forge enduring networks for collaboration. The Dutch and the second UK TFP exercises are examples (There are also some regional level activities—for example in the UK's north-east—that focus almost exclusively on developing capabilities and institutional support for regional actors to undertake their own ForSTI, without feeling a need for a central programme producing codified outputs). Such "soft" outputs are more difficult to grasp, because these typically take the form of knowledge embodied in people's practices and approaches to issues. Though these may be harder to identify and quantify than documentation, they represent a very important aspect of the benefits of ForSTI.

Mixed approaches attempt a deliberate synthesis of the above. The creation of products is seen, in practical terms, as a helpful device to encourage people to work together and network effectively. It also provides, more politically, a legitimating tool to convince auditors that money is being spent well. Furthermore, networking provides a wider range of inputs and this wider participation itself gives social legitimacy to the process. The first UK TFP is generally seen as a good example of such a mixed approach.

Element 12. Policy Intervention

How are the results of ForSTI to be followed-up with action? This tends to be a neglected consideration, with project managers often overly preoccupied with getting the ForSTI process "right". Getting the process "right" can indeed increase the chances of successful follow-up action, but political awareness of the possibilities for follow-up action should ideally be considered from the outset. In most instances, successful implementation involves follow-up action by actors—who may not have been directly involved in an exercise. This is particularly challenging, and it is probably wise to ensure that these actors have some sort of "buy-in" to the process at appropriate stages. For example, they could be invited to be members of a High Level Advisory Group that would meet two or three times, at key moments of the ForSTI exercise. This avoids their being "taken by surprise" by the outputs and the expectations of action placed on them. We consider the element of intervention in more detail in Chap. 10 (cf. also Chaps. 9 and 11).

3.3 Conclusions

This chapter has reviewed a set of 12 elements that need to be addressed when initiating—scoping and planning for—a ForSTI exercise. Practitioners should be aware of the need for flexibility—there may be major changes required when contexts change (e.g. in terms of sponsors and their demands or resources), and understanding of the real problem may be transformed during the course of the exercise—and less substantial changes are frequently encountered (e.g. due to the loss of some key participants through career change or illness). But having a clear idea of how the 12 elements are configured, and how they will be addressed, is something that has to be addressed at the outset. A major reason for the failure of complex projects is lack of specification of such features.

The following chapters will elaborate on the issues of methodology, interaction, and evaluation and impact that arise in the context of an exercise. The aim is to provide basic information that can help practitioners, and others involved in or using ForSTI stakeholders better understand its organisation and principles—and what factors are liable to determine the degree of success of the specific activities that are undertaken.

4 Interaction: Participation and Recruitment

4.1 Introduction

ForSTI typically uses participative approaches that engage wider ranges of stakeholders and experts in appraising future prospects than was typical for many classical futures studies and technology forecasting exercises. The increasing interest in participation has been prompted by a mixture of reasons, including political trends towards greater transparency and inclusivity in policy making, recognition of the limits of "official" knowledge and of governments to dictate the behaviour of private citizens and firms, and the learning of lessons "from the corporate sector regarding the benefits of stakeholder inclusion" (Loveridge and Street 2003, p. 7).

There is a purely technocratic rationale for participation in ForSTI: our complex world calls for access to widely dispersed knowledge. Participation of experts and stakeholders allows for access to both scientific and non-scientific knowledge. Here the term 'expert' refers to the ones who bring their knowledge and experience to the exercise and discuss its issues from a particular perspective. 'Stakeholders' are the ones who can affect, or be affected by, the discussions and decisions taken during the ForSTI exercise.

There are also democratic and governance rationales for participation. Engaging more stakeholders in developing future visions can give ForSTI processes and recommendations more legitimacy. This does not necessarily mean involving all social actors, but it does mean broadening ForSTI beyond the views and quite probably the vested interests of a narrow set of players—whether these were the "great and the good" or the "usual suspects". Wide participation in ForSTI can provide channels for this intelligence to flow not only "upward" to the policymakers or other sponsors of the exercise. It can also flow "down" into broader communities of practice and debate, and generate more in-depth understanding—and commitment—than would be yielded by publication of an official report. This can be very helpful in circumstances where the active support of many parties is required if a policy is to achieve its objectives (or even be implemented to a satisfactory degree):

I. Miles et al., *Foresight for Science, Technology and Innovation*, Science, Technology and Innovation Studies, DOI 10.1007/978-3-319-32574-3_4

in complex societies, the fact that a leader mandates change is insufficient to ensure that the change will happen in the way intended.

If (representatives of) these wider communities engage at an earlier stage with the issues emerging around the focal object, and input their views, concerns, and knowledge into the process, then it is not just the ForSTI team and sponsors who become better informed. The enlistment of a wide range of actors in the process means that these individuals become:

- Members of social networks, forging contacts with the others involved in the process. This may remain a matter of better understanding the capabilities and likely strategies of other parties. It may spill over into new collaborations around opportunities identified in the process.
- Better informed about the issues and interests that underlie the formal products of ForSTI, and thus be more able and inclined to embed the messages of the programme into their own organisations and practices.

In a ForSTI exercise, experts and stakeholders come together to dialogue about the future from their own perspectives, negotiate future visions and discuss actions to reach to the most desirable future. Thus, participation elicits valuable knowledge and facilitates mutual understanding and learning and thus increases the legitimacy of ForSTI exercises. These are among the main process benefits of ForSTI exercises.

The number and range of participants will vary according to the scale and focus of the exercise. If there is a broad technology focus then the participants tend to be policy makers, academia, research institutes, and industry; if a particular sector or set of sectors are involved, then industrial groups, chambers of commerce, professional associations and SMEs are liable to be included in the exercises. If the exercise has a strong interest in wider social aspects of some STI area, then, consumer associations, social scientists and civil society organisations, will be target user groups.

Typical groups involved in a ForSTI exercise include[1]:

- Promoters
- Sponsors
- Project Team
- Steering Committee
- Stakeholders, users and target groups
- Process experts
- Working panels
- Domain experts

[1]The following discussion draws on Miles and Keenan (2002).

Promoters are the people or organisations who advocate the ForSTI exercise. Starting from the early stages of the activity, Promoters aim to identify the interested players and introduce the activity, its benefits, objectives, focus, and expected outcomes of the work. Securing high level of political support from the beginning will ensure that the ForSTI exercise receives serious consideration. Promoters would also have the responsibility for locating sponsors.

Sponsors are typically the clients of the ForSTI exercises. They are the main funding body and the recipients of the outputs received as a result of the exercise. National ForSTI exercises have been often funded by the Ministries of Science and Technology or equivalents of them in different countries. Regional governments, International organisations, corporations and research institutions would be among the sponsors of ForSTI activities. They usually set the objectives, focus and expected outputs/outcomes from the ForSTI exercise.

A **Project Team** is appointed to manage the exercise on a day-to-day basis and ensure its successful completion. Usually the project team is responsible for (i) leading the implementation of the exercise; (ii) keeping regular contacts with the stakeholders and the Steering Committee to ensure that the agreed focus and direction are maintained; (iii) maintaining records of costs, resources and time scales for the project; (iv) integrating management reports and their presentation to the Steering Committee; (v) ensuring that the exercise follows its technical objectives; and (vi) keeping the relevance of the exercise with eventual innovation activities.

A **Steering Committee** is usually employed, not for day-to-day oversight but in order to develop the objectives, and focus of the exercise, specify the broad principles informing the methodological procedures and the work programme, and both frame and participate in the communication and dissemination processes. It is likely to produce overall synthesis reports and action plans, and review the deliverables from working groups. The Steering Committee is liable to be a key to gaining support from critical stakeholders (especially those in the sponsoring organisation, where it must liaise with a ForSTI Champion—who may be a Committee member). It can play important communication and outreach roles—e.g. helping to identify and mobilise experts and other panel members. It also monitors the quality assurance process for the whole exercise. It can help in raising awareness, and in nominating and mobilising experts to various panels. To achieve these ends, the Committee needs to have high credibility and legitimacy, is not seen as being subservient to one or other interest group, and is visibly working with results of the participatory ForSTI process (rather than imposing its own perspectives on it).

Stakeholders, users and target groups are those people and/or groups that have the power to affect or who are liable to be affected by the STI phenomena and related economic, social and political developments. More "transparency" of the ForSTI process and "ownership" of its results (appraisals of future prospects and policies to address them) will be achieved through the involvement of stakeholders. Stakeholders can be involved in the process as sponsors and members of expert panels to provide their expertise and future expectations.

Table 4.1 Incentives for stakeholders to participate in ForSTI

Incentive	Description
Learning	Learn from other stakeholders through dialogue; learn about state-of-the-art from experts
Networking	Make valuable contacts with other stakeholders
Lobbying	Have influence on policy makers or on public debate by influencing the outcome of the Foresight (e.g. a vision), which is disseminated into society
Developing individual strategy	Use Foresight results to develop individual strategy for own organisation (e.g. business)
Developing collective strategy	Help in developing a collective strategy for national, regional and/or sectoral development

Source: Saritas et al. (2013)

Domain experts are highly significant for ForSTI exercises. These should be highly knowledgeable, experienced and acclaimed members of industrial, academic and/or other communities relevant to the focal object of the ForSTI exercise. They provide their expert judgement 'on tap', in depth and meaningful interaction within and between scientific disciplines. A mixture of expert panels and stakeholders are represented at working panels.

Process experts can also be engaged to provide advice on the ForSTI exercise based on their experience and knowledge. They can mentor/coach the Steering Committee and the Project Manager and can undertake specific activities such as giving advice on process and methodology, facilitating panel discussions.

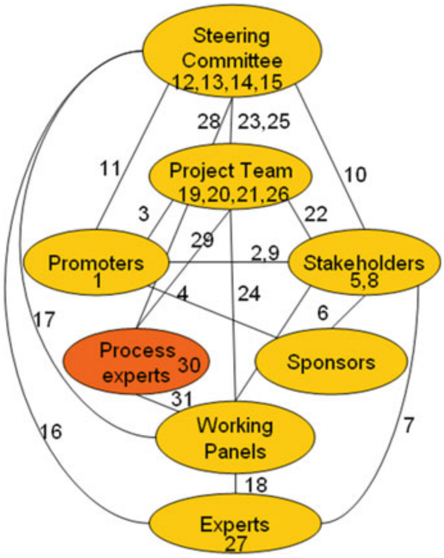
Some participants may need to invest considerable time in ForSTI activities, and this can be a scarce resource—especially for senior people. Therefore, an important practical challenge of ForSTI is to recruit and retain stakeholders—various incentives may motivate individuals to participate actively in ForSTI processes (Table 4.1).

Various obstacles to participation may be encountered. Loveridge and Street (2003) differentiate between (i) Physical and (ii) Psychological obstacles. Physical obstacles involve ignorance of methods and problems of coping with the additional workload. Psychological obstacles may relate to the assimilation of opinions from an ever-widening range of stakeholders; variability in confidence concerning legitimate expertise; the volatility of personal opinions; and the need to make some aspects of STI intelligible to non-experts.

Figure 4.1 illustrates how the various groups may be related together though the ForSTI process.

4.2 Panels: The Heart of ForSTI

ForSTI **panels** are the main process centres for the exercise. They are responsible for carrying out the activities by gathering and analysing relevant information and knowledge; stimulating new insights and strategies for the future; diffusing ForSTI



1. Promotion of ForSTI (written, oral and visual presentations)
2. Identification of interested parties
3. Drafting the first outline of the project (objectives and focus)
4. Search for sponsors
5. Involvement of stakeholders
6. Identification of sponsors
7. Selection of experts among stakeholders (Nomination)
8. Championing the ForSTI process
9. Consultations with stakeholders (to provide future ownership of the process and products)
10. Involvement of stakeholders in the Steering Committee (SC)
11. Approval of the objectives and focus of the ForSTI programme
12. Approval of the work programme and validation of strategy and tools for communication and promotion of the results
13. Definition/adjustment of the assessment criteria and reviewing the deliverables
14. Monitoring the quality assurance process for the whole project
15. Raising awareness
16. Mobilising experts
17. Nominating experts to panels
18. Involvement of experts in panels
19. Management of the project on a daily basis
20. Maintaining records of costs, resources and timescales for the project
21. Following the technical objectives of the project
22. Keeping contact with stakeholders to retain the project direction
23. Keeping contact with SC to retain the project direction
24. Meeting Working Panel managers
25. Integration of management reports and their presentation to the SC
26. Ensuring the relevance of the project to other STI activities
27. Gathering relevant information and knowledge, stimulate new insights and creative views and strategies for the future, as well as new networks, diffusing ForSTI process and results to much wider constituencies, contributing to the follow up actions
28. Mentoring/coaching the SC, providing ideas and external views, highlighting best practices, contributing to the SC meetings
29. Mentoring/coaching project managers, providing ideas and external views, highlighting best practices
30. Undertaking specific activities such as refining the work programme, giving advice on methodology
31. Participation in consensus building activities

Fig. 4.1 ForSTI framework and flow of actions. *Source*: Seidl da Fonseca and Saritas (2005) process and results to much wider constituencies; and increasing overall impact of ForSTI by networking and initiating follow-up action. The structure of ForSTI panels and ways of working with them in the process will be elaborated later in this chapter. Panels not only open up the process to potentially hundreds of individuals, they are also ideal forums for in-depth discussions and debate. Panels are used in most ForSTI exercises at all levels from small scale and corporate programmes to large scale national and international ones.

Before going into details of how panels work and can be facilitated, this section first discusses the benefits of working with panels, and the roles that they can play. Panels not only open up the ForSTI to large numbers of individuals, they are also ideal forums for in-depth discussions and debate. Currie-Alder (2003)[2] sees participation as a means to enrich decisions through greater understanding, legitimacy or capacity:

- Understanding: Participatory approaches can be used to cope with complexity and share understanding among stakeholders
- Legitimacy: Participatory approaches seek to make a process more relevant to interested stakeholders of the process and its outputs
- Capacity: Participatory approaches also seek to improve the skills, knowledge and experience of those involved in the management process through formal and informal learning (p. 11)

More precisely, in a ForSTI exercise panels provide:

1. Availability of expert judgement ‘on tap’ at the centre of an exercise, which can be particularly important when dealing with the uncertainties associated with the future
2. Gathering relevant information and knowledge from a variety of inputs—testimony, research reports, outputs of forecasting methods, etc. and synthesising them into future-oriented intelligence to provide a vision of future possibilities and needs for their topic areas
3. In-depth and meaningful interaction and networking between different scientific disciplines and areas of expertise that would otherwise be difficult to organise
4. The ease with which panels can complement other methods used in ForSTI. Indeed, with some methods, panels are a near necessity for the generation of inputs, the interpretation of outputs, and/or the overall conduct of the method
5. Stimulating new insights and creative views and providing a vision of future possibilities, as well as creating new networks
6. Credibility and authority lent to the ForSTI exercise through the profile of panel members and the visibility of expert/stakeholder panels
7. Diffusing the ForSTI process and its results to much wider constituencies as ForSTI ambassadors and change agents in support of panel findings

[2]See also Slocum (2003) for a guide to participatory tools.

The roles and functions of the panels are variable. In some cases, they are the main process centres ('hubs') of a ForSTI exercise, gathering and analysing data and community opinions, employing a wide variety of ForSTI methods, such as scenarios, and formulating priorities and recommendations for action. In other cases, panels can be given very specific tasks within a much wider process, for example, commenting upon weak signals picked up in environmental scanning or formulating Delphi topic statements. Typically, in a ForSTI exercise the expert and stakeholder panels have the following functions:

1. Gathering relevant information and knowledge
2. Synthesising the information gathered
3. Stimulating new insights and creative views and providing a vision of future possibilities, as well as creating new networks
4. Diffusing understanding of the process and knowledge of its results to much wider constituencies
5. Influencing follow-up action

4.2.1 Working with Panels in ForSTI: Seven Steps

Through the ForSTI process, a number of tasks are involved in working with panels, from the initial recruitment phase to the dissemination of results.

1. Assembling a Panel
The first step is to identify the sorts of expertise and stakeholders that should be represented in the light of the objectives of the ForSTI exercise and remit of the panel(s).[3] There are two considerations which should be taken into account when panels are set up and participants are recruited:

- Composition: What mix of knowledge is required to address the panel remit?
- Balance: What mix of views, positions, value judgements and scientific disciplines should be represented on the panel to ensure more even deliberation, analysis and conclusion?

While considering composition and balance, it should also be borne in mind that panel members will unavoidably bring their own interests and biases to the table.

On a practical level, there are several approaches for identifying panel members, including:

[3] Large ForSTI exercises may involve 10–12, or sometimes more, panels working in parallel on different themes or sectors. This is usually the case in national TFPs.

1. **Representative approaches:** Using names known to those already involved in the project or by identifying major experts and stakeholders in the areas of concern, and requesting them to provide further names.
2. **Resource-based approaches:** Valuable contacts can be obtained through searches in web resources and databases. There are a number of highly acclaimed organisations and work produced by them accessible on the web. These and their references would be useful sources for identifying potential panel members. Furthermore, a bibliometric analysis, for instance, drawing on databases of publications, would help to extract the most impactful scientists and researchers.
3. **Reputational approaches:** Also known as 'co-nomination', the process begins with defining the profile of desired participants (stakeholder type, expertise) and then continues with creating a list of initial names, who are then asked to nominate further key people. The initial aim is to generate a long list of candidates, which is then cut down to a short list of primary nominees and alternates. ForSTI exercises have used co-nomination approaches to broaden knowledge-base, by bringing new faces and fresh knowledge in to the process.

The more formal methods may require additional time and skills to implement, but they can prove significant for reaching beyond the 'usual suspects'. In general, it is considered to be a privilege to be involved in panels. Those individuals, who could not be engaged in a panel, may be engaged in other parts of the exercise, for example, through surveys and consultation processes, and/or attending wider conferences and workshops.

2. Distributing Roles in Panels

Following the appointment of panel members, there are three important roles to be fulfilled: panel 'chairperson', 'rapporteur', and 'facilitator'. The **chairperson**'s role involves keeping the panel to their task, ensuring that all participants have a say and that people are not being excluded due to other people's forcefulness or superior status, and defusing conflicts. The chair should have an ability to lead a team, good project management skills (especially given the time constraints common to most ForSTI exercises), and political skills for dealing with sponsor and stakeholder organisations. Having someone who is well known and (more importantly) well respected in a given community (or even nationally) will provide an invaluable boost to a panel's work, lending it authority and legitimacy. People will be more inclined to respond to surveys and to read a panel report if the chair is well respected.

A **rapporteur** is responsible for keeping notes on the process and decisions to be recorded and presented back to the panel. Rapporteur may also take notes, or draw sketches, onto whiteboards and flip charts to represent and visualise the discussion hold by the panel.

Facilitators understand and communicate to panel what its role is, where it stands in the overall ForSTI process structure and timetable, and what deliverables and associated logistics are. They utilise expertise to complement that of other members in panel work and liaise more generally with other parts of the ForSTI programme.

All the panel members are then asked to participate to the panel work on the basis of their views and knowledge. The members are expected to participate as an individual rather than a representative of an organisation. The ground-rule for ForSTI is that remarks are not attributed to individuals and people should be able to express their views independently. They may argue each other's views, provided that it is in the spirit of a constructive dialogue.

In parallel with the appointment of the panel members, chairperson and rapporteur, the panel's mandate should be clarified.

3. Defining a Panel's Mandate

In a ForSTI exercise, expert panels are expected to carry out specific tasks within a given timeframe (e.g. the duration of the exercise) related with their functions. There are two documents that are used to inform the panels about their tasks prior to the start of their works (i) Proposal and (ii) Terms of Reference.

The proposal document explains what the panel will do, and who should be involved. A short and succinct Terms of Reference document can detail and distribute the tasks, perhaps with the following four elements as organising principles:

1. Background, which provides some background on the ForSTI programme and the purpose of the terms of reference document
2. Description of each phase of the programme, setting out (i) what needs to be achieved, (ii) how the panel should go about its work, and (iii) a series of milestones
3. Description of the way in which the panel's work fits into the overall Programme
4. Account of the human, infrastructural (including training) and financial resources available to the panel in support of its work

Such a "terms of reference" document can be distributed to all panel members in the Programme, and can be used by the sponsor and project management team to monitor progress of the panels.

4. The Outset: Getting Started

It is useful to distribute project plans, summaries of process and expected outcomes, and brief résumés of the other panel members so that the participants will have a sufficient knowledge of the exercise by the time they arrive the first panel meeting. Some training workshops can also be organised to acquaint the participants with working practices and methods used in ForSTI. Panel work should start with the introduction of the panel members and objectives of the exercise. The sorts of things that will need to be discussed and decided upon include: working practices and panel structure; data and research requirements; schedule of panel meetings and schedule of interim and final deliverables.

5. Conduct of Work

During the course of ForSTI work, there is a challenge of getting panels to think creatively about future prospects, and the ways to achieve the more desirable prospects. Out-of-the-box thinking should be encouraged, but panels should be as wary of wishful thinking as they are of "business as usual". Their work and recommendations need to be based upon sound analysis of the past and present, as well as appraisal of future possibilities and options. During this process the following points should be considered:

- Wider consultation can be used when necessary. On the top of involving further information and perspectives, wide consultation lends a panel visibility
- Various organisational forms can be used to carry out work, such as the use of sub-groups within panels, which might focus upon a particular topic or task
- Continuity should be provided in panel work
- Panels may have some leeway to carry out the tasks they are given. However, it is important to meet the panel's remit
- Accountability and transparency of the panel process should be provided. In this regard, the substance of discussions within closed panel meetings may be publicly reported, although the norm is to keep these confidential. In this way, panel members have the relative freedom to express opinions without having to publicly account for them. Meetings should be transcribed and minutes prepared—the latter could be made publicly available on a web site if personal opinions are sufficiently anonymised
- Brief progress reports should be published at regular intervals. Such opportunities may be used to consult with wider communities of actors.

Implicitly or explicitly, methods must be employed to select and motivate the panel, assign tasks, and to activate them in the development and sharing of knowledge. Brainstorming and SWOT analysis are among the methods commonly used in panel work.

The operation of ForSTI panels is often far from routine and unproblematic. Panel members bring their own interests and biases to the table. Problems that may impede effective work include:

1. A dominating personality or outspoken person takes over the panel process so that the outcome tends to be his or her view
2. Individuals are unwilling to commit themselves on an issue
3. The superior vs. subordinate relationship hampers free expression of opinion by subordinates
4. The unwillingness to abandon a position once it has been taken publicly

5. Committee members who do not grasp the ForSTI process may fall into a conventional mode of analysis, and fail develop longer term appraisals of the focal topics.

These factors, which emerge on the panel work process, are likely to affect the ForSTI process, the ideas created, and the quality and quantity of the output. Thus the management of the group and individual behaviours is important: leadership and conflict management skills are required to maintain motivation and morale, and to resolve disagreements.

The depth and breadth of panel members' knowledge, and their experience in the field, are crucial; but so are personal characteristics—creative thinkers, who can work well in groups, are required. Creativity inherently involves risks: individuals have to be willing to try and to possibly fail. The participants should thus be able to speak freely without fear, to generate alternatives and examine disagreements without rancour. Expert panels need to avoid narrow representation that will limit challenging thinking: diversity can facilitate creative performance (Additionally, the networking benefits of ForSTI are enhanced by bringing together different stakeholder types—who might not normally meet—in the course of a panel). Broader organisational structures that promote open and on-going contact with external others or information seeking from different or multiple sources may also increase communication and creativity.

Panels need to be chaired and facilitated effectively in order to maintain motivation and morale, to resolve conflicts, to keep an eye on timetables and to prevent over-dominance of strong personalities. In order for creativity to occur, effective facilitation is needed to play an active role in fostering, encouraging, and supporting the activity. Sometimes the facilitator may play an "outsider" role, though another person may be recruited for this purpose. Participation of an outsider in an expert panel (e.g. in brainstorming and discussion sessions) can be useful for obtaining diverse information and ideas to motivate and support divergent thinking (reflections from someone outside the usual circles can provoke reflection on unexamined assumptions); but this can also cause friction or a feeling that their authority is being undermined, on the part of members of the panel.

Finally, it is important to know that an expert panel may not produce a statistically significant outcome. The results provided by a panel will most likely not reflect the response of a larger population or even the findings of a different panel. The panels usually consult through surveys, meetings or conferences to gather opinions from wider participants. However, at the end the outcomes will represent the synthesised opinions of the panel.

6. Reaching Closure: Achieving Consensus and Identifying Priorities

One of the chief aims for ForSTI panels is to nurture deliberation amongst a group of recognised experts and/or stakeholders around the focal object, with a view to generating policy advice, or at least useful understanding for policy development.

In some ForSTI exercises, panels may not be required to reach consensus or to identify priorities, let alone outline recommendations for policy and investment.

Typically reaching consensus on key issues, identifying priorities, outlining recommendations for policy and investment are among the outputs of expert panels. Some level of consensus and closure is usually achieved through analysis and panel debate, which does not mean that serious disagreements between panel members will all be obliterated: these should be highlighted rather than obfuscated. Where panels must prioritise large lists of topics, for example, in critical technology exercises, voting procedures are commonly used. Voting is nowadays done online, and can be opened up to invited individuals from outside the panel.

Following the identification of priorities a ForSTI exercise needs to produce a set of strategies in the form of recommendations. Recommendations set out actions that follow from the priorities identified by a panel: they tend to be directed at named organisations, and are thus more or less political in nature. For this reason, many (more academic) ForSTI exercises chose either not to make any recommendations at all, or, if recommendations are to be set, this may be left to a Steering Committee or to special forums of stakeholders who consider the implications of panels' analyses and priorities.

7. Reporting and Dissemination of Findings

Panels will need to report on their findings, both at the end of their work and in interim. The main rationale for reporting is to disseminate analyses, results, priorities and recommendations for further action. Impact requires that reports should be tailored to their intended audiences, both in terms of presentation of content and enough detail of methods to demonstrate that the work has been conducted with integrity, drawing upon the best available evidence and expertise. Costs of producing, "marketing" and distributing reports will need to be budgeted for, along with the expectations of input from at least some panel members (especially the panel chair) in further activities. These topics will be discussed towards the end of this book, in connection with the Intervention and Impact phases of ForSTI.

4.2.2 Ways of Working with Panels

In panels, participants usually meet face-to-face, normally in private session, at regular time intervals over a fixed time period of the ForSTI study. During this time, they use their judgement in interpreting available evidence. They share their findings, usually through a written report that is later disseminated and, in ideal situations, acted upon. At the other extreme, some panels do not meet in person, but provide interaction through the Internet or through a survey process, e.g. a Delphi. This also means that panel numbers need not be limited to 12–15 members but can be much larger. A mixture of face-to-face and virtual meetings is likely to become increasingly common.

Fig. 4.2 Modes of engagement

Panels can also meet in public sessions, although this tends to be reserved for those instances where panels wish to consult with a wider public. Often such meetings are used for evidence-gathering or for eliciting reactions to draft conclusions and recommendations. The substantial deliberation within the panel will rarely take place in such a setting.

Finally, panels can, in some instances, be constituted for an indefinite period of time. This often occurs where the desire is to establish an 'independent' authority for dealing with long-standing challenges, e.g. global warming. Such panels report periodically, usually on a specific topic or theme. This is different from the role of a ForSTI Agency or Unit as mentioned earlier, which will typically address a succession of focal objects.

Alternative modes of engagement in panel work, varying in the reach and frequency required by the ForSTI exercise, are illustrated in Fig. 4.2.

The financial costs of panel work may stem from various activities:

- Honoraria may be paid to panel members and/or the panel chair. This has not been common practice in ForSTI up until now—the prestige associated with being a panel member in a high profile exercise has usually proved to be sufficient reward. The amount paid represents a token of appreciation rather than a payment for services at normal professional consulting rates.
- Salaries for "functionaries". Panels tend not to run themselves but are typically supported with facilitators and/or secretaries. Secretarial support, for instance, minute taking and document preparation, may be provided by staff from the sponsor or the organisation awarded the contract for running the exercise. Facilitation of meetings is largely carried out by the panel chair, but additional specialist facilitation is also often required in ForSTI (e.g. for the running of scenario sessions, the writing of Delphi topic statements). Such skills may reside in the organisation managing the exercise, although when this is not the case other contractors may be brought in.
- Research and technical services will probably be needed to support the work of the panel. Some of this can often be prepared before the panels start their series of meetings, but other research and technical assistance demands are likely to

emerge as the panels undertake their work. Research and technical services can often be provided 'in-house', for example, by the sponsor or the project management team. In other instances, however, it will be necessary to bring in outside expertise to write specialist reports, collect and analyse data.

- Travel costs and other communications (e.g. telephone, document courier) also need to be factored for. In some countries, most expertise resides in the capital city and meetings are held there. But even in such situations, some people will have to be brought in from elsewhere, though costs are likely to be quite low. In many ForSTI exercises, expertise or stakeholders are more geographically dispersed. Here, meetings may be held in many different locations with perhaps most panel members having to travel. Some countries have two dominant centres between which meetings may be split (as in the Turkish case where national ForSTI panel meetings were largely distributed across two centres, Ankara and Istanbul).
- Rental of facilities may also be necessary, especially if panel meetings move about. It is normal for the sponsor to make its premises available for meetings. Sometimes panel members' own organisations may offer similar facilities for free (this happened extensively in the UK's original national TFP, but it should not be taken for granted). If meetings stretch over a day or more, and require participants to travel, it may also be necessary to pay for hotel accommodation.
- If panels are to carry out questionnaire surveys and/or organise workshops, materials will need to be provided. Moreover, reports will have to be published and disseminated.

Furthermore, time is needed for assembling the panel and any support staff, holding meetings, using methods such as Delphi or scenarios, preparing reports, and disseminating the final results. Realistic estimates must be made of the time and costs required to complete these tasks. This can prove difficult at the outset, and it is common to underestimate, especially with respect to the time needed. Indeed, it is not uncommon for ForSTI exercises to overrun—usually by only a few months, but sometimes it can be longer.

Across many different steps of ForSTI, there will have situations where working with groups is a major element of the process. Several methods may be employed here, and we shall briefly touch upon two of the most common methods-, brainstorming and mind-mapping, which can be applied at various phases, and for various purposes, within an exercise.

4.3 Common Interaction Methods

4.3.1 Brainstorming

The main objective of **brainstorming** is to elicit ideas from a group of people, who may be able to stimulate each other and produce a wider range of ideas collectively than they would achieve individually. First of all, we need a topic around which ideas are to be generated—this might be the drivers of change (often a subject of ForSTI brainstorming), application or market opportunities for an innovation, STI approaches for solving a problem, or many other topics connected with the focal object of a ForSTI exercise. By reducing the redundancy that would happen should each individual generate their own list of ideas, the process should give us a greater number of different ideas. A greater quantity of ideas does not, of course, necessarily mean a greater average quality; it is likely that some ideas will be put on the table that people would have dismissed as too weak had they had more opportunity to reflect. On the other hand, there is more chance of a wider range of approaches being generated if people are given more opportunity to let their imaginations roam, and are stimulated by the inputs from others.

The process will begin with the facilitator introducing the topic of the brainstorming (and the purpose of the session, if this is not understood by the group) and to explain the basic ground-rules of the session. The most important ground-rule of brainstorming is that, in the first stage of the process, ideas are to be presented without comment or evaluation. This is intended to improve the volume of participant input and encourage creativity: the ideas will be evaluated at a later stage. They are not subject to critique or further analysis (except for points of clarification) until a sufficient number has been generated. This ground-rule should be clearly stated at the outset, and may need to be enforced with reminders in the course of the activity. Another ground-rule is that all participants have equal status, and are provided with equal opportunity to share their ideas. Box 4.1 reproduces some notes we used as an aide memoire for participants in a break-out group during a scenario workshop; the aim is to reinforce the account given by the facilitator.

The facilitator of the session will then ask a specific open-ended question to focus the discussion. For example: “what are the main social and economic factors that will affect the development of this technology?”; “how does R&D need to be reoriented to help us solve this social or environmental problem?” and “what might be some surprising uses of this technology in the next decade?” The ideas should be recorded down and collated without critical comment (though ideas may be spun off from earlier ideas). They may be spoken out loud and recorded onto a flip-chart or poster—this is probably the most common approach (i.e. 3P approach: poster, pen and post-it!). There may be a period where people first jot down ideas onto pieces of paper or post-it stickers, and then share them. They may enter their ideas into computers so that they appear on a “virtual wall”. Sometimes it is helpful to define a target number of ideas in advance. When the group feels comfortable that there are no more ideas to add (usually captured on whiteboards or flipcharts or, in some recent implementations, on computer screens), we enter a next phase of the process. Ideas are typically grouped to reduce redundancy and allow for related ideas to be brought together. It may be useful to ask clarification or more information on what was meant by each item—sometimes ideas will be merged, sometimes disaggregated into separate ideas.

In concluding the brainstorming process, the group will usually move into a period of discussing and evaluating ideas. They may be asked to vote as to which are the most important, most original, most challenging, most feasible ideas, for example. Often, so many ideas will have been generated that it is important to undertake some basic selection before they are examined in detail—there are just too many ideas for each one to be scrutinised at length. In many workshop settings, the group will be asked to present its work back to a plenary session, where they hear ideas from other groups—often they will be asked to outline just their top three, five or ten ideas, using the criteria appropriate to the task.

Box 4.1: Participant Notes on Brainstorming

Brainstorming is often used in Break-out Groups. It aims to capture a large number of ideas from participants, and to allow many participants to stimulate creativity and novel viewpoints, to input ideas in an uninhibited way, including "wild" ideas. In this case, we want to capture multiple suggestions, from the whole set of participants, about different possible influences on the future of the information systems environment.

The process involves a period of freethinking, which is used to articulate and capture ideas, with no critical comments. People are encouraged to generate ideas, and have these captured on flip charts. We write them down first, under each of your headings.*

Do not spend time debating (and especially not criticising) the ideas here and now. This is liable to inhibit creativity and willingness to think outside the box. You can ask for clarification (*What does this mean? What aspect of this are you talking about?*). Ideas can build on earlier ideas.

This is just a starting point; the lists you come up with here are not the sorts of systematic input that can be used directly in reports; so do not be inhibited. The step that follows brainstorming is a more rigorous discussion of these ideas, where we will select key ideas to focus on in more depth.

*People could be writing down extra ideas on these while the discussion is going on, and put them up on the chart later.

4.3.2 Mind-Mapping

Whereas brainstorming seeks to generate ideas, mind-mapping methods seek to organise them. The mind-map is a visual representation of the discussion, with ideas captured as brief statements (usually single words) and connected through links. The process of organising ideas and the connections between them is intended to create a memorable visualisation of the discussion or the implicit mental model of the thinker. It can be used as a memory aid, or to help further articulate ideas (e.g. by suggesting missing links). Thus it can capture a mental model of a particular topic—which is often not restricted to a model of the system of concern. Even in ForSTI work, a mind-map may involve all sorts of topics and debates around a STI subject, without an effort to map the STI system itself.

The basic ideas of mind-mapping may have been around for a long time, but one version of the approach was popularised in a series of TV programmes and an associated book in the 1970s (Buzan 1974; see also Buzan and Buzan 1993). The approach is often used on an individual basis, for example, authors preparing the structure of an essay, teachers planning a curriculum, students taking notes on a lecture or a film or TV programme they are studying. But mind-mapping can also be applied in groupwork—where an individual may map the group discussion for the group (or others) to reflect upon, or where the group itself may map its ideas, perhaps as a structured way of brainstorming ideas, or perhaps as a way of organising the results of a brainstorming.[4] The approach can also be used to report on group deliberations, with the mind-map capturing, grouping and linking ideas expressed in the group, as they are being expressed. Typically one member of the group with some familiarity with the technique will capture the map on a white-board or flipchart (or in specialised software, see below). The results are displayed immediately, and can be discussed by the group and/or used for communication with other groups in plenary sessions, etc. Since group discussions are often rather disorganised, conventional transcripts and lists of ideas can require readers to do quite a lot of work to make sense of the argument (this is why skilled rapporteurs play such a large role in groupwork!) be quite problematic. Mind-maps can be brought to life with use of different coloured pens, and of symbols to accompany ideas. They can be developed into system maps, when the focus of the discussion is on the system being concerned. Note that this involves a shift in what is being modelled—to the system of concern, away from the mental model of a speaker or the patterns of discussion in a group.

The typical stages of mind-mapping as outlined by Buzan (in his inimitable style) are reproduced in Box 4.2.

Box 4.2: Mind-Mapping Stages

- Start in the CENTRE of a blank page turned sideways. Why? Because starting in the centre gives your Brain freedom to spread out in all directions and to express itself more freely and naturally.
- Use an IMAGE or PICTURE for your central idea. Why? Because an image is worth a thousand words and helps you use your Imagination. A central image is more interesting, keeps you focussed, helps you concentrate, and gives your Brain more of a buzz!
- Use COLOURS throughout. Why? Because colours are as exciting to your Brain as are images. Colour adds extra vibrancy and life to your Mind Map, adds tremendous energy to your Creative Thinking, and is fun!

(continued)

[4] A good example of mind-mapping being used to share understanding in an interdisciplinary group is provided by Meier (2007) at http://sru.soc.surrey.ac.uk/SRU52.pdf (accessed 24/04/12014).

Box 4.2 (continued)

- CONNECT your MAIN BRANCHES to the central image and connect your second- and third-level branches to the first and second levels, etc. Why? Because your Brain works by association. It likes to link two (or three, or four) things together. If you connect the branches, you will understand and remember a lot more easily.
- Make your branches CURVED rather than straight-lined. Why? Because having nothing but straight lines is boring to your Brain.
- Use ONE KEY WORD PER LINE. Why? Because single key words give your Mind Map more power and flexibility.
- Use IMAGES throughout. Why? Because each image, like the central image, is also worth a thousand words. So if you have only 10 images in your Mind Map, it is already the equal of 10,000 words of notes!

Source: Tony Buzan's website (http://www.tonybuzan.com/about/mind-mapping/ accessed on: 22/04/2014).

There are many Software tools to support mind-mapping. As we pointed out in Keenan et al. (2003), the "outline" facility in word processing packages can be seen a very simple mind-mapping tool, with the section headings it portrays being stages in an argument. But this is essentially a linear structure, and several more sophisticated programs are available that allow for more elaborate visualisations of mind-maps.[5]

Mind mapping is often used by individuals to record the course of discussion in ForSTI workshops—as in many other contexts. It may be a more collaborative tool when, for example, it is used to group the ideas emerging from brainstorming or other approaches to eliciting ideas connected with the focal object of the exercise, or the topic of a specific workshop. A mind map of the Malaysian ForSTI Programme itself was published in the December 2010 issue of their magazine, *myForesight*![6] This featured links stemming from the core activities of ForSTI, Diagnosis, Prognosis, Prescriptions, tools and Stakeholder Engagement, and is reproduced in Fig. 4.3.

[5]There are many guides to this rapidly evolving area: two recent website reviews are http://lifehacker.com/five-best-mind-mapping-tools-476534555 and http://mashable.com/2013/09/25/mind-mapping-tools/ (both accessed 09/09/2014).

[6]Published by MIGHT in Cyberjaya, Malaysia, and available at http://www.might.org.my/en/SiteAssets/myForesight1.pdf (accessed 09/09/2014) and http://community.iknowfutures.eu/pg/file/popper/view/8234 (accessed 06/04/2015).

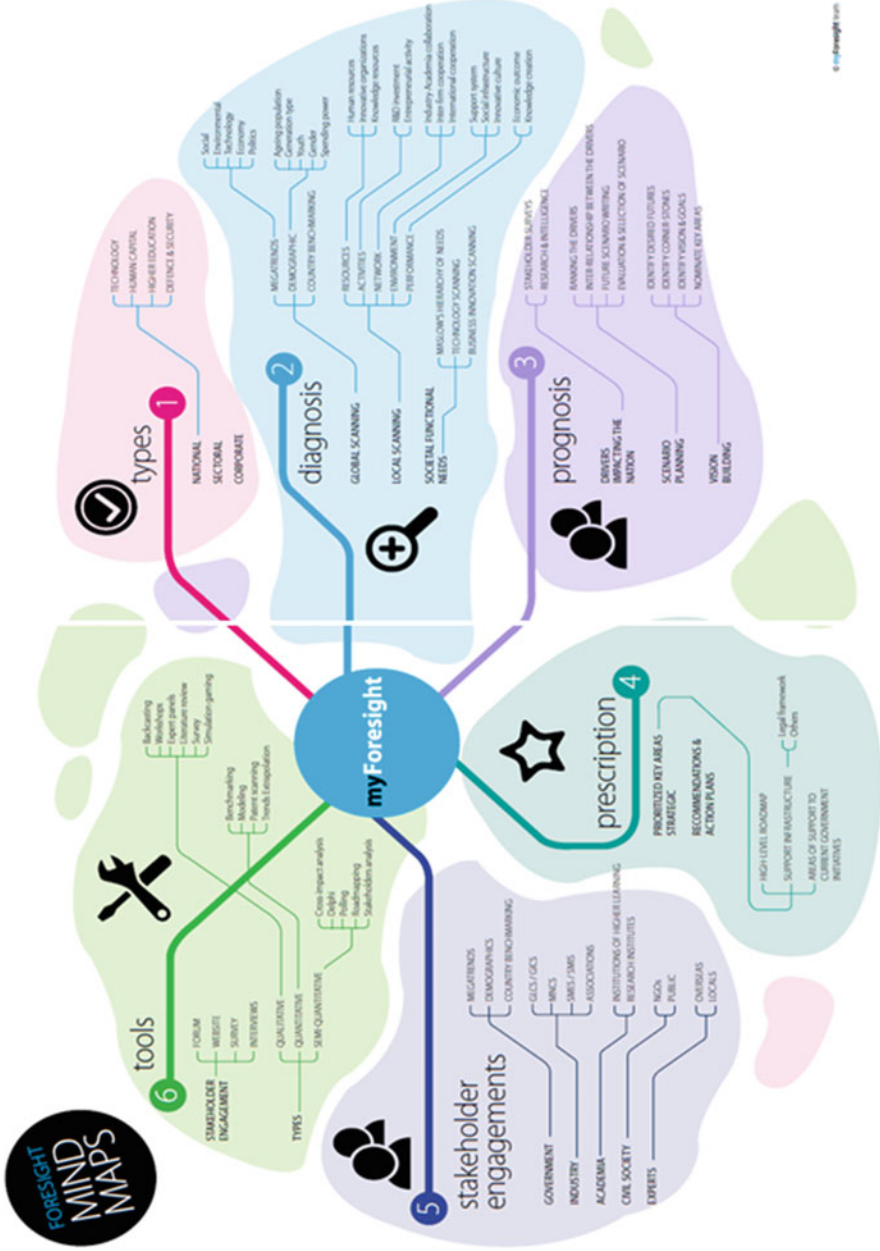


Fig. 4.3 A mind-map of the Malaysian ForSTI. *Source*: *MyForesight*, December 2010, pp. 6–7

4.4 Conclusions

Since ForSTI is intended to enable informed decisions to be made, it is important to draw on the best information that can be made available, and made sense of, in a timely manner. The message of this chapter has been that this information will frequently need to be obtained from, and shared with, key actors. Many of these actors may need to be engaged in the decision-making and change process, since they may have the power to influence events, or to raise the awareness of those that do have this power.

Engagement, interaction with many stakeholders, is thus a prominent feature of ForSTI. However, engagement in this process requires caution. It is not always possible to build consensus, and sometimes stakeholders may become even more polarised and hard to reconcile. ForSTI is not always going to be successful in bridging deep-seated ideological differences or community divisions. The view that every cloud has a silver lining, and that failures are simply good opportunities for learning, will not usually convince a sponsor that their investment has been worthwhile, nor will it help to build support for future ForSTI activities. Thus engagement and broader participation is something that needs to be treated with just as much care as the more technical aspects of the exercise.

Interaction carries on throughout the ForSTI activity, though it may take different forms. Different actors may be engaged more or less intensively, at different phases of ForSTI exercises. One result of this pervasiveness of interaction is that brainstorming and other approaches outlined in this chapter are quite liable to be used recurrently at different phases of the activity. The tools may be applied for different specific aims, but the general purposes of facilitating the articulation and sharing of ideas and information remain the same. Some methods discussed in later chapters—such as Delphi, mind-mapping, and scenario workshops, are also useful in this respect.

5 Intelligence: Environmental and Horizon Scanning

5.1 Introduction

The Intelligence phase of ForSTI begins with a comprehensive understanding and scanning exercise, which provides input for the overall activity. The aim is to attain a reasonably comprehensive view of situations involved in the STEEPV systems and their future directions of development. This provides a shared understanding and mutual appreciation of situations, issues, and influencing factors as systems within their own contexts by uncovering uncertainties about the values and preferences of actors and stakeholders, and clarifying the goals of the entire ForSTI activity. In this way, the Intelligence phase offers a mind-set for understanding how systems work and behave, and what their emerging characteristics are. The goal is not necessarily to bring about a convergence of views, but, at least a partial convergence is likely to emerge from this process in practice.

In ForSTI, scanning exercises can be carried out at two levels. The first one is scanning the wider context of influencing factors, which may be mentioned as "Environmental Scanning". A STEEPV framework can be used for this purpose. The second one is "Horizon Scanning", which is concerned with what could plausibly unfold in the future in the form of trends, drivers of change, weak signals of emerging developments, wild cards/shocks/surprises and discontinuities (Saritas and Smith 2011).

All scanning activities may be undertaken by using various quantitative and qualitative ForSTI methods, such as brainstorming, workshops, review of existing literature and studies or through the bibliometric and semantic analysis of large amounts of data and information. The outcomes of the process should enable a better understanding of the focal object and ForSTI 'context'. This can support the identification and scoping of the main areas of the activity (i.e. establishing the main boundaries of the ForSTI). Furthermore, this should clarify such aspects of the 'content' of ForSTI as the themes, topics or sectors to be focused on. The context and content of the activity will help to design a 'process' for ForSTI with the selection and combination of methods and tools. In this chapter, we will first begin

I. Miles et al., *Foresight for Science, Technology and Innovation*, Science, Technology and Innovation Studies, DOI 10.1007/978-3-319-32574-3_5

by introducing Environmental Scanning, and will then focus on the more future-oriented Horizon Scanning activity.

5.2 Environmental Scanning

We define Environmental Scanning (ES) as:

> the systematic identification, monitoring and examination of issues of relevance to the topic of concern.

ES does not just consider the natural environment. It can include two types of contexts, in which ForSTI is embedded. These are illustrated as external and internal contexts in Fig. 5.1.

The external context consists of a set of interrelated and interdependent systems, which, in practical terms, can be explained with the STEEPV acronym (Box 5.1).

Box 5.1: STEEPV Acronym

STEEPV is one of a family of classification systems that are often used in horizon-scanning. Loveridge (2002) explains the emergence of the concept and ways of using it. STEEPV acronym stands for the categories: Social, Technological, Economic, Environmental, Political and Values.[1] The aim of such a list of categories is very simple: it is to encourage users to think through a range of factors—they could be trends to examine, driving forces underlying trends, weak signals of emerging developments, possible wild cards or impacts of trends. We use such lists not because they represent a deep ontology of how the world is constructed, but simply in order to avoid getting trapped by just considering one or other set of factors as if these were the only important ones. Examples of the issues to be considered under each category are given below:

Social	Ways of life (e.g. use of leisure time, family living patterns) demographics (population growth and age structure), social inclusion and cohesion (fragmentation of lifestyles, levels of (in)equality, educational trends, conflict across age groups or subcultures).
Technological	Rates of technological progress, pace of diffusion of innovations, problems and risks associated with technology (including security problems). Technologies that might affect health,* life expectancy, interpersonal communication, personal security.
Economic	Levels and distribution of economic growth, booms and busts, industrial structure (e.g. growth/decline of particular industries), pensions and wages,* competition and competitiveness, markets and financial issues.

(continued)

[1] Other systems include PESTLE, where the L is Legal; TEEPSE; where the E is Ethical.

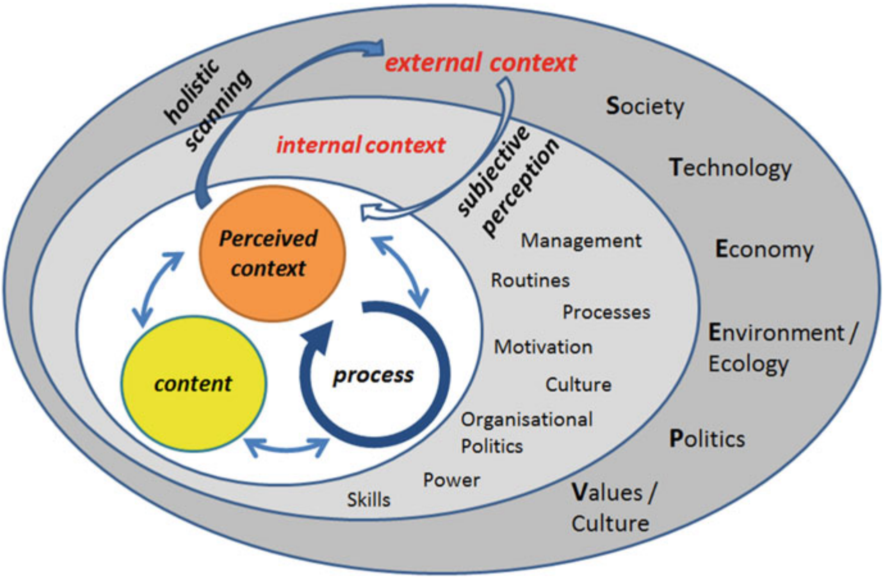


Fig. 5.1 Contexts of ForSTI for environmental scanning. *Source*: Saritas (2006)

Box 5.1 (continued)

Environmental	Pressures connected with sustainability and climate change in general; more localised environmental issues (including pollution, resource depletion, and associated biodiversity, health and safety concerns).
Political	Dominant political viewpoints or parties, political (in)stability, role of governments and quangos in regulation, political pressure and lobbying by non-state actors (e.g. pressure groups).
Values	Attitudes to health/ill-health*, to working life (e.g. entrepreneurialism, lifelong careers, mobility across jobs, countries, etc.), deference to authority, identity in relation to leisure, culture, political values, etc.

*These and several other examples reflect the focal topic of the exercise from which these example instructions are drawn—it was related to individual careers in health services

In some cases the practitioners of ForSTI may hesitate where a particular trend or development may fit within STEEPV categories. For example, the topic of 'sustainability' can be considered under environmental, economic or social category. What is important to know is that the aim is not to come up with a perfect classification system under STEEPV, but to capture as widely as possible issues in the course of discussions, and to address them during the ForSTI activity, whichever category they may fall under.

The aim of scanning the STEEPV systems is to develop a view of where important developments are taking place, what trends need to be watched, and who the key players are and might be. Methods used here are very varied: they include systematic analysis of media (nowadays this most critically means the Internet), perhaps using content analysis tools (to indicate emerging social attitudes and political movements), review of reports from financial analysts and specialised consultancies (to suggest emerging markets or business models); examination of specialised databases (e.g. patent or bibliometric data, to give warning of developments in science and technology). It is possible to become too tied to specific methods and data sources, so that alternatives—especially paradigm-challenging ones—may be neglected. Many organisations routinely engage in such scanning. It may include the business, political, or technology environment, for example, "Competitive Intelligence" is one flavour of ES used by firms to examine their competitors. The activity is most often conducted in a "one-off" fashion, when a new activity is being planned. This may save costs, but reduces learning opportunities.

The internal context is also an important element of the scanning activity. It usually functions as a filter when the external contexts are considered. For instance, organisational goals, worldviews, motivations, politics, behaviours, skills and competences are important determinants for interacting with the external world. This gives a subjective characteristic of the scanning and ForSTI activity. Although the ForSTI exercise aims at developing visions, ideas and innovations to present to the external context, it has also benefits for the advancement of the internal context. For instance, one of the key impacts of the ForSTI, "behavioural additionality" introduced by Georghiou (2002), takes place in the inner context, where practices, routines, and organisational and individual behaviours change substantially following the exercise. The concept of behavioural additionality will be touched once again in the evaluation chapter of the book.

The ES scanning activity provides a useful input for ForSTI right from the beginning of the activity. First of all, the ES links ForSTI into its aforementioned contexts. In this way it helps ForSTI to understand systems' behaviour and recognises critical issues, and impedes the flow of information amongst the key stakeholders and decision makers. Three important inputs to ForSTI can be derived from the further examination of the ForSTI's context (Saritas 2006):

1. A rich understanding of existing systems, their history and possible futures
2. Analysis of different stakeholder perspectives and their social relations in the system which can affect and be affected by the process
3. Examination of formal and informal networks and procedures, which can be in favour or in conflict with other systems

Analysing the contexts of ForSTI in the course of ES helps to build the content of the activity, where content represents the subject areas taken into consideration such as technologies, themes or other topics, which may generate the biggest socio-economic and environmental impacts, and therefore, are worthy of focusing in the exercise. Content for ForSTI can be defined in a more open-minded, creative and flexible way, at least at the outset. In the long-term future, the boundaries of many phenomena are liable to be redefined. We need to be able to take this into account, rather than limiting our appraisal to what we know now. To give a simple example: assuming that "homes" involve only houses and apartments in the USA failed to take into account the large numbers of people living in mobile homes (currently estimated to be almost 7 million); the implications for housing, urban development, education, medicine and social welfare are enormous.

During the ES process, ForSTI will explore a range of important and uncertain issues (like demographic change, socio-cultural evolution, technological advancements, environmental issues, or political transformations). In most cases, the ES with the use of STEEPV analysis can be an ideal first step for planning future scenarios. A more detailed description of the process of working with STEEPV systems is given in Chap. 7 of the book.

Moreover, the ES activity also helps to develop a proper methodological approach for ForSTI, which may be customised in line with the specific context and content of the activity.

Following a good understanding of the contextual factors affecting the future of the key areas of focus in ForSTI through an ES, a more future-oriented intelligence gathering exercise can begin with a Horizon Scanning activity, as described in the following section.

5.3 Horizon Scanning

For ForSTI activities, we can define Horizon Scanning as:

> *The systematic identification and examination of emerging issues (including emerging developments in established issues) that are of relevance to the topic of concern* (i.e. the focal object and content of the study)[2]

Some of the terms used in this definition are elaborated in Fig. 5.2.

Horizon Scanning (HS) is often confused with Environmental Scanning (ES), but as explained above, as a broader term ES looks into the contexts (or environments) of ForSTI topics, while HS, which can be considered as a subset of ES, is concerned with future-oriented 'emerging' trends, issues and uncertainties in the topic of concern. While the issues stressed in HS are especially those involving novel and emergent features, ES may be very short-term in focus. Thus, for instance, in corporate environments the focus may be on what competitors and regulators are doing or preparing to do next, how markets are responding to their activities, what they are stressing in press releases, and the like. Well-informed managers naturally monitor many key issues on an ongoing basis, and large

[2]We have derived this from a UK Foresight formulation of HS as: "the systematic examination of potential threats, opportunities and likely future developments including but not restricted to those at the margins of current thinking and planning. Horizon scanning may explore novel and unexpected issues as well as persistent issues or trends" (dating from at least 2004, this is reproduced often, e.g. Government Office for Science 2011).

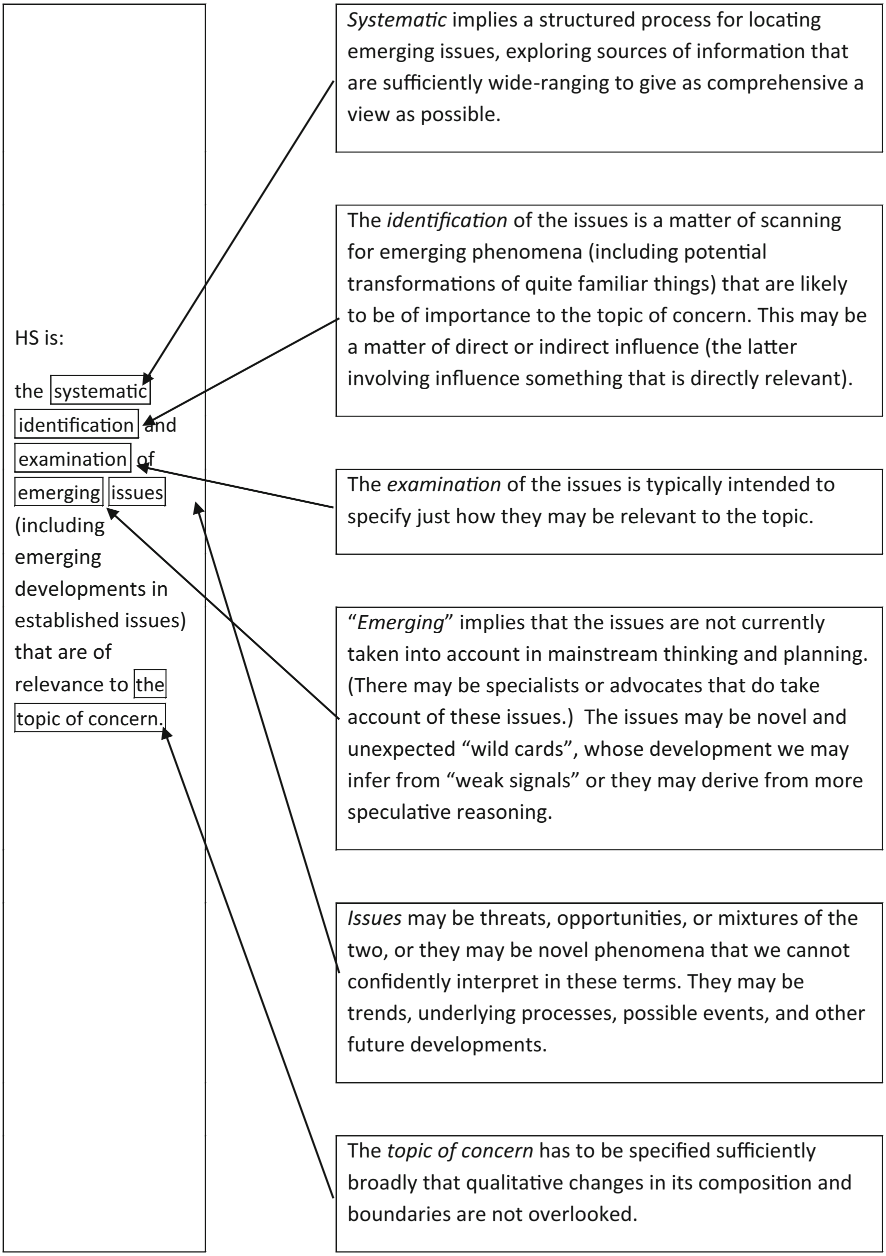


Fig. 5.2 Unpicking a definition of horizon scanning

organisations will often have several departments that feed relevant information they have picked up to senior managers.

The specific focus of HS will tend to be on changes that are evidently underway or the subject of controversy or speculation. Often these are matters that are entering into immediate and short-term decision-making, and that are the topic of discussion within the organisation and its networks. This is not to say that HS is always about obscure, unrecognised topics. It is often the case that there has been considerable discussion of future contingencies—for instance, the likelihood of a future pandemic of highly fatal strain of influenza. Organisations and individuals charged with risk management and resilience are often focused on such phenomena, and they may occasionally surface in the mass media. They will typically only enter into ES when the threats in question start to become manifest, or when the organisations in the environment of our scanner are engaging in activities connected with the risk.

Regarding the scope, the HS activities are typically concerned with:

- Trends
- Drivers of change
- Weak Signals of emerging developments
- Wild Cards/Surprises/Shocks
- Discontinuities

These will be elaborated in the next sections.

5.3.1 Trends

The starting point for scanning is usually to identify the key trends which are presently evident in the broad sense of being both discernible and (usually are) somewhat gradual forces, factors and patterns that are pervasively causing change in society generally. The speed of change may be deemed comparatively slow or fast depending upon one's vantage point, but the important aspect of a trend is its pervasiveness (Saritas and Smith 2011). Box 5.2 gives a few examples of Trends.

Box 5.2: Examples of Trends

- Demographic change observed in the form of ageing population observed mainly in Western societies, whereas increasing population in other parts of the world such as Africa and India
- Increasing concerns for energy efficiency and renewable and sustainable resources for energy generation
- Trends towards mobile devices with the integration of higher number of functions and services, with lighter and faster devices

Saritas and Smith define other concepts related to trends, including “Mega-trends”, “Potential trends”, and “Branching trends”.

Mega-trends typically extend over generations of human life and describe complex and systemic interactions between many factors. For instance, as a mega-trend climate change has been observed for a long time prior to human existence.

Potential trends are the ones which stem from innovations, projects, beliefs or actions that have the potential to grow and eventually go mainstream in the future. For instance, alternative medicine remained an outcast from modern medicine. However, currently, it has links with business and has achieved a degree of respectability in some circles and even in the marketplace.

Branching trends represent a group of trends, which are linked to each other as branches and twigs. For example, a well-documented movement toward equality between men and women might represent a branch trend. The trend toward reducing differences in the relationship between the salaries of men and women in the Western world could form a twig on that branch (cf. Saritas and Smith 2011).

A recent report by WEF (2016), entitled “*Global Risks Report 2016*” introduces the concept of “Global trends”, which is defined as: “*a long-term pattern that is currently taking place and that could contribute to amplifying global risks and/or altering the relationship between them*” (p. 6). Among the examples of the global trends are: changing landscape of international governance, climate change, environmental degradation, and rising global mobility.

5.3.2 Drivers

In HS we are usually looking for things that might change the situation, or change the way in which it is developing. The term ‘Drivers’ (or Drivers of Change) simply refers to the major influences on a phenomenon, especially the major forces that underpin trends. Though in wide use among managers and policymakers, the terminology of ‘drivers’ is one that is resisted by many social researchers. They regard it as an unscientific term, as perhaps implying a one-way, linear causality that cannot exist in reality. The point may be expressed in different ways, but one point of view is that social affairs should be understood as emergent from systems, in which there are multiple variables linked together in a complex web of feedback loops. Others may stress the reflexive nature of social activity (human beings can gain awareness of what they are doing, why, and what the possible consequences are; they can conceptualise and communicate this to others; and this can lead to new patterns of behaviour).

In contrast to these sophisticated points of view—which are often counter-posed to each other as quite different approaches to social understanding—the notion of drivers is much more of a lay, everyday concept. On the basis of a review of the ForSTI literature, where the idea is often invoked, we can say that:

- Drivers are major factors that are known, or believed, to be shaping or influencing our topic of concern, or to be liable to do so in the future.
- Drivers are the forces underlying the trends (e.g. investment in bioscience R&D). Some commentators will see trends as more the outcome of the action of drivers, which are then seen as longer-term factors whose dynamic interplay moves trends in one direction or another. Events, in turn, are the outcomes of trends—an event may be purely statistical (we now have more than 50 % of the population in this category, for example), or phenomena that mark step changes of one sort or another (e.g. the introduction of a new policy in response to a trend).
- Drivers may influence our topic of concern directly or indirectly. Some drivers are outcomes of other drivers. For example, improved nutrition, public health, and treatments of common diseases, are among the factors that are leading to a growth in the elderly population, which is a major driver of increasing demand for healthcare related to this population's needs.
- Some drivers are relatively predictable (bar major wild cards); we can anticipate, for example continuing decrease in the cost and increase in the power of much information technology; we can forecast the age structure of the population into the next decade or so with some confidence. Others are much more uncertain, for example major policy changes may result from quite small swings in electoral behaviour, or even from complex trade-offs in a governing coalition.
- There can also be uncertainties to do with the actual effect a driver is liable to have on our topic of concern. This may be because the emergent issue is too novel to properly assess; because we believe it will interact with other drivers to produce different outcomes; because we do not know what the reaction to a development will be.
- Drivers may be internal to our own organisation (e.g. ageing and turn-over of the workforce), or external to it (e.g. factors restricting the immigration of workers with particular skills or capabilities).
- The sorts of influence that drivers may have can also be very varied. A driver may increase, decrease, or qualitatively change a variable we are interested in; it may set limits or thresholds to change; it may indeed inhibit change.

Some ForSTI practitioners have attempted to sharpen the terminology by drawing new distinctions and introducing new formulations. For instance, van der Heijden (2005), from the perspective of strategic management, differentiates between the Factors in the Contextual Environment (which we survey and appreciate, since our ability to influence them is limited), Driving Forces from the contextual environment that influence (a) the Transactional Environment where our organisation interacts' with others (and here there is scope for influence and co-design of developments) and (b) the Actor (organisation) itself, where we have the opportunity of controlling choices. Such a framework can be helpful in classifying and organising different drivers, though it is more common to use one of the all-purpose frameworks such as STEEPV, which will be further elaborated in Chap. 7 of the book. Some examples of drivers are presented in Box 5.3.

Box 5.3: Examples of Drivers

- Climate policies and resource practices are the drivers of carbon credits, taxes and footprint accounting
- Resource restrictions and political instability in the Middle East and North Africa drive scores of people to immigrate illegally through dangerous ways
- Information and Communication Technologies and the Internet have been the main drivers for electronic commerce

5.3.3 Weak Signals

Weak Signals are the first important indications of an emerging future change associated with society, technologies, innovations or other domains. They may be first signs of future trends, paradigm shifts, drivers or discontinuities yet to materialise. There may still be uncertainties whether the signals can be accepted as an evidence, as there may be some faulty signals—either due to an error in the signal detection process, or mistakes in data. This may not be known immediately. Even if it is emerging, there may still be uncertainties about the direction of future change and the extent of impacts it may have on our systems. The main benefit of analysing Weak Signals can be observed when their impacts on society and organisations are assessed, and strategies and policies are developed. An example of Weak Signals from the past is the first mention of the climate change, which was made in the 1970s. However, not much has been done until recently. Further examples of Weak Signals can be found in Box 5.4.

Box 5.4: Examples of Weak Signals

- Virtual second lives of people dominate the real first life. People have double personalities as who they are in reality and who they would like to be virtually. Social differences in real life like age, sex, race, language, religion blur in the second life
- The use of digital currencies will be widespread across the globe resulting with faster commercial transactions and more stable markets—though only after economic and security issues are addressed!
- Legislation, justice and execution functions of governments are implemented through ‘crowdsourcing’ resulting with the abolishment of the traditional parliamentary systems and elections with real time public participation

5.3.4 Wild Cards

Wild Cards—which can be what are referred as Black Swans (Taleb 2007)[3]—represent those unexpected/surprising/shocking events and developments, which are generally believed to have low probability of occurrence, but would substantially impact the human condition once they occur (Petersen 2000). Consider our present world: many of its key aspects have been shaped massively by events that would not have been predicted a few decades ago, from the emergence of AIDS to 911 and the conflicts that accompanied it. We can be fairly confident that much of the world of the 2040s, for example, will be similarly shaped by unpredictable and uncertain wild cards, which may originate either from the factors out of our control (such as natural disasters like earthquakes, and asteroid impacts) or human-controlled factors (such as nuclear disasters, pandemics, terrorist attacks). Box 5.5 presents Wild Card examples with their associated trends in which they may exist.

Box 5.5: Examples of Wild Cards

- Due to rapid technological developments, humans will lag behind in computation, production, and service provision, and will look for ways to slow down or stop technological development
- Extraction of precious raw materials, like gold, from extra-terrestrial reserves collapses the global economic system
- Due to increasing use of electronic health systems and mobile devices, ‘digital viruses’ become more serious medical threats than conventional ‘organic’ viruses

Wild cards may also be introduced into ForSTI in order to increase the ability of practitioners to adapt the future-oriented ideas to surprises, which may arise in turbulent environments. For instance, Wild Cards can be introduced into the process of scenario planning for the ‘wind tunnelling’ of alternative scenarios under unexpected circumstances.[4]

[3]There are several differences between the two concepts, though both have high impacts. Wild Cards are (supposedly) unexpected when they happen, but they can simply be events that are seen as having a low probability of occurring (at least within a specific time period). Black Swans are phenomena that were not previously seen as possible—e.g. it was long assumed that all swans were white.

[4]The wind tunnelling concept will be elaborated further in Chap. 7.

5.3.5 Discontinuities

Discontinuities are rapid and significant shifts in trajectories, or the forces behind these. Some of them may originate from wild cards, but many are less surprising. Indeed, some are widely anticipated, for example, the displacement of analogue media by digital ones was long expected—the main uncertainties concerned how soon and how fast this will happen. In the ForSTI field, 'technological discontinuities' are particularly important.

The introduction of the advanced Information and Communication Technologies, and the Internet has created major discontinuities in our lives. They have already resulted in major changes in the ways societies and personal relations organised as well as the ways products or services are produced, delivered and used, such as in finance, education and trading. While creating new opportunities, discontinuities may also pose threats for instance for those who use inflexible technologies, or even for elderly citizens, who may not be able to stay up to date with technological developments and may be isolated from the rest of the society. Some more future-oriented example discontinuities can be found in Box 5.6.

Box 5.6: Examples of Discontinuities

- Electronic communication and social networking tools like Google, Wiki, Facebook, YouTube and similar innovations create the ways for transformations in personal relations and business practices
- Additive manufacturing and 3D printing will transform production processes, such that existing production and logistics infrastructures and practices will need to be redesigned
- Lightweight and durable building materials using nanotechnologies may substantially change heavy, lengthy and dirty construction work

The terminology presented in HS above features a number of concepts that are frequently confused with each other. In fact, it may not be very important whether they are called or classified under one or the other, as long as they are captured and considered in ForSTI exercises. However, in order to help with the clarification of the HS terminology, the following example on demographic change is given in Box 5.7—though it may still be subject to discussion!

Box 5.7: An Example for Comparing HS Terminology

- **Trend:** Ageing population
- **Driver:** Declining reproduction rate, longer life spans of individuals through better medication, diet and lifestyles
- **Weak Signal:** Social, economic and structural tensions due to lesser opportunities for younger people: rise of intergenerational conflicts of various kinds
- **Discontinuity:** Elderly become more influential in politics and decision making, with many older people active in civic affairs and campaigning
- **Wild Card:** Unlike the present, cosmetic surgery is undertaken to look older and wise!

There are some other concepts, which can be considered as closely associated with HS. For instance the 'Global Risks' concept can be considered somewhat closer to the Wild Cards concept. As defined by WEF (2016): "*A global risk is an uncertain event or condition that, if it occurs, can cause significant negative impact for several countries or industries within the next 10 years*" (p. 6). Among the global risks mentioned are: failure of climate change mitigation and adaptation, profound social instatibility, and interstate conflict.

Following the description of the HS concepts and terminology, Box 5.8 presents an example of HS in the health field, where HS activities are often undertaken—not always accompanied by other ForSTI approaches. HS seems to be particularly prevalent in the health area for a number of reasons. One is simply that new medical treatments are continuously emerging, and it is important to be able to anticipate and assess these if they are to be introduced effectively into practice. On the other hand, training of medical staff is problematic: there are often shortages of skilled staff, and the skills required change as medical practice does. There are also trends and discontinuities in the pattern of ill-health in the population which have to be taken into account in planning.

Box 5.8: Horizon Scanning in Health: UK Example

HS in the heath/medical fields of one sort or another has a long history, but it was given a considerable boost by the UK Government's TFP. From the 1990s on, this programme has evolved through several stages, notably from undertaking a wide analysis of practically all sectors of the economy and areas of promising technologies, to a more focused approach where a succession of studies examine either important areas of technology development (e.g. "detection and identification of infectious diseases"), or specific social problems (e.g. obesity) where there is scope for the application of STI along with other policy interventions. A common The aim is to help coordinate different departments of government whose activities of would otherwise proceed in a piecemeal fashion and quite possibly undermine each other.

Confronting pressures of their own, and needing to deal with unpredictable change in society and technology, several departments of the UK government became active in HS activities. Sometimes these conformed to the restricted definition of HS discussed above, sometimes they involved broader futures and ForSTI activity (the "Horizon Scanning" label was probably applied because "Foresight" was identified with a specific department's Programme). While departments have their own specific interests and requirements, there was inevitably some duplication, and an effort to centralise HS was made by creating the Horizon Scanning Centre (HSC) in 2005. Hosted by Foresight, the HSC was intended to feed futures work into departments across government, and to encourage cross departmental activity at Permanent Secretary level to develop scenarios for use by government.

As an example of cross departmental use, the Department of Health (DH) and Department of Work and Pensions (DWP), asked the Foresight Horizon Scanning Centre to help them explore how trends might interact in the future to affect people aged over-50. A set of scenarios was created suggesting four possible future worlds together with a fifth scenario, setting out a preferred future for an ageing population. The three elements of this vision were: a more inclusive, 'age-neutral' society where people of all ages are valued for different types of social and economic contributions; full realisation of the potential of the over-50s population to contribute to society; and alignment of the provision of public services and support with need. The scenarios have been used by policy makers to test potential interventions. The project's outputs supported the futures work for the Foresight project "Mental Capital and Wellbeing", and were used in the analytic report published by the departments sponsoring the project.

More generally, the term Horizon Scanning is widely used in the UK health system, with a wide range of organisations engaged in HS activities, especially with respect to the impact, regulatory processes and application of new medicines and technologies. The organisations include, at the national level, UK Medicines Information, the National Horizon Scanning Centre (NHSC),

(continued)

Box 5.8 (continued)

National Prescribing Centre, Scottish Medicines Consortium, All Wales Medicines Strategy Group. Horizon scanning is, however, an integral part of some of the more science-based areas of policy development and is also part of the role of the Department of Health's Scientific Advisory Committees.

The NHSC's definition of HS, which has been adopted by the Department of Health, is well in line with our own understanding of the term (see Fig. 5.2).

In 2007, the Department of Health (DH) set up a specialist Horizon Scanning Unit (HSU) and Network to provide support to embed horizon scanning capabilities in order to improve the robustness of their evidence base and policies, within the Divisions of the DH. The HSU operates an internal DH's intranet as a corporate resource to share scanning information, contacts and methodology. Specifically the HSU is intended to:

- Promote a shared understanding of horizon scanning within the Department
- Improve capability and engagement across the organization, and with stakeholders
- Explore and share good practice with stakeholders in using horizon scanning to inform strategy and policy
- Share relevant findings from horizon scanning in OGDs, Select Committees etc. and Foresight with staff and stakeholders (including SACs)
- Promote the use of a wider spectrum of scientific and industry expertise in horizon scanning
- Work with industry on scenario planning
- Commit funds to act on the outcomes of horizon scanning as appropriate

Horizon scanning via HSU operates across government departments and at different levels of the Department, for example collaboration with the National Horizon Scanning Centre (see below); as part of the NIHR Health Technology Assessment (HTA) Programme ; and participation in ForSTI projects such as brain science, addiction and drugs, tackling obesity, infectious diseases, mental capital and well-being.

The NIHR funds a National Horizon Scanning Centre (NHSC) at the University of Birmingham. This has a relatively short-term focus, dealing with advances in technology and medical practice up to 3 years before launch in the English National Health Service. Data are derived from focused routine scanning of literature and internet resources; from a specialty-based work programme, liaising with the Royal Colleges and other specialty professional organisations to identify gaps in awareness, prioritise technologies in that specialty; and from in-depth scanning of patient pathways, usually at the request of, and in collaboration with, national decision making bodies.

(continued)

Box 5.8 (continued)

Important advances to examine in more depth are selected, and further work then develops briefings on these topics. The NHSC seeks to provide intelligence about such developments, describing the technology and patient group concerned, knowledge on clinical effectiveness, unit costs and alternatives, and the clinical, service and financial impact, as far as possible.

A high level committee (the Futures Group) of the Health and Safety Executive (HSE), a national independent watchdog for work-related health, safety and illness,) oversees its own HS system, and ensures that relevant information and advice is fed into strategic thinking and planning. The HSE set up a "futures team" at its Health & Safety Laboratory (HSL) to gather and analyse information on trends and developments across a wide range of subjects and disciplines. External contractors, including HSL, provide in-depth studies of emerging issues. The team calls on a variety of sources, including the considerable numbers of skilled policy and frontline operational and technical staff in HSE who are able to identify emerging issues and evaluate their likely impact. External input is also obtained through formal and informal networks and the website. In addition to the usual approach of deploying experts (or "expert generalists") to prepare a detailed study of the subjects being scanned, the HSE has also commissioned a scenario study, and engaged stakeholders in discussing these scenarios.

Although the terms used, time scales involved, precise remits and target audiences may differ, essentially similar processes are undertaken across many parts of the health system—only a sample of the whole spectrum of activities has been provided above. Expertise is shared amongst individuals and expert groups undertaking horizon scanning for different organisations.

These, and many other HS activities, use a mixture of consultation and engagement of wider or narrower pools of stakeholders, with more in-depth dedicated analysis from a small team, typically producing reports that can be widely circulated to provide decision-makers with critical intelligence. Consultation and workshops can be valuable in providing stakeholders with richer understanding of the issues and underlying dynamics than is likely to be achieved simply by circulating a report. Furthermore, this is an important opportunity for developing cross-departmental and cross-specialism coordination. Different parts of the policy and practitioner systems can share their understandings and objectives, in dialogue that makes it possible to clarify the meaning of the terminology used, the sources of evidence behind professional opinions, and the like. The horizon scanners, too, can learn more about who knows what, and about the types of information and ways of presenting results that are most effective for sponsors and other stakeholders.

Many of these HS approaches explore just a few years ahead. But workforce planning necessarily takes us into the longer-term, since it can take much longer

(continued)

Box 5.8 (continued)
than this to train professional and medical staff, and they will be in place for much longer still. Though there are frameworks for modelling the longer-term development of supply and demand for the HSC workforce, we have not located a great deal of longer-term systematic HS here. The Centre for Workforce Intelligence (CfWI) is now placing a great deal of emphasis on this theme.

ES and HS activities can be undertaken by using various qualitative and quantitative methods or a combination of them. The most frequently used methods range from reviewing of available sources for Scanning and creative and thought-provoking brainstorming exercises to surveys. Furthermore, more sophisticated applications of trend monitoring based on Big Data, bibliometric and semantic analyses, and network analysis are increasingly used for the purpose of scanning. We describe these methods in the following sections with examples.

5.4 Tools for Environmental and Horizon Scanning

5.4.1 Reviewing

First, the most straightforward way of undertaking Scanning is to review the outputs of other sources, which are engaged in similar efforts. Some sources with wide-ranging interests are listed in Box 5.9.

Box 5.9: A Selection of Sources on Horizon Scanning, Wild Cards, and Related Techniques[5]

- European Commission—Futurium: https://ec.europa.eu/futurium/en
- Shaping Tomorrow: http://www.shapingtomorrow.com/
- Millennium Project—State of the Future: http://www.millennium-project.org/
- The OSI Foresight Programme's Horizon Scanning site, as well as containing a large number of HSC-related topics, presents a guide to HS (https://www.gov.uk/government/publications/futures-toolkit-for-policy-makers-and-analysts). Many of the reports of Foresight are also highly HS-relevant—for example projects that have undertaken detailed analysis of future developments around Drugs, Cognitive Systems, Obesity, Mental Capital (https://www.gov.uk/government/collections/foresight-projects).

(continued)

[5]All webpages were accessed on: 14.01.2016.

Box 5.9 (continued)

- Many other countries have undertaken ForSTI Programmes, and some documentation about European experiences was made available from The EU FORSOCIETY network, which also published a good overview of HS practice (https://www.era-learn.eu/network-information/networks/forsociety).[6]
- There are several journals seeking to bring more rigour and documentation to the field, including *Foresight* (http://www.emeraldinsight.com/loi/fs), *Futures* (http://www.journals.elsevier.com/futures/), *Technological Forecasting and Social Change* (http://www.journals.elsevier.com/technological-forecasting-and-social-change/), *Foresight and STI Governance* (http://foresight-journal.hse.ru/en/).
- There are several organisations of futurists and foresighters, with the UK hosting The Foresight Network (http://shapingtomorrowmain.ning.com/) which brings together many individuals in a social network, and which has several active and relevant discussion groups. Several groups link people working on health, and on HS. The organisation behind this network has produced some extensive documentation on futures methods, including HS: see Chap. 4 of their Practical Foresight Guide (http://www.shapingtomorrow.com/media-centre/pf-ch04.pdf).
- There are (at least) two active global membership groups: the World Futures Society (www.wfs.org), and the World Futures Studies Federation (http://www.wfsf.org/).
- Two Foresight guides that are available online provide documentation on tools and methods, with many links to relevant information and expertise. These are Practical Guide to Regional Foresight in the United Kingdom (http://foresight.jrc.ec.europa.eu/documents/eur20128en.pdf) and The Handbook of Knowledge Society Foresight (http://www.eurofound.europa.eu/sites/default/files/ef_files/pubdocs/2003/50/en/1/ef0350en.pdf). An overview of TF methods and practice around the world has been produced by Georghiou et al. (2008).
- World Economic Forum (WEF)—Global Challenges (http://www.weforum.org/global-challenges). Global Competritiveness and Risks Team of WEF publishes regular Global Risks reports (the latest report is available at: http://www3.weforum.org/docs/Media/TheGlobalRisksReport2016.pdf)
- ARUP—Drivers of Change (http://www.driversofchange.com/)

[6]At the time of writing unpleasant cybersquatters seem to have taken over the Forsociety website, but a report on the experience is available in an academic journal, it is to be hoped that the extensive documentation of (especially UK and Dutch) HS will become available again shortly.

5.4.2 Brainstorming for Scanning

Brainstorming was introduced in Chap. 4 as a technique that is widely used to generate ideas from groups of people. In Scanning, it is done in a workshop setting, often using a STEEPV or similar framework is used for ES. Similarly, a template can be created to identify Trends, Drivers of Change, Weak Signals, Wild Cards and Discontinuities for the purpose of HS. The Scanning activity can be undertaken in a few hours or longer in the availability of time and other resources. As a reference, below we give a list of tasks for a STEEPV activity, which can be accomplished in a couple of hours in a workshop (Box 5.10). The duration and activities can be tailored to suit the contents of the activity and resources available.

Box 5.10: Tasks for STEEPV Brainstorming to Identify Drivers of Change

TASK 1

TASK 1A: STEEPV Brainstorming

Time allocated: ~45 minutes

The **Brainstorming** activity is undertaken as described in Box 4.1. A number of drivers are discussed under each STEEPV categories, which are then discussed in the next task "working with the outputs".

TASK 1B: Working with the Outputs of STEEPV Brainstorming

Time allocated: ~15 minutes

The task now is for each break-out group to work through its suggestions. The aim is to come up with the top three or four MOST IMPORTANT drivers under each of your STEEPV drivers, and to write these down very briefly (a few words per driver) in large and legible text, onto a set of flip charts (one S chart, one T chart, and so on). You may well discover that several of the ideas that have been generated are very similar or closely related, so it may make sense to group them together under a new heading, so form any such groups if they apply to drivers that you think are important. Select your top drivers for each STEEPV area by group discussion: try to reach a consensus; if this is very difficult, then a vote may be in order (for example, concerning which of two drivers should stay on the list and which go).

Your rapporteur should have a set of flip charts, each containing a list of drivers under an individual STEEPV heading, on which they can report to other groups by the end of this task. It is convenient if each set of drivers has a succinct label!

TASK 2

TASK 2A: STEEPV Brainstorming Reporting Back

Time allocated: ~25 minutes

Put the flip charts up on to a wall, or set of stands, so they are clearly visible.

Rapporteurs: Each rapporteur should report back to the plenary group on the set of drivers that they consider most important in influencing their topic area. Try to make a strong case for these being important drivers.

Make brief presentations—5 minutes at the absolute maximum. Discussion at this point should be mainly a matter of clarification and points of information. It is just possible that some items from some groups will be seen as highly relevant to the others.

TASK 2B: STEEPV Voting—Importance

Time allocated: ~15 minutes

Each participant is allocated three post-it notes.

Each participant: The task now is to use these as "votes" to nominate which of the drivers you believe to be most important in shaping the pattern of development of your topic.

You vote by sticking the post-its next to those drivers that you consider most important. You can put all three cards against one topic if you think this is overwhelmingly critical, or distribute them in some other way.

(Please record these votes. This is useful material for later analysis and a final report.)

TASK 2C: Top STEEPV Items

Time allocated: ~5 minutes

This is a job for rapporteurs!

Rapporteurs: The task now is to write the top five or six drivers from each of the two topics down onto flip charts. Choose drivers which have most votes. If there is a tie for the fifth or sixth item, then you can allow two items in. If there is a clear concentration of votes, so that (say) only four items get the vast majority of votes, then you can just use these and need not bother with trying to get up to five or six.

TASK 2D: STEEPV Voting—Uncertainty

Time allocated: ~15 minutes

Each participant is allocated ten post-it notes. You may not use them all!

The task now is to use these as "votes" on the single flip chart representing you groups' most important drivers for in shaping the pattern of development

(continued)

of your topic. But this time we are not voting on importance, instead the task is to indicate how UNCERTAIN you are about the development of each driver and/or its impact on the topic you are examining.

Each participant: You vote by sticking post-its next to drivers that you consider uncertain.

IF you are very confident about what will happen and what its effects are liable to be, then stick NO post-its by the driver.

IF you are slightly uncertain about what will happen and what its effects are liable to be, then stick ONE post-it by the driver.

IF you are moderately uncertain about what will happen and what its effects are liable to be, then stick TWO post-its by the driver.

IF you are moderately uncertain about what will happen and what its effects are liable to be, then stick up to THREE post-its by the driver.

If you have run out of post-its before you have finished, then you will have to choose how to distribute them so as to best capture your feelings about the uncertainties!

It may be that the result of this exercise will be a mass of stickers all over the place, or that there will be a clear concentration of voting in particular places.

Please record these votes—this is useful material for later analysis and a final report.

5.4.3 Surveys

Information for Scanning may be generated by surveying large amount of experts and stakeholders, which has proved to be a useful instrument for collecting ideas as to important topics to be included in ForSTI. A typical survey of this sort is the *Trends and Issues* survey, which was used in the initial stages of the UK TFP in the 1990s. This asked experts to suggest up to four important ideas in each of the topics in the area of interest: trends, driving forces, market opportunities, and technological requirements. The rich information elicited was open-ended and thus difficult to analyse, but provoked many ideas; it formed one source of several later Delphi questions (see Chap. 6).

Various other types of survey are currently used for a range of scanning purposes. For instance, the Millennium Project frequently undertakes real-time Delphi surveys to collect judgements from a wide pool of experts across the globe.[7] This is an electronic and web-based survey and is implemented on real-time basis. Another example is the TechCast survey, which is undertaken for the purpose of pooling collective intelligence of global experts to forecast the most

[7]http://www.millennium-project.org/millennium/RTD-general.html (Last visited on: May 19, 2015).

important technology breakthroughs, social trends, and wild cards for business and government.[8] The Big Picture Survey designed by Saritas and Smith (2011) was completed by many of the participants of the 4th Future-oriented Technology Analysis (FTA) conference. This survey generated a list of novel Trends, Drivers, Wild Cards, Weak Signals and Discontinuities, which were analysed and discussed in innovative ways by using network analysis (Nugroho and Saritas 2009; Saritas and Nugroho 2012). The use of surveys in ForSTI will be elaborated further in Chap. 6 of the book.

5.4.4 Big Data, Bibliometrics and Semantic Analysis

We live in an age of 'information overload'. New (or supposedly new) concepts, inventions, knowledge, technologies and innovations are introduced in an ever increasing number of scientific and non-scientific media. For instance, there are more than 20 million publications in the Medline database and this figure is topped up with 40,000 further publications per month. This is far beyond an individual's capacity to absorb, analyse and use. How to manage such an overload is the key question of "data science", a field that has attracted researchers from fields such as physics, computer science, genomics and economics, and which finds applications in health, science, and transport among other areas.

Big Data Analysis, bibliometrics, scientometrics, text analysis, technology mining, semantic analysis; these are among the terms frequently used to point to various ways of handling large amounts of data and information so as to reduce the effort involved in obtaining useful information. These methods help in detecting key trends and patterns of activity; they may signal developments that are important for thinking about future prospects. Definitions for some of these terms are given below (Box 5.11) to highlight the distinctions and overlaps between them—as a rapidly evolving field, the terminology is still being discussed in the literature extensively.

Box 5.11: Data Analysis Terms Defined

Big Data Analysis	Inventing and investigating new methods and algorithms capable of detecting useful patterns or correlations present in big chunks of data (p. 1).[9]
Bibliometrics	The application of quantitative analysis to measure publications and scientific output. Commonly used interchangeably with Scientometrics[10]

(continued)

[8] http://www.techcastglobal.com/web/guest/whatwedo (Last visited on: May 19, 2015).

[9] http://www.itu.int/dms_pub/itu-t/oth/23/01/T23010000220001PDFE.pdf

[10] http://thomsonreuters.com/products/ip-science/04_030/using-bibliometrics-a-guide-to-evaluating-research-performance-with-citation-data.pdf

Box 5.11 (continued)

Scientometrics	A mathematical and statistical analysis of science, technology and innovation with the aim of understanding scientific citations, mapping scientific fields, generating networks and measuring the impact of authors, articles, journals and institutions and generating indicators for policy and management (Leydesdorff and Milojevic 2015)
Data mining	The computational process of discovering patterns in large data sets involving methods at the intersection of artificial intelligence, machine learning, statistics and database systems[11]
Text mining	A systematic analysis of content in natural language text to determine the objective or meaning of communication
Technology mining	Technology mining refers to text mining of STI information. It makes exploitation of text databases for deriving knowledge about emerging technologies (Porter and Cunningham 2004)
Semantic analysis	The process of relating syntactic structures, from the levels of phrases, clauses, sentences and paragraphs to the level of writing as a whole, to their language-independent meanings. An associated concept "*Latent Semantic Analysis*" is defined as a theory and method for extracting and representing the contextual-usage meaning of words by statistical computations applied to a large corpus of text[12]

Many of the above-mentioned terms are used interchangeably in the literature (particularly bibliometrics and scientometrics). One source of variation across approaches relates whether they are analysing structured data (like Web of Science, Scopus or Patent Databases); semi-structured data (like Twitter, Facebook or other social networking data); or unstructured data (blogs, newspaper articles or any other open-ended data which can be found electronically). Whereas structured data can be analysed by using quantitative analysis and statistics, unstructured data is usually dealt with via semantic analysis and linguistic tools. Text mining is considered to be the application of Data mining to text (Thuraisingham 1999). A few other terms used in the literature include Infometrics, Webometrics, and Web scraping, and others will no doubt arise. Whatever type and source of data are used in ForSTI, the common objective is to generate future-oriented intelligence through exploratory analysis of data for research and investigation.

Figure 5.3 provides an illustration of how different source of data can be used for gaining intelligence on the different phases of technological development and STI evolution. This is an important point. While the analysis of publications can provide information on current research and development work, with potential future technologies, products and services; patent analysis generates information on already available and more near market technologies and applications to emerge

[11] http://en.wikipedia.org/wiki/Data_mining#cite_note-acm-2

[12] http://lsa.colorado.edu/whatis.html

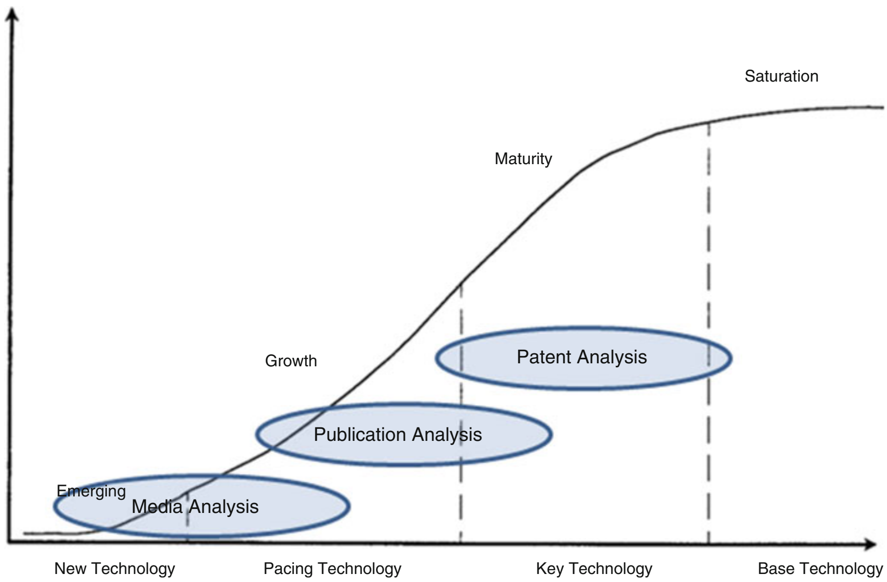


Fig. 5.3 The use of data sources across technology life cycle

in a shorter time horizon. Similarly, information from media, academic and business conferences, blogs, fora, and even data from CCTVs, sensors and satellites can be used to gain intelligence for different purposes and time periods.

For ForSTI activities, the analytical techniques can be used for:

1. Detecting futures
   a. Gathering intelligence on emerging technologies and socio-economic trends, which drive social and economic growth, and address Grand Challenges
   b. Identifying Weak Signals of possible future developments
   c. Early warning of Wild Cards, Shocks and Surprises
2. Responding futures
   a. Top countries, institutions and companies, funding organisations, potential collaborators and key people
   b. With implications on National STI policy and Corporate R&D strategy

Analysing more data in shorter spaces of time may help to reveal unknown information and can lead to better, more strategic and faster decisions. Thus, the analyses will:

- Increase the lead time for stakeholders to plan and address potential disruptions in the STI areas identified
- Provide early indications of potential emerging trends and disruptive technologies in those areas; and

- Enabling policy and strategy makers with tools for prioritising potential opportunities and threats; and allocating resources to increase the ability to capitalise on, protect against or mitigate the impacts of Grand Challenges, Wild Cards and related potential disruptions

Increasing number of applications and software are being launched for advanced data analytics. For instance, the Vantage Point is a text mining tool for discovering knowledge in search results from publication and patent databases.[13] Functions for data cleaning, natural language processing and principal components decomposition help to reduce complexity and locate meaningful patterns and clusters. After generating results though the analysis, it is often useful to generate visualisations for the interpretation and communication of data. Programs like VOSviewer[14] are able to create maps with various clustering algorithms. Network analysis and visualisation software, such as NetDraw[15] can demonstrate the inter-relationships between key terms, authors, institutions and other entities used in the analysis.

Quantitative data analytics methods can be combined with qualitative methods used in ForSTI exercises. Experts are frequently engaged in the scoping phase of the analysis, for instance, for the identification of the terms to be used in the publication and patent analysis; as well in the subsequent stages of the analysis such as for the interpretation of the interim and final results. (The interpretation of data reduction and mapping techniques usually requires expert judgement, since the purely technical algorithms used to choose, for example, the number of dimensions to be considered, have no understanding of the meaningfulness of the results.)

It should be remembered that the data analytics for the purpose of horizon scanning is usually carried out in the early stages of ForSTI exercises to provide input for the intelligence phase of activity. Therefore, the tools and approaches presented above can be combined with the other quantitative and qualitative methods throughout the study. Saritas and Burmaoglu (2016) present a ForSTI process where a patent-based bibliometric analysis is combined with other methods like scenarios, roadmaps and strategies in research looking in the future energy generation, transfer and storage technologies for the defence sector. Box 5.12 gives an example of how publication data can help us to understand trends in the use of ForSTI methods.

[13]https://www.thevantagepoint.com/

[14]http://www.vosviewer.com/

[15]https://sites.google.com/site/netdrawsoftware/home

Box 5.12: Identification of the Trends in the Use of ForSTI Methods Through a Scientometric Analysis

Saritas and Burmaoglu (2015) reviewed the evolution of the use of ForSTI methods through a scientometric analysis in the Web of Science (WoS) database. The use of "Foresight" as a search term in WoS generated 2659 publications from 1991 to present. The analysis revealed 4424 keywords/phrases initially. Following several rounds of data cleaning and fuzzy clustering through the use of the Vantage Point software, 68 ForSTI methods were identified in total. Figure 5.4 illustrates the occurrence of methods in publications across time, and thus shows the trends in the use of ForSTI methods and their integration.

As the figure illustrates, the number of ForSTI methods has increased dramatically in recent years. In the early 1990s, only a few ForSTI methods were referred in research and publications. However, the number of methods has increased to reach over 30. The variety of quantitative and qualitative methods used at present is noteworthy. The analysis reveals that key ForSTI methods—including scenarios, Delphi, forecasting and roadmapping—remain the key methods; while new methods are increasingly integrated with them such as bibliometric analysis, system dynamics, and network analysis. Various visualisations and other analyses are presented by Saritas and Burmaoglu (2015).

The approach described above to analyse the trends in the use of ForSTI methods can be applied, using different sources of data, to the analysis of socio-economic and technology trends in broader contexts.

Saritas and Burmaoglu (2016) outline a research methodology, which presents a way of integrating bibliometric analysis of patents with scenarios and strategic roadmaps with the case on the energy requirement of future military operations.

Tools such as bibliometric analysis can also be used at the evaluation (Impact) phase of the ForSTI process, for instance, to understand the impact generated by the Foresight exercise in various publications and other media across time.

5.4.5 Network Analysis

Network Analysis has attracted an increasing attention in recent years, largely because of its ability to reveal relationships and links that make up various social processes (Carrington et al. 2005). Within STI studies, this method has been proved useful to understand clusters of actors (e.g. Allen et al. 2007; Lee and Song 2007) and hot topics (Nugroho and Saritas 2009), collaboration practices (for instance Levy and Muller 2007; Roth et al. 2008; Tuire and Erno 2001) and diffusion across networks (among others, Cowan and Jonard 2001; Hussler and Ronde 2007). Network Analysis focuses on relations among a set of phenomena (e.g. actors and

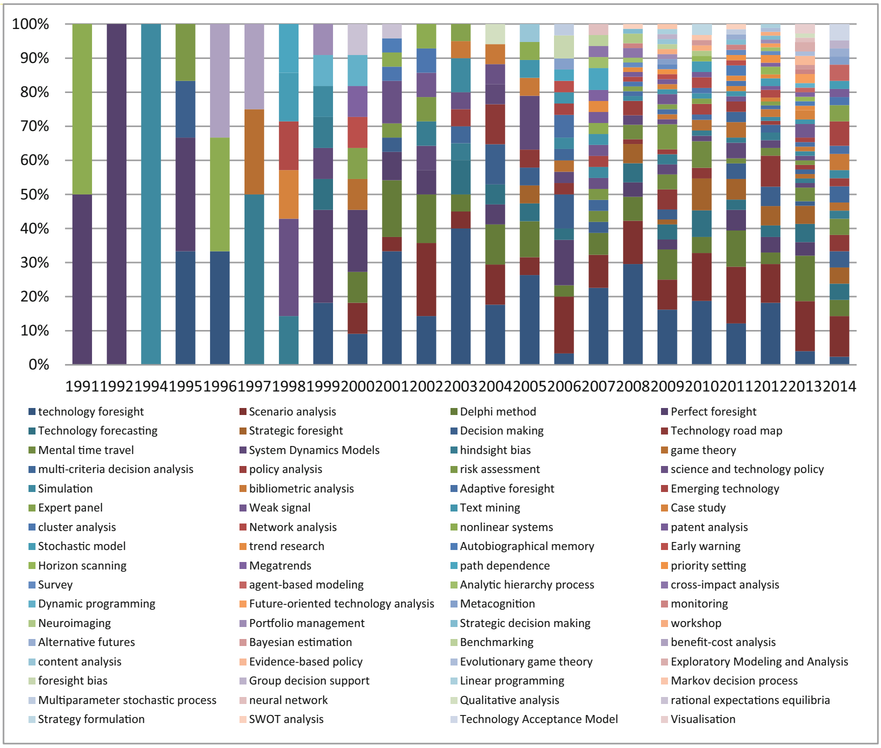


Fig. 5.4 Trends in the use of ForSTI methods

events where the number of connections can be assessed from various data sources—such as co-occurrence in newspaper stories, authorship of patents or publications, and so on).

Network Analysis includes techniques for data collection, statistical analysis, and visualisation, among others, that can be applied simultaneously to both the whole system of relations and parts of the system. The ability to capture the structure of the whole, or parts, of interacting system might be what makes Network Analysis particularly interesting for researchers working on organisations or systems approach (Kilduff and Tsai 2003), which makes it attractive to apply Network Analysis with ForSTI as a systemic activity (Saritas 2006).

Nugroho and Saritas (2009) propose two ways of incorporating network analysis in ForSTI:

- First, through the inclusion of network analysis into the formal methods of ForSTI
- Second, by conceptual incorporation of network perspective in ForSTI's phases

The first way to incorporate Network Analysis in ForSTI is via a straightforward use of it as a methodological tool for the purpose of analysing ForSTI data. In the ForSTI exercises data can be of any form: experts' opinion, statistics, survey responses, among many others, which are processed using certain methods. The contributions of Network Analysis in ForSTI can go beyond the ES and HS in the Intelligence phase, to cover the entire process of ForSTI:

- In the Initiation phase, Network Analysis could help to draw the boundaries of the exercise and to decide what topics/issues are crucial and how different topics/issues relate to each other.
- In the Interaction phase, Network Analysis could be used to map key actors. Further it can also help analyse the actors' positions in the network and map the importance of their affiliations relative to others. If the data is collected over time (panel/longitudinal), network dynamics analysis will be able to identify the shifting role of the actors.
- In the Intelligence phase, Network Analysis can be used to illustrate the systemic relationships between the outputs of ES (i.e. STEEPV factors) and HS (Trends, Drivers, Weak Signals, Wild Cards and Discontinuities). For instance, Fig. 5.5 illustrates the links between the trends identified by Saritas and Smith (2011) through the Big Picture Survey (Nugroho and Saritas 2009). The links based on the co-occurrence data in the figure clearly illustrates, for instance, the links

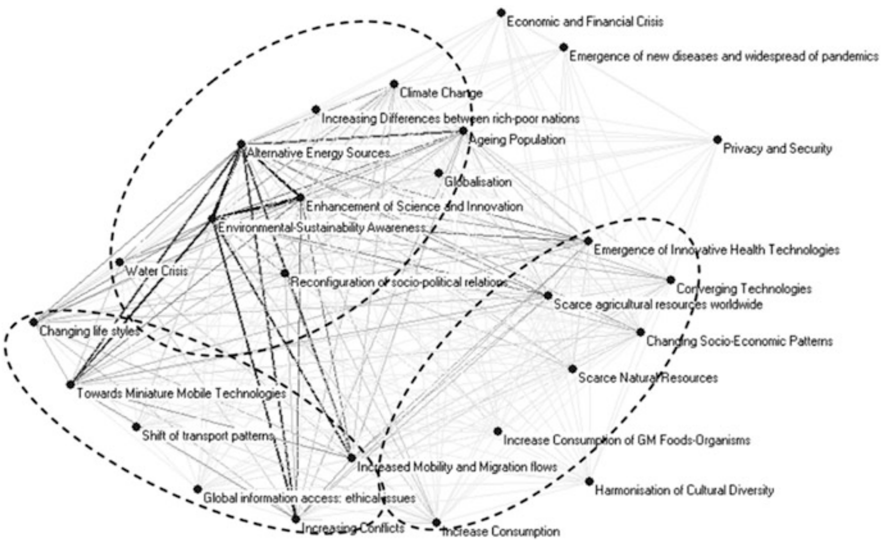


Fig. 5.5 Network of trends. *Source*: Nugroho and Saritas (2009)

between three trends: Environmental and Sustainability Awareness, Alternative Energy Sources and Enhancement of Science and Innovation.

- In the Imagination phase, which focuses on the development of alternative scenarios and models of the future, Saritas and Nugroho (2012) present the "Evolutionary Scenario" approach by analysing a series of networks based on HS data in different time horizons (i.e. every 5–10 years starting from the present into next 20 years and beyond). Thus they are able to explain the process of evolution from the present state into the future.
- In the Integration phase, network analysis can illustrate the central, broker and peripheral factors (for instance, based on network centrality measures), actors, organisations and institutions, and can help to determine the priorities and critical success factors, which might help for appraisals and vision building.
- In the Interpretation phase, network analysis can be used to build understanding of the structure upon which the ForSTI exercise is based. Further, as already elaborated earlier in this section, Network Analysis can help model, analyse and select important actors (and further, issues) and inform the transformation agenda.
- In the Intervention phase, network perspective can contribute to set up more effective collaboration and interdisciplinary actions.
- Finally, in the Impact phase, network analysis could be used in the evaluation of the whole process of ForSTI, particularly by examining the networks of actors and activities, and their relationships.

5.5 Conclusions

- Different data and information sources may be telling us about quite different things, all of which we should be attending to at first (even if some are later discounted from the further analysis). We can think of a life-cycle of ideas about what is on the horizon:
  - At first there may only be very "Weak Signals" as discussion about a possible driver or outcome of change is restricted to a few radical thinkers—they may be visionary scientists and engineers, artists and Science Fiction authors, avant-garde figures in social movements, etc. Some of these ideas may prove ill-founded or too far over any planning horizon (the events considered may be too far off, as would be the case, perhaps, of large-scale space colonisation or "downloading" human consciousness into information technology systems; or they may simply be so disruptive and uncontrollable with present knowledge that they will render our planning irrelevant, as would be the case with some major natural disasters or political catastrophes—such as a supervolcano or large-scale nuclear conflict). But many important developments have begun life as such apparently wild ideas.
  - Gradually, some of these ideas will be picked up and disseminated more widely. They may be manifest in ForSTI studies, in newspapers and popular media, and the like. They are deployed by management gurus and other

public figures who want to stay ahead of the game and cultivate an image of being forward-looking. Often at this stage there is a proliferation of new terminology to describe the phenomena, and there is increasing articulation of views about its meaning and implications. Striking examples or harbingers of the phenomenon bring it to public attention.
– Finally, the issue becomes the standard fare of policy reports and official documents. A few ways of describing and conceptualising the issue have been forged into a mainstream narrative of what the drivers of change are. The issue has become a matter of common sense and received wisdom, and people have quite possibly forgotten that it was once a wild idea.

It will be important to avoid restricting Scanning just to the issues that are already the topic of much discussion and debate. When we are using a longer-term time horizon, then some things that currently seem quite outrageous may well become everyday phenomena.

There are no panaceas for solving problems in complex policy environments. Scanning is only one input into the process of informing policy; like other inputs, it is subject to human fallibility and the very partial knowledge we have about many STI developments. This is particularly likely to be the case if Scanning is not being carried out in a systematic way; if there has not been enough effort to provide those responsible for Scanning with adequate skills, time and other resources, access to data and key informants, and so on. The Scanning function needs to be effectively scoped and related to other elements of the planning process, not to be taken as a stand-alone activity. This will help assist the Scanning team in asking the right questions and providing answers that can be used effectively.

Scanning is only as good as our ability to detect important signals, trends, and drivers. It may be worth applying different worldviews to the topic of concern, and thinking about what sort of factors might be seen as major influences by, for example, a believer in “tech-fixes”, a techno-sceptic, an environmentalist, feminist, radical socialist, libertarian, and so on. What would be stressed from different scholarly disciplines or practitioner professions?

In addition to weaknesses in the Scanning activity itself, there can be problems in the way it is used in the planning process (We will not venture to discuss ways in which the planning process itself may fail to be properly implemented or used). It will be important to present the results of Scanning in ways that are meaningful and cogent to the intended audience, and if possible, to involve key decision makers in the HS activity that they can provide intelligence as to how to do this—and gain intelligence about the significance and scope of the Scanning itself.

Scanning exercises often feed into scenario development and analysis. One very good reason for this is that often the drivers and factors identified in HS activities are the ones, which are highly uncertain. We do not know whether a certain development will or will not occur in our timeframe (e.g. will medical treatments that effectively prevent the further progress of Alzheimer’s Disease be developed?); we may not know how far it happens or what stage of development it may have attained (will these treatments be in wide use, what is their cost?); we may be uncertain of their implications or effects (will there be a requirement for substantial retraining of patients who have not exercised cognitive skills for a period of time, will the treatment require new skills among staff?); we may be uncertain about interactions with other drivers (will the treatment be working in a context where other age-related conditions are also being tackled effectively, or not?).

Given the many uncertainties we confront, it is inappropriate to make a single forecast—we have no real basis for estimating a most likely future, and we can be fairly sure that Business as Usual will not prevail. Scenarios are used as one way of confronting such uncertainties.

Overall, Scanning is one of the most frequently used methods in ForSTI. HS of various sorts is typically used alongside scenario building, trend analysis, Delphi and other expert consultations. HS is often a preliminary step in a ForSTI exercise and mainly used in the Intelligence stage of the activity in an effort to see what are the major forces liable to shape the topic of concern, before launching more detailed studies of specific themes.

Intelligence: Delphi

6

6.1 Introduction

Delphi approaches are often seen as the main tool in ForSTI studies. Though many major exercises have been mounted without any use of these at all, the variety of forms and applications means that they can then prove valuable. Given their prominence, and their particular features, a chapter devoted to Delphi approaches makes sense in this book. Another reason is that there are many misunderstandings about why and how to conduct Delphis.

Delphi methods involve surveys, usually online or postal surveys; and in principle these are surveys of expert knowledge, judgements, or opinion. Often the topics are ones where there is considerable uncertainty about the current or future situation, and many participants in the survey are asked to express their views—opinions—about how likely or feasible various developments are, what factors might affect these, and/or what outcomes might be expected. Delphis take various forms, as we shall see, but the tool is largely used so as to be able to engage a large number of people in the discourse, without necessarily bringing them together in one place for a conventional discussion, and usually keeping the authorship of particular views anonymous (to limit the influence of powerful people). Surveys that elicit opinions are of course used in many settings—there are huge industries devoted to opinion surveying, and it is not uncommon to find expectations of short-term, and more rarely long-term, developments covered as topics in their work. These are practically never Delphi studies, though they may provide insight into trends in public opinion, fears and expectations that can be relevant information for ForSTI exercises. In the futures and ForSTI fields, not all studies described as Delphis actually do follow the Delphi approach as opposed to more conventional surveying.

A great deal of use has been made of Delphis, but most of the reported studies are describing results, with relatively few discussions of methodological choice and issues arising. Remarkably, the most detailed discussion of the approach remains that of Linstone and Turoff (1975; now available online). When Scapolo and Miles

I. Miles et al., *Foresight for Science, Technology and Innovation*, Science, Technology and Innovation Studies, DOI 10.1007/978-3-319-32574-3_6

(2006) set out to compare a best-practice Delphi with a best-practice cross-impact analysis of the same topic, they found many detailed methodological decisions remaining obscure.

What does makes Delphi unusual compared to other surveys is that it is designed to be reiterated, feeding information back to its respondents, in contrast to most polls of opinion. In a classic type of Delphi, after a first "round" of questioning, it is returned with feedback to the original respondents, who are then able to revise their answers in the light of this information about the distribution of responses in the first round. The process may be further reiterated, with second and even third round results being fed back to respondents. The respondents in later rounds are not only asked to answer the same set of questions again, but also receive feedback on the structure of responses at previous rounds. They should be able to look at the pattern of results—how many people replied in each possible way to a given question. Ideally, they should additionally receive information on *why* judgements, and especially extreme judgements, were made.

The purpose, then, of providing this feedback, and offering the chance for respondents to modify their judgements in its light, is to promote exchange of views and information—and in the case of Delphi forecasting, to allow people to see how far their forecasts and expectations correspond to those of a wider pool of respondents. The anonymity of the survey is, furthermore, intended to reduce the dominance of discussions and the exercise of influence by the loudest or most senior figures.

The Delphi approach is argued to have the following virtues:

- The Delphi is generally an anonymous survey: the idea is that people's expression of their views should be freer of the influence of loud voices and reluctance to disagree with authority than a conventional face-to-face meeting is liable to be. (We may ask respondents about their level of expertise concerning the topic, and it is possible to provide data contrasting people who feel they possess more expertise, with the average.)
- Experts are liable to make better-informed judgements when they can compare their own views with those of others: the most common form of feedback consists of information on the distribution of answers to each of a set of questions, with participants having the opportunity to revise their responses in the light of this information.
- The distribution of replies should provide all respondents with insight into whether there is largely consensus or sharp disagreement; in many classic Delphi studies the reasons for divergent judgements are sought, so that participants can have access to special information that only a few possess, especially when these underpin judgements that diverge from the average. (Unfortunately, the effort of collecting and circulating open-ended data like this often means that this step is often curtailed, or even missed completely.) Often Delphi users focus on consensus or at least the majority or average view among respondents. At least three points should be borne in mind in this context:

  - Even though there may be less exercise of influence in a Delphi survey than in a face-to-face meeting, people may still be subject to conformity pressures at work, shifting their judgements towards an average view for no other reason than its being a "popular" one.
  - While some convergence of views is commonly found, those topics where this does not happen are worth attention. They may be pointing to divergent views about current processes and future trends, the presence of different implicit scenarios among respondents, or contrasting social or political perspectives. Delphis that are oriented towards forecasts normally asks for peoples' best guesses about what will happen. In principle it would be possible to ask respondents to reflect on alternative scenarios, though these would have to be spelled out explicitly to ensure that people are considering at least roughly the same set of alternatives.
  - Delphi results can be analysed so as to cluster viewpoints and differentiate among perspectives. While such approaches have been developed, and sometimes used to help construct the alterative scenarios they may be pointing to, consensus-oriented approaches are by far more common.
- A Delphi survey typically allows for much greater outreach than a conventional meeting, allowing for inputs from a huge range of experts. With the use of the Internet, reach can be effectively global, though often we will require a much more localised group.
- Well-formulated Delphi statements allow for more precise comparison of views and assessment of their relevance for forecasts than do the vaguer, more qualitative statements that typically emerge from open-ended discussion and workshops. Achieving statements of sufficient quality can be time-consuming, and ideally requires substantial piloting.

Delphis have traditionally been conducted through postal surveys. They can also be used within group meetings, and recently there have been examples of workshop participants completing their questionnaires online (and thus being able to see the shape of opinion in the group almost immediately). Currently most, if not all, Delphis are undertaken on the Internet, which allow in principle for a faster turnaround of material among geographically dispersed groups and provide very rapid, or real-time, feedback as to the views of the whole group. Although online tools makes this a great deal easier than it used to be, the task of designing and implementing Delphis and assessment of results should not be underestimated—again, Linstone and Turoff (1975) remains as a major reference for the Delphi method.

Not all Delphis involve the succession of "rounds" that was typical of early studies. The Real Time Delphi introduced by Gordon (2008) takes advantage of online systems and rapid computerised data processing, to provide a "roundless" approach to the Delphi. In this case, advanced analytics including Natural Language Processing are used; the respondents fill out an online questionnaire, and both quantitative and qualitative results are updated as responses are recorded immediately. Respondents can revisit the questionnaire as many times as they wish. Each

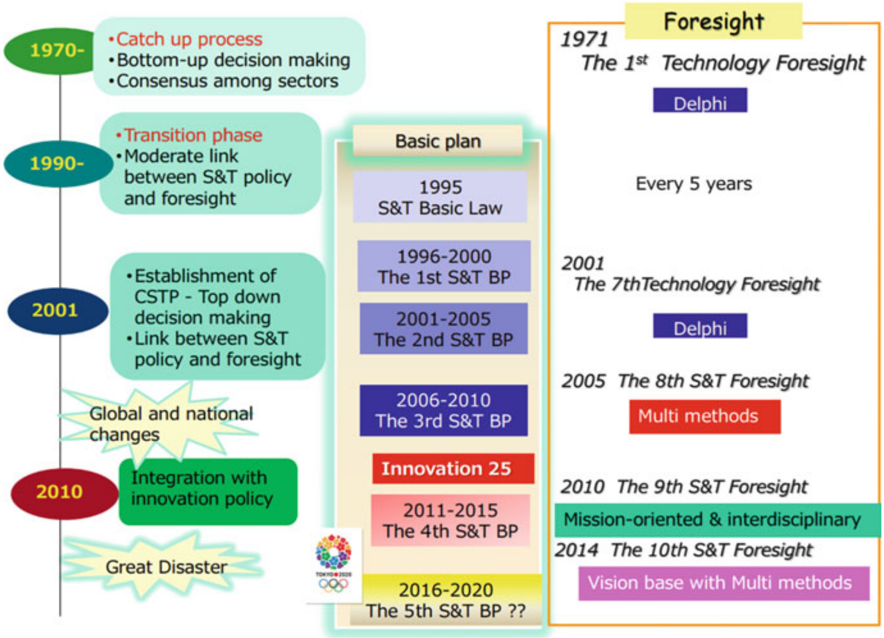


Fig. 6.1 Japanese Foresight chronology and methods used. *Source:* Urashima (2015)

time, their own responses are shown as well as the updated answers of the others, and they can revise and change their own inputs based on this feedback. It is also possible to see qualitative feedback and justifications provided by the respondents and input additional comments. We can anticipate much more development of approaches to Delphi that make use of modern computer-communications systems in ways such as these.

Japan is one of the countries, which used Delphi surveys continuously from the beginning of the 1970s (Fig. 6.1). While Delphi was the sole method applied until the beginning of the 2000s, recent years have seen a move towards a multi-method approach with the integration of Delphi with other ForSTI methods such as scenario planning in the 9th and 10th iterations.

In the following sections, we will present the Delphi method with examples from the Japanese Delphi surveys.

6.2 Applications of the Delphi Method

The most common application of Delphi has been to investigate **when** particular developments might happen. The survey requests judgements about the most likely time period in which a particular development might occur (e.g., at which of a set of 5-year periods is it most likely that more than a quarter of the workforce will be engaging in one or other form of teleworking). An alternative, used less often but more useful for some purposes, is to enquire about **how far** a development might have occurred by a particular point in time (e.g. what proportion of the population might be living in single person households by the year 2030).[1] Often, alongside these forecasting questions, there will be other survey questions about possible drivers, constraints and facilitating factors, or about the economic or social implications, of particular trends. Alternative ways of organising Delphi surveys with questions and topic statements will be presented in the subsequent sections.

Delphi methods can be applied to eliciting and interrogating judgements about practically any issue. For instance, opinions may be sought as to the extent to which various innovations (social as well as technological) might contribute to helping solve (or potentially exacerbate) each of a number of a social, economic or environmental problems. Opinions may be sought as to what priority should be given to different objectives of these sorts, or policy measures aimed at addressing them. Such policy and goals Delphis have been applied in many studies, though they are outnumbered by studies that elicit expectations about when specific developments are most likely to materialise.

6.3 Resources Needed for Delphi

A Delphi survey can be one of the most resource-intensive ForSTI methods, though online methods have reduced at least some postal and time costs. Nevertheless, it is essential when planning for a Delphi to establish whether there is enough expertise, money, time and managerial capacity available to achieve what is intended.

For example, consider the experts to be surveyed in the study. If an already existing database of key peoples' email addresses is available, time may be saved, though it may be important to ensure that this set of people does not omit informants who may be particularly relevant to the study. Turning to the statements to be used in the Delphi, these may be based on statements in the literature, or in earlier Delphi studies. If so, compilation of a set of statements may be achieved relatively rapidly. But this runs the risk of dealing with statements that are too generic for local circumstances, or that fail to take recent developments into account. It will take considerable more resources if the list of relevant respondents, or the Delphi statements themselves, are produced through workshops involving engaged panellists, or by a specialised survey designed to collect potential statements from a wider pool of people. Consultant teams or the main ForSTI experts often play a major role, either in originating, searching for, or fine-tuning statements, which are typically discussed in panel meetings.

Widespread use of the Internet has enabled the distribution of surveys and of the interim and final results to be accomplished much more rapidly and cheaply then when printing questionnaires, leaflets and reports, by conventional means—these

[1]Two examples are: Loveridge and Miles 2004 and Popper and Miles (2005).

can be a major cost item. Typically there are additional expenses for follow-up events such as conferences, and newsletters and other publications. Delphis can now be run more cheaply, but still require expertise, creativity and intellectual input.

Appropriate resources like IT skills, a communications team, necessary time and budget should be in place before embarking upon a Delphi survey. Especially in the case of electronic surveys, the system should be up and running continuously, with failures addressed immediately. Respondents should be able to receive feedback for their queries at the earliest time possible.

6.4 Delphi Process

The process of a Delphi exercise can be seen in terms of five steps:

1. Preparatory work for Delphi
2. Formulation of topic statements
3. Development of questions and assessment criteria
4. Survey implementation
5. Analysis and dissemination of results

6.4.1 Preparatory Work

In many ForSTI exercises, Delphi is in combination with other methods (such as Horizon Scanning, Scenario Planning and Roadmapping). Often a small expert panel will generate Delphi topics on the basis of their horizon scanning (literature reviews and the like). Therefore, the process usually requires workshops, where experts come and work together offline or online. This means several meetings should be dedicated for the preparatory phase and sometimes for the analysis of results. During the first meeting, the purpose of the Delphi method and where it fits in the overall process should be explained to the panel members clearly. The structure of the method and forthcoming preparation and organisation phases will need to be explicated; at this point it can be helpful to introduce examples from Delphis conducted successfully elsewhere (for instance, the Delphi survey from the first round of the UK Technology Foresight Programme has been used widely for inspiration in other countries, but German and Japanese Delphis also make good examples).

Designing a user-friendly survey layout is a major task. Respondents should be able to navigate through the survey easily without confusion about which task to address, and when. The forms used in earlier studies, and online templates, can be drawn upon to assist in this aspect of design. (This also applies to different ways of presenting feedback from earlier rounds of the survey.)

The Delphi topic statements and the questions asked about them are usually designed by the panels. If there are several surveys to be run in parallel, such as in large national ForSTI exercises, where there is more than one topic/theme/sector, the project team organising the ForSTI exercise should be able to coordinate the parallel processes.

Besides coordinating the survey, the project team may also be responsible for checking the ambiguity of Delphi statements and fine-tuning them if necessary. During the discussions on the statements, the process will produce numerous open-ended input of material, which may also be fed back so as to enlighten respondents about reasons for specific responses, other categories of response that might be included, and so on (In practice most project managers are limited in the qualitative feedback they provide on the Delphi, due to the labour and time this can involve).

6.4.2 Formulation of Topic Statements

Delphi involves a survey of expert opinion about a topic, and thus it is vital to select statements dealing with key aspects of the topics being considered; and to formulate these in concise and comprehensible ways. The selection and formulation of statements is challenging, but at the same time can be extremely valuable in enabling ForSTI teams and participants to determine the most important aspects of the exercise's focal object.

Various guidelines can be suggested for preparing topic statements. The topics for the Delphi need to be stated in terms that:

- **Are unambiguous.** A single question, asking for a judgement on a single issue, is the ideal; combining several issues may create confusion, may lead different respondents to answer different questions; it may also run the risk of generating the impression that these issues are (or are assumed to be) necessarily related in particular ways.
- **Are succinct,** using as few words as possible. One rule of thumb is to summarise the specific topic in 30 words or less.
- **Are fairly precise.** Many Delphis, that ask for forecasts of when or how far things may evolve, avoid precise formulations—instead of terms like "more", "a large extent" and the like, and instead ask about percentages or other ranges of numbers, for example. Where there is a likelihood that events will follow a sequence, we may be precise about the stage reached in the sequence. For example, technological innovations may be discussed in terms of their being in laboratory demonstration, released into commercial use, finding mass markets, etc.
- **Avoid overtly evaluative language.** Even a statement which labels something a "crisis" or "problem" may imply a diagnosis of the situation which some respondents will not share.
- **Minimise arcane technological language** and especially unnecessary jargon. Jargon is liable to deter respondents who may not need to know this terminology in order to reach an informed opinion. Jargon often varies across disciplines and

professions, in fact; and there may be a danger of foreclosing discussion of options that are excluded by a particular formulation.

- **Be cautious about foreclosing possibilities.** Often, we may be mistaken in assuming the dominance of one or other of a number of options as providing the solution to a challenge—fibre optics as opposed to wireless broadband communications, fuel cells versus batteries for less polluting vehicles, etc. It may be unwise to assume that a particular technological solution is likely to be adopted as the main way of addressing a problem. To take another example, the shift away from fossil fuels might involve various sorts of solar power, onshore and offshore wind, wave and tidal sources, geothermal, nuclear fission or fusion, and more. Instead of asking when or how far one specific solution might be adopted, it could be better to elicit expectations of when or how far the goal might be achieved, and use other questions to explore the development of specific potential solutions. If the competition between possible solutions is specifically the object of enquiry, it may be of interest to know how far respondents favour one or other option. While it may be wearying, and using up valuable survey resources, to ask for detailed estimates about the timing or take-up of each of a number of competing solutions, it might make sense to ask about factors that would affect this, such as expected performance improvements in alternative technologies. It may also be useful to consider whether there is any cause-effect relationship between the questions, so that the respondents can give more accurate logical answers when they make their assessments, for instance, when determining times of realization for certain technologies, which can be prerequisite for other technologies or products to emerge in the longer term future (examples of this can be seen in Saritas and Oner 2004).
- **Be realistic.** Statements that involve overly idealistic or implausibly rapid rates of development may lead to respondents feeling that the survey is not really to be taken seriously. The aim is to formulate future possibilities in ways that give respondents credible options. For example, a statement asking about when all of the population will be completely vegetarian—or indeed be adopting practically any practice!—is likely to evoke many “never” responses.

If topic statements fail to meet such standards, respondents are liable to rapidly be alienated, and dropout rates may be high; persuading them to fill in successive questionnaires may be even more troublesome than it already is. Additionally, problems with the statements may mean that responses are unintelligible, either because respondents are not taking the task seriously, or because they are interpreting the topics in different ways. One way of testing the adequacy of topic statements is to pilot test the survey prior to the full launch. There are usually minor adjustments to be made, commonly related to ambiguities that are discovered in the formulation of the Delphi statements.

The number of statements that are used affects the length of the survey, of course. Respondents should be able to complete it before getting exhausted, and it may be helpful to make it clear that the survey is not an endless one–for example by information as to how far they have completed it. In some cases, they may be asked

Table 6.1 Examples of statements from the earlier Japanese Delphi surveys

Statements	Survey year	Average forecasted year of realisation
Direct access to overseas data banks for giving and receiving data	1971	1987
Establishment of worldwide real-time reservation system for transportation or accommodation in big cities or major sightseeing areas	1971	1980
Establishment of international data-communications network covering almost all the areas in the world communications network covering almost all the areas in the world, enabling automatic connection from domestic network to overseas ones	1982	1994
Practical use of automatic protocol conversion technology, enabling easy interconnection of various communications networks	1987	1996
Widespread use of online rental service or exchange system for recycling used items	1987	1995
Widespread use of communication systems for retrieval of still or motion video information from electronic libraries (containing character data, books, still videos, movies, TV, documentary films, etc.) through broadband lines	1992	2005
Widespread use of computer networks in which a virtual space can be shared in real time by a large number of unspecified, geographically dispersed persons	1992	2005
Generalized technology, extended from total building management systems and home security Information security systems, which is coupled with seismic detection systems so that the safety of human life can be ensured before seismic waves arrive, in an earthquake whose epicenter is distant.	2005	2016
Forecasts of diseases and disasters through advanced modeling and simulation technologies for large-scale ecological, environmental, or other systems.	2005	2019

Source: Okuwada (2010a, b)

only to make the effort of answering those questions where they feel themselves to have sufficient expertise. Some practitioners consider it useful to vary the order of the Delphi statements presented to different respondents—then, if people give up answering before completing the whole survey, we should still have a more balanced response throughout the survey.

Experience and creativity are both required in order to formulate topics. Table 6.1 presents several examples from the Delphi surveys conducted in Japan starting from the early 1970s.

Current technological developments will quite possibly lead to shifting from purely text-based statements, supplementing these with, for example, video or cartoon images (or other forms of media depiction of future states of development), in Delphi surveys.

6.4.3 Formulation of Questions to Be Asked About the Topic Statements

The statements specify the topics around which the expert opinions are being sought. The opinions are elicited by asking questions about these topics. Typically there are four types of question that Delphis ask:

1. The respondents' knowledge about the topic (for example, 'expert'—who works in the subject area, or 'non-expert'—who worked before, or is interested in the subject area)
2. Assessment criteria (for example, the time at which the statement should be realised; the extent to which the statement will have occurred by a specific time; the probability of the statement happening, etc.)
3. Evaluative criteria (for example, the impacts that the statement would have if realised on, for example, Wealth Creation, Quality of Life, Employment, Sustainable Development; the contribution made towards achieving various goals, etc.)
4. Contextual criteria (such as things that might render realisation more or less likely, for instance factors that might facilitate or inhibit development—e.g. ethical, technical, financial constraints, requirements for collaboration between various actors, national strengths in related fields of science and industry, etc.)

The questions that are asked will depend upon the type of Delphi to be used, and a later section of this chapter will consider some of the major varieties of Delphi surveys used in ForSTI. Figure 6.2 shows the structure of the 9th Japanese Delphi survey with questions and example topic statements.

The arrangement of the Delphi survey with statements and criteria may depend on the means of implementation (i.e. paper based or online) and the type of the survey used. In a conventional paper-based Delphi survey the statements and prioritisation/assessment criteria are brought together in a matrix and respondents are asked to fill out the matrix type of survey. In an online survey each statement can be assessed in a single webpage. In any case, it is useful to have space for open questions and comments by the respondents, where they are given an opportunity to raise new issues, to suggest additional topics, or to provide alternatives to the statements given. Before fully launching the survey, it is always a good idea to pilot test the survey and make necessary adjustments in statements, questions or electronic interfaces as required.

Finally, a rather obvious point, the formulation of both topic statements and the Delphi questions may need to take into account the different languages with which respondents are familiar. Many countries feature more than one national language, and cross-national surveys are quite likely to extend across a number of primary languages. Experience shows that great care has to be taken as to the accuracy of translations if it is not possible to base the survey on a single language.

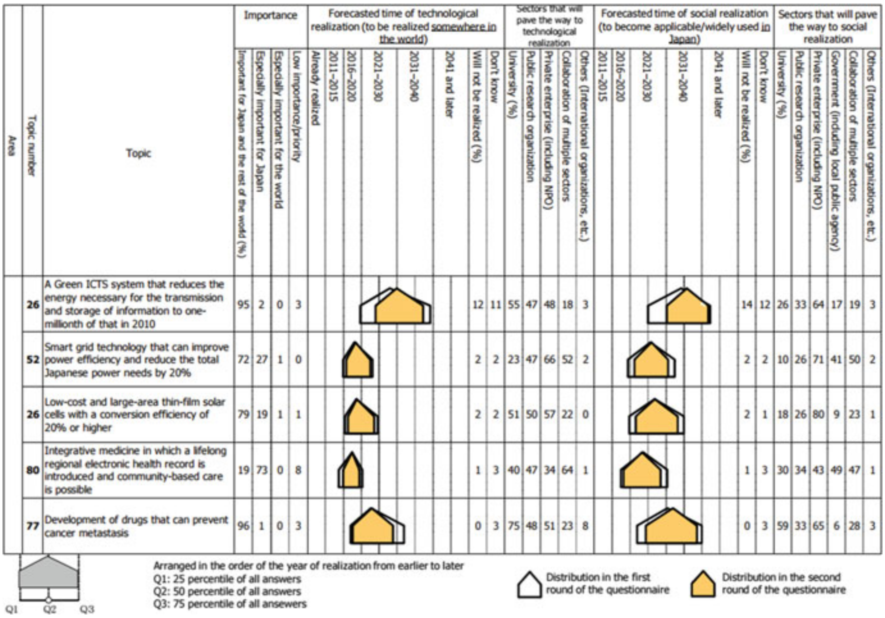


Fig. 6.2 Structure of the 9th Japanese Delphi survey (The 10th survey was completed in 2015, but the results have not been published in English yet.). *Source:* NISTEP (2010)

6.4.4 Survey Implementation

The process of designing the survey can be valuable in its own right; the interchange and learning involved here can yield "process benefits". It has been known for the panels constructing the Delphi survey to feel that they can fairly accurately guess what the main results of the survey are likely to be, they have been so immersed in the topics. Of course, these results are achieved only when respondents provide answers to the questions. It is necessary to locate and recruit relevant people to whom to send the Delphi and, hopefully, enlist cooperation from them. We have discussed issues concerning participation in ForSTI in general in Chap. 4. Delphi surveys are particularly dependent on mobilising **relevant expertise**. Visually impressive quantitative results, displayed in the most striking charts and graphs, are worth next to nothing if the opinions and information used lack sufficient input from very well-informed people.

It is necessary to define who the experts are that should be sampled—and, especially when they are fairly few in number, to motivate enough of them to participate in the survey. Often this is best accomplished by personal contact from sources who are themselves knowledgeable. Locating the appropriate experts may involve 'snowballing' a list, for instance by contacting a few known authorities and relevant scientific and professional associations and communities, and asking for their recommendations concerning whom to contact.

The first question that many people have about Delphis, is how many respondents do they need to have for the results to be credible? In principle, one respondent would be sufficient- if we could be sure that this person really knew what s/he was talking about! Most often, there will need to be a substantial number of knowledgeable respondents for the survey to be regarded as yielding credible results by its users. However, a Delphi survey is not a public opinion survey: we are not trying to estimate the distribution of views across a huge population (in which case we might require upwards of a thousand respondents!). The aim is to get a good sampling of informed opinion, and if we can manage to get a few dozen experts responding to each question, that will usually be deemed sufficient.

The attitude towards surveys can vary from country to country, and according to how the survey is delivered. In some places, and especially with email-based surveys, response rates can be extremely low—around 1 to 3 % of all the potential respondents. Response rates may be boosted to 60–70 % or above, for example when surveys are conducted more labour-intensive methods, such as face-to-face or telephone interviewing. (Sometimes people are happier to complete an online questionnaire when they can talk through their answers with somebody—and they may be less prone to be distracted halfway through.) Occasionally, the survey is administered in a workshop of some form; pencil and paper or by online methods (in which case, rapid feedback may permit a second round to be undertaken on the spot, if not there can at least be some discussion of the results). In any case, the list of respondents to be invited for the Delphi survey should be long enough to reach desired levels of responses. One issue that arises with email and online surveys is that participants (or other people) may send on the invitation to take part to other people whose views they consider relevant. This can boost respondent numbers, but means that we do not necessarily know how many people have been invited to take part—and unless we collect the information, we may not know who respondents are (Normally, results are anonymised, so that no information is shared as to whom has provided particular answers: but some way of identifying participants is necessary if responses are to be updated over successive rounds, or if the ForSTI team wants further information from a respondent concerning why they have provided particular inputs).

It is common for the number of respondents to decline across successive iterations of the survey (especially after the second round), unless there are strong incentives to keep respondents on board. Paying honoraria to each respondent might be quite costly. However, incentives like access to the ForSTI exercise's database, invitations to the conferences and other events with broader participation, and acknowledgement of the names of participants (without associating them to specific responses) can be among the incentives given.

Japanese Delphi surveys have traditionally achieved high response rates. For instance, 3992 experts were invited for the 9th Japanese Delphi survey. In the first round, the response rate was 84 %. The second round of the survey had 87 % response rate (of the 84 % participated in the first round), which amounted for 73 % overall response rate and 2900 experts (Shrikawa 2011). Figure 6.3 illustrates the demographic data of the survey respondents.

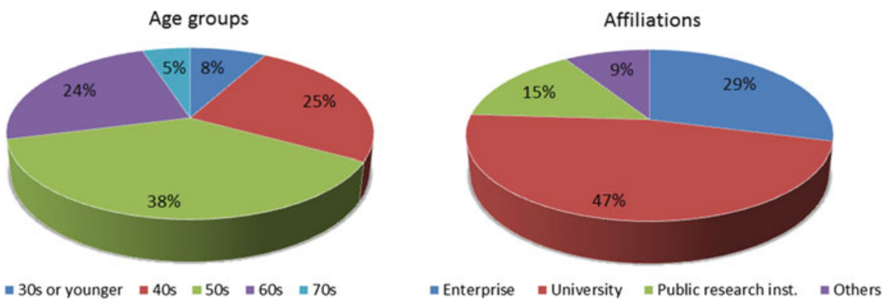


Fig. 6.3 Age and affiliation of the 9th Japanese Delphi survey respondents. *Source:* Reproduced from NISTEP (2010)

6.4.5 Analysis and Dissemination of Results

A large amount of quantitative data is produced in a typical Delphi survey. Much of the time, relatively basic descriptive statistics are provided, for example, on the distribution of responses (it is common to display these using bar charts and similar visualisations). One issue often focused on is the degree of consensus (and whether any topics feature strong disagreement, for example a bimodal distribution). Typically attention is first paid to the question of when or how far the topic is expected to be realised, and then other issues are addressed successively. Often there will be comparison of the responses of different sorts of participant—those considering themselves to be expert in the topic with others, for example, or sometimes in terms of personal characteristics such as age or job title.

It is certainly possible to undertake more sophisticated statistical analyses, such as using correlations, or data reduction methods such as factor analysis. Such approaches can be useful for examining, for example, whether people who tend to be "optimistic" about the timing or benefits of one development are also "optimistic" about others. This sort of analysis is, however, relatively rarely conducted, though it can give insight into different points of view, and even be used to inspire creation of alternative scenarios built around major points of disagreement. It is also possible to analyse the relations of topics with each other, locating, for instance, statements that tend to elicit similar patterns of responses.

While the time or extent of development of a topic is typically the first thing that observers are concerned with, when examining Delphi results, the other questions that are addressed can be of equal or greater significance. It is liable to be more useful to examine which developments are seen as having greatest impact, on one or other criterion, than to compare the timing of low-impact developments. Thus, ForSTI Delphi reports will often engage in some **ranking** of topics in terms of the individual criteria used in the survey, or on the basis of an index built out of several criteria (e.g. the attractiveness/importance and feasibility of the statement).

Visualisations and **graphical representations** are useful to illustrate and make understanding and communication of the results easier and faster. Ranking can be a first step towards more sophisticated visualisation. As an example, Figure 6.4

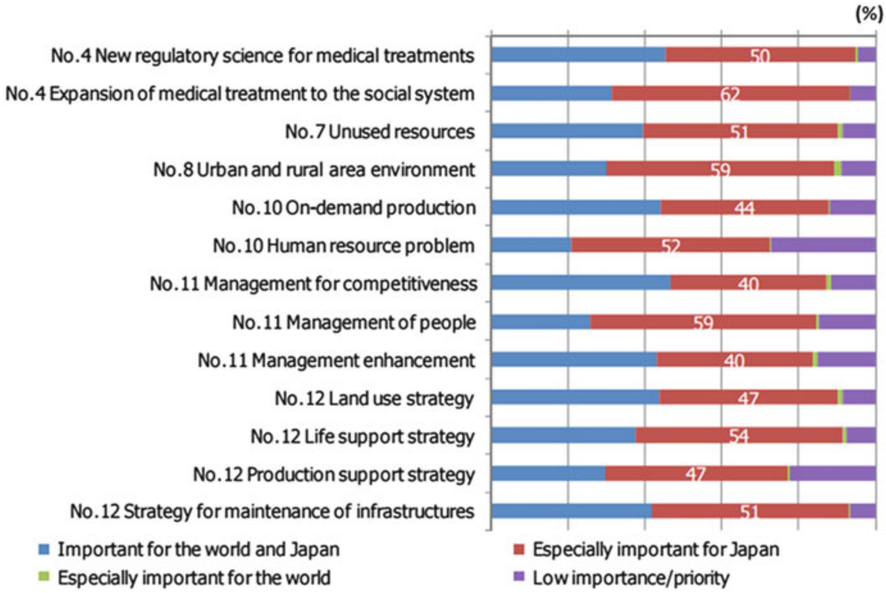


Fig. 6.4 Ranking of areas evaluated as "especially important for Japan". Numbers in each area represents the number of the panel. *Source:* NISTEP (2010)

illustrates the ranking of topics in the 9th Japanese Delphi survey based on their importance for Japan (areas with the selection ratio of higher than 40 %).

More recent technologies like semantic analysis, gives possibilities for further processing of survey data and its visualisation. Figure 6.5 shows the semantic mapping of the Japanese Delphi statements. Each small node in the figure illustrates the thematic categories in the survey with their potentials for addressing global and national challenges in colour-coded circles.

Some other creative visualisation techniques have been used to portray and communicate the Delphi results, such as the one in Fig. 6.6, which show the results of the 9th Japanese Delphi survey using cartoons to illustrate sections of life around year 2025.

New visualisation techniques have become available using computer technologies. Social networks, tag clouds, various kinds of maps, and other means can be used for various purposes of analysing and communicating data. (Often the visualisations make use of bright colours; sometimes they involve 3D images, or even portray dynamic change over time.) In online Delphis combined with statistical tools, such as real-time Delphi, results can be analysed and presented once sufficient responses are received, and may be updated as more responses are collected. They are visualised in multiple ways and made available to the respondent for re-assessment. It is through the project team the results are analysed statistically. Then the results generated are presented to the expert panel, which

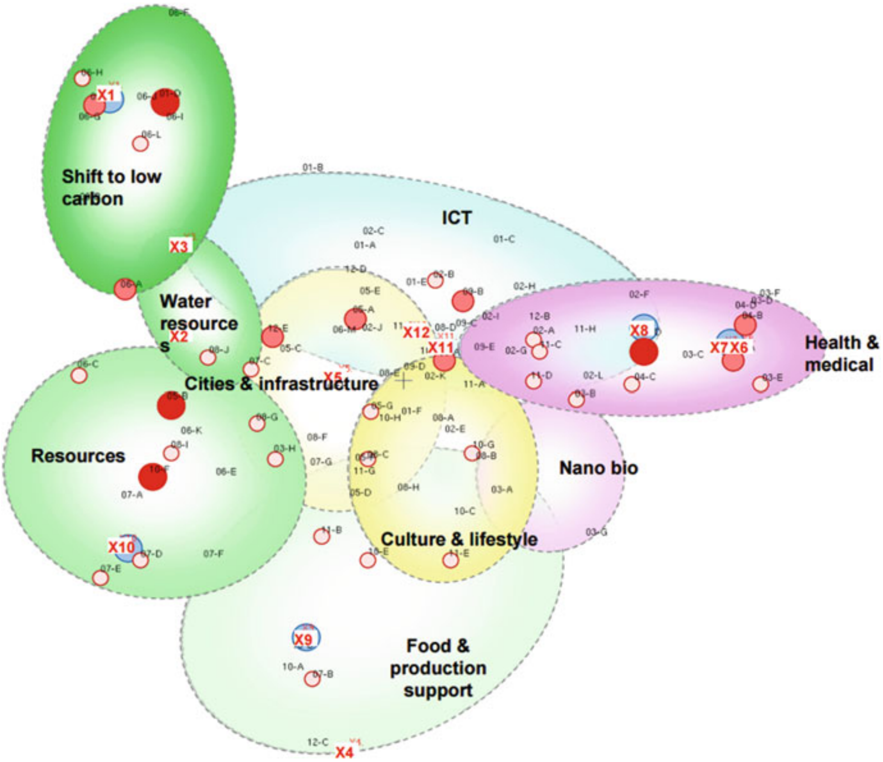


Fig. 6.5 Semantic mapping of Delphi topics. *Source:* Shrikawa (2011)

formulated the statements and criteria. Real added-value from the study can be extracted through expert analysis of the results: their interpretation of the final results is as important as the basic data analysis itself.

As mentioned earlier, Delphis can generate qualitative input from the respondents, who use the open space provided for them for this purpose, usually to explain or comment upon their judgements. These comments tend to be extremely useful. However, the Delphi team often does not have time or resources to make full use of this feedback. These responses would ideally be shared with the Delphi respondents in the course of the survey, but even if this is not accomplished, they can be made available to panel members.

Dissemination of the Delphi results is often undertaken as a separate part of the ForSTI activity. There is often much data and detail that cannot be squeezed into the other reports and outputs, and stakeholders may want to assess the pattern of results across many topics. It is important to be aware that these may be of value for the next steps of the ForSTI exercise—for example, as information to aid scenario development, prioritisation of the topics, and developing strategies for those priorities. The data also can provide opportunities for further analysis, including analyses by other researchers or stakeholders concerned with the ForSTI study.

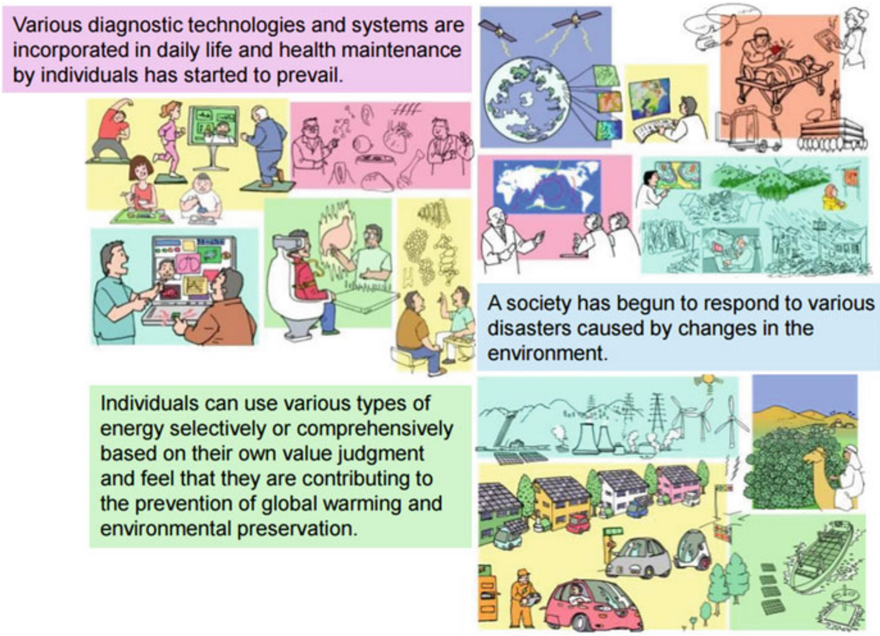


Fig. 6.6 Visualised Japanese Delphi survey results. *Source:* Shrikawa (2011)

The boxes below (6.1 and 6.2) present two case studies on Delphi surveys based on, respectively, an international and national experience.

Box 6.1: Delphi Survey – An International Case Study
This box concerns a Delphi survey that was performed in the framework of ERA. Net RUS project (2011–2013) supported under the EU's FP7 programme. The aim was to coordinating STI policies and support programmes between EU Member States, countries associated to the 7th Framework Programme (FP7), and Russia.

The survey covered a twofold area: societal challenges and prospective fields of research for EU-Russia S&T collaboration. The major data sources for the survey were the nomenclature proposed as part of the draft Horizon 2020 proposal of the European Union (6 societal challenges with each up to 2 sublevels) and four thematic areas, with each up to 2 sublevels, drawing on the basis of the Russian S&T Foresight 2030 implemented by the Higher School of Economics in 2011–2013.

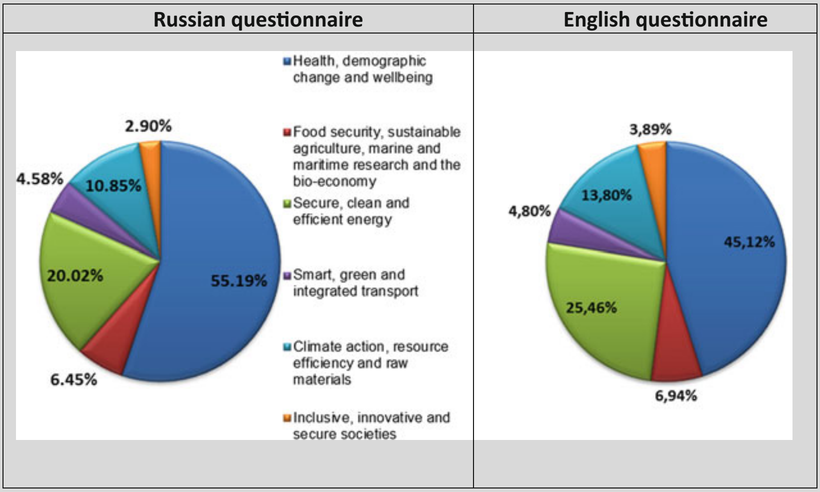
An overall sample of 6695 experts (4408 from EU MS/AC and 2287 from Russia) was invited to fill in both Delphi rounds. The experts contacted were scientists from EU Member States (MS)/Associated Countries (AC) and Russia who were co-authors of jointly published papers in the Web of Science journals in 2010. The survey questionnaire was developed in two language

(continued)

Box 6.1 (continued)
versions, in Russian and English languages, but with the same questions. The overall response rate to the second (thematic) Delphi round was around 15 % (13 % for EU MS/AC and 18 % for Russia).

Societal challenges of Horizon 2020 and promising thematic fields identified in Russian foresight studies were taken as a basis for the questionnaire and then surveyed in the Delphi.[2] The list of thematic fields was not meant to be exclusive; there might be other areas such as reformation of innovative systems or industrial reorientation that are also of interest for the EU MS/AC-Russia cooperation.

The thematic Delphi allowed identifying societal challenges important for the EU-Russia RDI cooperation (see the Figure below). The EU experts answered the English-language questionnaire.



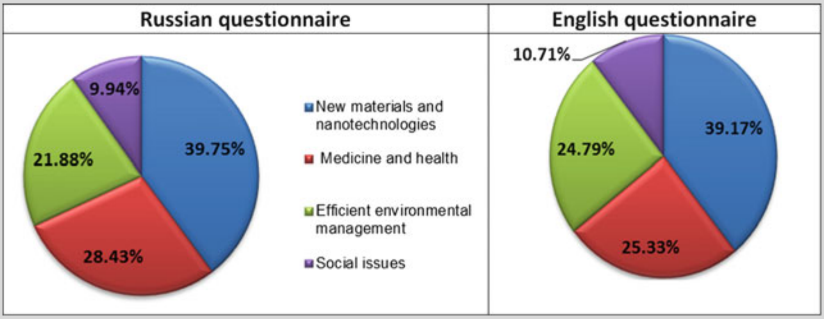
Promising thematic fields for EU-Russia RDI cooperation are presented in the second figure (below); these promising research areas can also be examined at much greater levels of detail. The distribution of answers by Russian and European respondents was surprisingly similar. Around 40 % of Russian and European experts agreed that the most perspective field of cooperation is “New materials and nanotechnologies”; “Medicine and health” was in second place (more than 25 % of respondents), and efficient environmental management in third place, with more than 20 %. Among the societal challenges addressed by

(continued)

[2]For a detailed analysis of the survey regarding challenges and thematic fields for cooperation see the ERA.Net RUS foresight report at www.eranet-rus.eu

Box 6.1 (continued)
the Horizon 2020 programme, the most important ones (see Figure 2 above) for EU-Russia RTI cooperation, according to experts, were the following:

1. Health, demographic change and wellbeing (55.19 %—the Russian questionnaire; 45.12 %—the English questionnaire)
2. Secure, clean and efficient energy (20.02 %—the Russian questionnaire; 25.46 %—the English questionnaire)
3. Climate action, resource efficiency and raw materials (10.85 %—the Russian questionnaire; 13.80 %—the English questionnaire)



Box 6.2: Delphi Survey – A National Case Study
The Russian Delphi survey— Russia 2025—was commissioned by the Ministry of Education and Science. Conducted in 2007–2008. The survey covered all major S&T fields, including over 60 subject areas and more than 900 topics—key research advances, breakthrough technologies, promising innovative products. Over 2000 experts from leading research organisations, universities and innovative companies took part in the survey, from more than 40 Russian regions. The involvement of so many experts was due to the need to obtain representative results for each key S&T development area. They were selected from the ranks of leading professionals in enterprises, academics (taking into account their citation indices in journals indexed in the Web of Science), and members of government agencies. A co-nomination (snowball) technique was also used to extend the pool of experts. Expert panels, comprising about 300 leading researchers and practitioners, were constituted, drawing on this list.

The survey involved a first tier of nine priority areas:

- Information and telecommunications systems
- Nanosystems and materials

(continued)

Box 6.2 (continued)

- Live systems
- Medicine and health
- Efficient environmental management
- Power generation and energy saving
- Production systems and industrial infrastructure
- Aerospace and transport
- Safety at production facilities, transport and daily life

Each of the above fields was divided into 5–7 subject areas: this constituted the second tier of the classification. In turn, each subject area included specific designs and technologies—more than 900 altogether—and these formed the topics of Delphi survey. The topics were expressed briefly (up to 30 words) in the survey. They included innovative products, technologies (breakthrough ones, or those setting the developing rate in relevant narrow technological fields), and fundamental research results with the potential to generate radical innovations. More than 5000 such topics were suggested at the preparation stage, which involved bibliometric, and patent research (including identification of "S&T research fronts" through analysis of publications with the highest citation indices during the previous two years), and review of the results of international ForSTI exercises. Draft lists of topics to be included in the Delphi survey were prepared on the basis of this work, and then expert panels (for specific subject areas) selected those to include. An important part of finalising the list of topics was justification of the criteria for their selection. A special study was conducted for that purpose, in which an expert group (comprising prominent social researchers and economists, together with representatives of government agencies) developed a system of socio-economic objectives that STI development could achieve.

The Delphi survey was conducted in two rounds, following the classic fashion, with results of the first round being fed back to the experts in the second round of the survey, so they could adjust their initial responses taking into account the professional community's position. As noted, over 2000 experts submitted completed questionnaires—coming from about a thousand research centres, universities, and production companies across all major S&T development areas.

For each STI area the survey set out to identify:

- Key S&T results which could be achieved until 2025;
- Breakthrough technologies, with an assessment of their potential contribution to meeting major socio-economic challenges and ensuring national security;
- Promising market niches for Russian producers;

(continued)

Box 6.2 (continued)

- Potential socio-economic and environmental effect of implementing the new technologies;
- Recommendations for S&T and innovation policies to promote advanced development of relevant S&T areas.

The Delphi survey creates a foundation for systematic analysis of STI prospects, identify priorities for research and STI more generally, and for assessing the possible socio-economic effects of applying the results of S&T. But on the whole, the experts' assessment of STI's contribution to Russia's development was quite modest. Russia was seen to be significantly lagging behind the leading countries in various areas of STI; in the situation of sharply reduced availability of resources, this is taken to imply the need to develop more efficient S&T and innovation policy tools, and to further concentrate efforts on areas with the highest potential effect. Russia was seen by a majority of experts as being able to improve its position on the global markets only in the fields of aerospace and production systems; prospects for increasing competitiveness on domestic markets were better in power generation and power supply, while nanotechnology had most potential for being integrated into value chains.

The main challenges for STI that government policy should address were linked with R&D funding, development of research infrastructure and of a suitably qualified workforce; with other widely-noted issues concerning the attracting of entrepreneurial funding and development of an innovation infrastructure to help transform R&D results into commercial products. The survey revealed that a very small proportion of Russian companies have sought to develop strategies (even for 5–7 years ahead); its results should inform enterprise managers as to new opportunities and pitfalls associated with emerging technologies.

6.5 Types of Delphi Surveys

Many sorts of Delphis can be designed and implemented in the context of a given study. Different types of Delphi address different types of policy need. It is not necessary to slavishly follow the most common Delphi models, and indeed these may be customised depending on the purposes. Options for Delphi surveys for ForSTI activities include:

1. Standard Delphi 1: Forecasting "What" and "When"
2. Standard Delphi 2: Forecasting "How far"
3. "Impacts" Delphi

4. "Policy" Delphi
5. "Multiple scenarios" Delphi

We will describe each of these in the next sections and then present ideas for other types of Delphi which can be used for ForSTI.

6.5.1 "Standard" Delphi 1: Forecasting "What" and "When"

The most common application of Delphi is in essence, straightforward forecasting. Most often, it involves asking WHEN a particular development will take place. For example: "*in your opinion, which is the most likely period in which we would see the use of "two-dimensional" materials (such as graphene) being used in the displays or active electronic components of at least 25 % of new mobile phones coming onto the market.*"

Respondents would answer such a question in terms of such time slots as:

Before 2015
2015–2020
2021–2025
2026–2030
2031–2035
2036–2040
Beyond 2040
Never

Ensuring that different respondents understand the question in the same way is crucial. This is the number one issue in formulation of Delphi statements! The topic statement has to be precise—we might use terminology such as, for example:

1. *Complete domination of the market*
2. *X% of the market*
3. *Widespread use*
4. *First commercial introduction*
5. *First demonstration of prototype/laboratory examples*

We need to be precise, too, about such things as the geographical area being studied. Are we referring to the whole world, or a specific region?

Typically, additional questions would follow, along the lines of "*if this happened, what would be the effects on employment in [one or other sector or country]*" or "*which countries/regions are most likely to capture the gains from this development*"/"*how far does country/region X possess capabilities to take economic advantage of this development?*" *In each of these cases we would request answers in terms of a rating scale or a list (e.g. a scale ranging from "very* *negative" to "very positive"; a list including "scientific/research", "technological/ engineering", "financing/commercial development", "marketing" and the like.*

6.5.2 "Standard" Delphi 2: Forecasting "How Far"

This is a minor modification of the first approach, in which, instead of asking WHEN a particular level of development of something would be reached, we ask HOW FAR the development has proceeded by a particular date. For example:

> In your opinion, by [year—e.g. 2025] how far would the use of personal health systems—portable or wearable devices that monitor the user's health and reports data to health and emergency services—have developed?.

Respondents would answer such a question in terms of parameters reflecting things such as the development of the technology, the market, the market share, and the like—using for example a simple numeric scale such as, for example*, the proportion of the adult population aged in country X over 60 routinely using personal health systems would be*:

- *Greater than 90 %*
- *76–90 %*
- *51–75 %*
- *26–50 %*
- *11–25 %*
- *less than 10 %*
- *Not at all*

Sometimes some early versions of the technology in question may be in use, but survey respondents may lack knowledge of the current share of the market. If data are available, it is appropriate to cite these. It may be important to be explicit about how the envisaged future technology has moved on from current systems; we need to ensure that respondents have a shared understanding of the application in question, and just what are the boundaries of the market being considered (the number one issue mentioned above applies to all sorts of Delphi).

The two versions of Delphis just discussed are effective for explicating expert views of what is likely to happen, when (or how far), and with what consequences. By asking about facilitating and constraining factors, such Delphis can also be used to get a sense of actions and policies that could address the topics.

6.5.3 "Impacts" Delphi

This sort of Delphi focuses on the impacts and/or implications of future developments. The basic formulation is: *if this development occurs [by such a* *date], what will be the implications for these issues (e.g. the set of goals we are concerned with)?*. For example, *if procedures are put in place to enable the repair of the great majority of cases of serious spinal cord damage through accidents, what would the implications be for {on a scale from very positive to very negative]: medical system expenses; social car expenses; requirements of highly trained medical staff; quality of life of patients; life expectancy of patients.*

Such a formulation implies two challenges for survey design. First, as always, we have to select a topic. We have to decide whether we choose only specifications of topics that we think are likely to happen within the timescale addressed by the Delphi, or by a particular date within this period.

- Some things are liable to be pretty predictable, which is the case for many areas of technology development and diffusion. For example, *increased used of Information Technologies for observation and sensing, processing and logistics, and management and planning of agriculture* is very likely to happen, though the extent to which this takes place will over time, across regions, and across types of agriculture.
- Some things may be less predictable, which may often be the case of social and political phenomena, as well as the precise set of technological solutions and/or standards that come to dominate. Taking a regulatory issue, we could ask, for example, following the topic statement (e.g. *application of tough sustainability criteria in a large share of Western markets, to fabrics and related products based on natural fibres or synthetic substitutes*). We might well ask respondents to say in their view, how likely this is to apply at the date in question (say 2030), or how far it would apply (e.g. using a scale from *overstates the situation—about right—understates the* situation).

Second, we need to consider against which goals (and which things we wish to avoid) the topic developments are to be considered. For example, for the topic of fabrics just discussed, these might include such issues as:

- Health and well being
- Sustainability
- Rural job creation/loss
- Urban job creation/loss
- Economic (in)equality
- Exports from fibre-producing countries

Participants may be asked to select those developments which are most likely to contribute to the achievement of specific goals; or they might be asked to rate each topic in terms of its positive or negative impact on the goal (We can also ask for open-ended responses as to specific aspects of the policy or development that might be particularly likely to improve goals such as job creation).

Let us give an example of such a Delphi survey, as applied to the development of the "Knowledge Society" in Europe (Box 6.3).

Box 6.3: European Knowledge Society Foresight Delphi Survey

This survey was conducted for the European Foundation for the Improvement of Living and Working Conditions (EuroFound), based in Dublin (Loveridge and Miles 2004). The interests of EuroFound were captured under three broad headings. For each a set of three specific issues were identified (using EuroFound and EU policy statements):

1. Living Conditions
   1.1 Social Cohesion
   1.2 Social exclusion or divides
   1.3 Sustainability/environmental quality
2. Industrial Relations
   2.1 Employer-employee relations
   2.2 Economic growth/wealth creation
   2.3 Entrepreneurship and innovativeness
3. Working Conditions
   3.1 Employee autonomy and responsibility
   3.2 Work-life balance
   3.3 Job creation.

Each of these nine criteria was rated in terms of the influence on it that the respondent thought would result from each of a number of topics that an earlier workshop had seen as potentially characterising European Knowledge Societies by 2015 (about 12 years ahead from the time of the study). This was the approach adopted to resolve the questions of what topics to consider, and how to frame them in ways that were plausible for the timespan in question.[3]

(continued)

[3]The workshops had asked members to identify topics under a number of headings: Governance & mobility; Health & privacy; Industrial relations; Living conditions; Sustainability & development; and Working conditions. Those considered to be reasonable as descriptors of the Knowledge Society by 2015 were: Widespread use of ICT in e-governance enhances transparency in the procedures concerning the relationship between the citizen and the state in my country; EU policies are used to promote labour market mobility, despite resistance from individuals, trade unions and employer organisations.; Widespread use of telemedicine and on-line health monitoring systems increases the ability of people with serious chronic and age related diseases to maintain their independence; New forms of networked business organisation, that were unknown or very rare at the turn of the century, will now account for a substantial level of economic activity in my country; A major increase occurs in my country in the use of electronic networks for remote supervision of new kinds of work (teleworking, mobile working), and new atypical forms of work; Harmonisation of educational standards (including certification) across the EU increases trust and transparency in my country's educational system; Life-long learning becomes widespread with a majority of workers undertaking more than one period of substantial retraining during their working life.; Despite social and employment policy interventions, for most workers their work-

Box 6.3 (continued)
The influence the criterion could be to strongly increase, increase, have no effect on, decrease, or strongly decrease it.

An example of the results obtained then comes from the topic "Life-long learning becomes widespread with a majority of workers undertaking more than one period of substantial retraining during their working life". A majority of respondents thought that this was a plausible description of the future European Knowledge Society. In terms of its impacts, it was generally believed to improve the industrial relations factors (employer-employee relations, economic growth/wealth creation, and entrepreneurship and innovativeness), along with two elements of working life (employee autonomy/responsibility and job creation—with more mixed views and disagreement concerning the impact on work-life balance.[4] While there was a general expectation that it will improve social cohesion, and many participants anticipated benefits for sustainability/environmental quality (though a substantial minority considered that it will have no effect here); impacts on social exclusion/divides also meet with disagreement among respondents (i.e. a bimodal distribution of responses).

An impacts Delphi can be useful in terms of giving insight into expert views about which probable or possible developments are seen as being most beneficial or problematic. It can readily be extended to get a sense of the major problems and difficulties that might be confronted, and the relative ease of different actions.

6.5.4 "Policy" Delphi

Policy Delphis are rather like "impact" Delphis, but feature much more emphasis on how particular outcomes could be reached. (One variant of this is The Decision Delphi, which aims at prioritising particular immediate actions—here we might formulate topic statements in terms of "what should be done"). For example, there could be a number of alternative visions of the future, and respondents are asked to select among and/or combine these. Or we might start with rather more consensus about a desirable future, and begin with a brief "vision statement" of what the goals are for the future of the topic or social unit that concerns us.

life balance deteriorates causing rising family stress and conflict; Europe has developed into a leading force in the area of sustainable development and the use of environmental technologies; Social and policy changes in my country encourage female entry into professional and technical jobs that are currently male-dominated, leading to substantial decreases in gender-related pay inequalities; and Widespread abandonment of conventional notions of retirement in my country enable the elderly to continue working if they wish to.

[4]Work-life balance was the criterion concerning which respondents to the Delphi were least likely to anticipate positive improvements as a result of Knowledge Society developments.

In either case, we need to formulate key goals or issues of concern; each needs to be concisely stated and able to evoke a good deal of shared understanding. When there already is a single integrated vision that has been agreed upon as a set of desirable features of the future, then the goals associated with this need to be widely viewed as feasible and desirable (also, they should not be too numerous). If part of the exercise is to prioritise or assess the degree of support that a number of goals or subgoals receive, then these need to be expressed in broadly comparable terms—otherwise very broad "motherhood" goals are liable to meet with overwhelming support, while more tightly specified ones get less attention. (Thus "poverty reduction" is likely to get more support than "reduction of rural poverty levels".)

The method focuses on how the goals can be achieved. One way in which this can be done is to ask about how important various actions, strategies, or circumstances would be for this goal to be achieved, which might involve direct comparison of, and selection between, these different factors. For example, we could ask for the respondent to check the three most important factors from a list. (Asking for a ranking of factors can be quite onerous, especially of the list is long.) Another way is to ask for ratings of how far each topic would contribute to the goal. The obvious limitation in these methods is that in quite a few situations, it is important to have what is known as a "policy mix"—for example, both investment in equipment and development of skills are essential, and neither will suffice on its own.

In ForSTI studies, the sorts of strategy and policy recommendation that may be considered could be, for example, regulations (including, possibly, standards and intellectual property rules), public procurement, or investment in education, infrastructure development, and research, or support for entrepreneurial activities. For example, a policy action might be "major investment in R&D aimed at improving the production and use of XXXX technology, by the year 2030"). In this case, we might be less interested in views of the likelihood of the policy being implemented—hopefully we would have already weeded out things that are widely felt to be unfeasible. Instead the interest is in how important the action or development would be for the goals we are interested in, and what facilitating and constraining factors might be confronted.

Examples of the core question being asked in ForSTI contexts could include:

- How important would it be for this policy to be implemented in order for [a particular goal to be achieved] in 2030? (5 point scale from *very important* through to *not at all important*)
- If event/policy were to be realised, how much of a contribution would it be making to [region/country X] reaching the goal described for 2030? (Answers could be in terms of a 5 point scale from *very positive influence* through to *very negative influence*)

Such core questions would be asked in respect of each of a number of specific goals (see "Impact" Delphi, above)—or they could be applied to a whole scenario of development). Most often, we would ask about whether the impact was positive or negative, and judgements could be elicited on, for example, 5-point scales.

It could also be useful to ask a second question asking about the likelihood of the action (topic statement) itself, e.g.:

- How likely do you think it is that this policy (or one very much like it) will be widely introduced and implemented in the next [10] years? (answers could be in terms of a 5 point scale from *very likely* through to *very unlikely*) and
- How uncertain do you feel about this state of affairs being reached in the next 12 years? (*very certain that it will happen* to *very uncertain that it will happen*)

The big challenge here is determining a set of policies to address, and formulating them in an appropriate way. This will require various types of analysis, for example reading the policy proposals in the literature, those suggested by various political actors, and those generated through workshop activities.

6.5.5 "Multiple Scenarios" Delphi

Most often a Delphi asks bout "the future", but a fundamental assumption of futures and ForSTI work is that there is a range of alternative future possibilities, reflecting different choices and contingencies. Thus it is perhaps surprising that Delphi studies examining alternative futures are rarely implemented. A Delphi can ask about what would happen under various contingencies—for instance, it might ask what a particular feature would look like in Scenario A, Scenario B, and so on. In scenario workshops such judgements are often requested, and participants have the opportunity to immerse themselves in (and help to develop) different scenarios—but these judgements are more often the product of group discussion rather than Delphi-style voting. Occasionally, especially when workshops are using computer tools to support data capture, some ratings are requested from individuals, and alternative futures can be introduced in a Delphi survey. The main problems are (1) the increased number of judgements that may be requested and (2) the need to ensure that all respondents have adequate and similar understanding of the alternative scenarios. Again, several approaches are possible here, and we just focus on a few of these.

One approach involves analysis of just what would happen under only two contingencies: for example, business as usual versus a more desirable path of development. For each topic statement, then, two judgements have to be made—for instance, what is *most likely* or alternatively what is *the current path of development*, and what would be the *most likely* state of affairs to reach a more desirable future. Thus the Delphi could ask how far a certain event/development might progress "if current trends or business as usual approaches persist" and then "if feasible shifts in policy and funding were implemented over the next few years" (The precise formulation of the goals and the importance ratings will be rather similar to those outlined in above). The above approach essentially contrasts an extrapolative future with a more normative one, leaving it up to respondents to determine the content of these two poles. An alternative approach is to specify two or more (perhaps up to four) scenarios that represent alternative paths of development. For instance, it would be possible to consider circumstances in which global economic growth is more or less buoyant, in which climate change impacts are more or less severe, and so on.

This approach has the virtue of opening minds concerning alternative futures—there is not one single unalterable trajectory into the future. But it requires careful design of the scenarios and how they are presented, and the challenge of limiting the size and complexity of a survey that poses questions about alternative scenarios has to be confronted.

6.5.6 Other Types of Delphi

Delphi is a flexible tool, and new sorts of approach can be devised and experimented with in ForSTI applications. For instance, something close to a Decision Delphi approach could focus less on where the impacts lie, and more on *what* needs to be done by *whom*. For example, it would be feasible to ask "how much change would be required in each of the following areas of policy/or the following policy areas and agencies" in order to reach specific goals such as substantially greater levels of economic growth and job creation, while maintaining or improving environmental sustainability, associated with particular STI developments—from agencies responsible for:

- Science and R&D policy
- Education policy and institutions
- Social policy (e.g. welfare, pensions, health)
- Labour market and industrial relations policy
- Enterprise and industry policy
- Infrastructure policy (transport, communications, etc.).

Alternatively, the formulation could be along the lines of "how far would policymakers responsible for the following areas be required to take these developments into account in their policymaking?". Another approach would be specified to focus on different actors rather than specific policy areas, asking for instance "how much change would be required from the following stakeholders?", for instance:

- overseas investors
- large firms
- small and medium-sized enterprises
- universities
- schools
- government ministries dealing with rural affairs, industrial affairs, etc.

and so on.

6.6 Conclusions

Delphi studies can provide impressive results when conducted well. Often the results complement more discursive argumentation and more formalised modelling in fruitful ways; the volume and detail of information provides material for many interested parties; the wide sourcing of data can offer more legitimacy than would a smaller body of expertise.

These advantages carry their own dangers. Numerical data can be overvalued, and it is important to recall that Delphi results reflect the views of particular sets of people at a particular moment in time. The numerical data can be processed rapidly and presented in various striking ways, but users will need to check that they are drawing on results from more than just one or two respondents, and that the questions being answered are clear and meaningful (so that different people actually are answering the same question in reality). As with other data, Delphi results are really a decision aid, an input to a wider process: they are not providing final answers to the questions of ForSTI exercise!

Achieving really useful results from a Delphi survey will require careful and laborious preparation: selection of the participants, elaboration of the topics addressed and questions asked, and ways of providing the feedback to participants; the final reporting of results is also no small matter. In particular, as we have argued, great care has to be taken in formulating appropriate topics.

Delphi surveys are fairly time-consuming and labour intensive, and not just on the part of the questionnaire respondents. This is why some so-called Delphis do not reiterate the survey or provide adequate feedback to respondents: they are essentially conventional surveys, and while they may have value as such, they lack key features and much of the quality of a serious Delphi.

To conclude, we should emphasise that the choice to use Delphi method alongside other ForSTI methods, and choices about what type of Delphi to be used, must be considered in the light of the particular objectives of the exercise. Just because Delhi has been used in some other study does not mean that it has to be used in every exercise. Given the resources required, if a Delphi is to be undertaken, it will be helpful to build support for it, for example by explicating what the technique has been able to bring to earlier ForSTI exercises. Designers must be prepared to deal with several common misapprehensions about Delphi, too—that it is always seeking consensus, that it is always a matter of forecasting, that one is seeking the same kind of statistical representativeness as in an opinion poll.

Delphi results are produced in order to be used, and effective use typically requires that they are:

1. Synthesised, with adequate discussion of features of the results and key points of interpretation; and related to the results of other methods used in the exercise
2. Disseminated through appropriate channels (typically with a specific Delphi report)

3. Linked to policies and actions, and to the needs of the users; this may mean preparing different reports for different user groups (e.g. for different economic sectors)
4. Engage key stakeholders who have the power to decide on how the ForSTI exercise is to be used, and how far key recommendations are to be implemented, and whether analyses are to be taken further.

Imagination: Scenarios and Alternative Futures

7

7.1 Introduction

In ForSTI, scenarios are systematic accounts of particular configurations of future possibilities—a scenario is a systematic account (we might say “appraisal”, and people often talk of “vision”) of a possible future state of affairs and the paths of development leading to it. There are many uses for scenarios in ForSTI, for example, to:

- illustrate and communicate features of forecasts and future-relevant analyses—working as a tool for communicating appraisals of long-term prospects, and making abstract accounts more concrete
- structure and guide discussion so that appraisals, their constitutive elements, and the assumptions that underpin them, can be explicated and elaborated.
- provide contexts within which vignettes can be elaborated, so as to enable closer scrutiny of possible implications of developments in environment, technology and society
- allow for different views of the future to be integrated and/or contrasted (e.g. brought together into single scenarios or form the bases of multiple scenarios)

As with most, if not all, other methods used in ForSTI, then, scenarios may be brought into play in various phases of the activity. Scenarios, especially those produced as background inputs to an exercise or derived from earlier studies, may be used to inform and guide horizon scanning; they may be used as tools for communicating the results of an exercise. Scenarios are often used as a way of integrating different elements of a study, a scenario is underpinned by a model of the focal object and its context; and roadmapping can be seen as a specific kind of scenario process. But we will particularly stress the role of scenarios in the phase of ForSTI we have labelled as ForSTI.

I. Miles et al., *Foresight for Science, Technology and Innovation*, Science, Technology and Innovation Studies, DOI 10.1007/978-3-319-32574-3_7

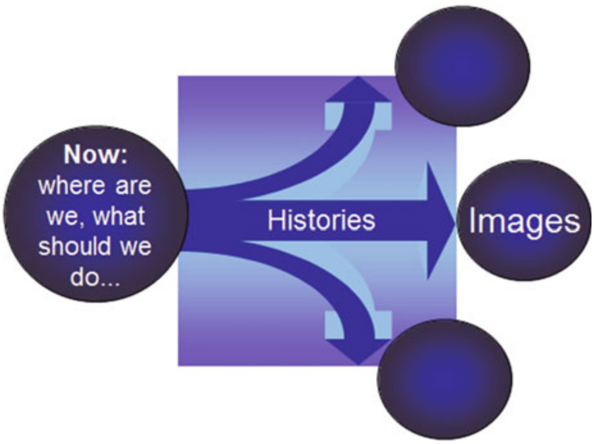
This phase of the ForSTI activity particularly requires creative and divergent thinking. Input gained from the Intelligence phase is synthesised around models and scenarios about the Future. Various ways of representing our understanding of the systems we are dealing with may come into play: narratives (storytelling), visual illustrations of systems (their elements and the relationships between them) or situations.

7.2 Introducing Scenarios

The term "scenario" has various meanings—in film and theatre productions, in information systems design, and elsewhere.[1] In ForSTI work, as already stated, a scenario deals with a possible future state of affairs and the paths of development leading to it. The focus can be more or less on (1) a dynamic sequences of events or developments of trends ("future histories"), or (2) more static features of a future point in time ("images of the future") as illustrated in Fig. 7.1.

Of course, often we have a combination of the two, but the emphasis will typically be evident on one or other aspect: in either case we can see a scenario as being a *systematic account of future possibilities* (Miles 2005). The term *systematic* implies (a) internal consistency and (b) covering developments in a fairly holistic way, going beyond simply profiling the future in terms of one or two key variables, as might be the case in simple models and extrapolations. A scenario presents a more fleshed-out picture, linking many details together. Typically the account of a scenario will combine quantified and non-quantifiable

Fig. 7.1 Future images and histories



[1]For an interesting discussion of the etymology, stressing Herman Kahn's contribution, see http://english.stackexchange.com/questions/147450/what-is-the-real-history-of-the-word-scenario (accessed on: 17.04.2014).

components. It may involve narratives (illustrated with vignettes, snippets of fiction and imitation newspaper stories, etc.), or be presented in the form of tables, graphics, and similar systematic frameworks. In multiple scenario analysis, alternative scenarios can be tabulated against each other, revealing key points of convergence and divergence.

Scenarios can be distinguished from **Profiles of the Future**, which specify a future state of affairs in terms of very few variables. A profile may represent a desirable or feared state of affairs (e.g. "this technology is in widespread use for these applications"), or a combination of key end-states (e.g. a future where this technology is in wide use, and where economic growth is proceeding rapidly). Scenarios are more multidimensional accounts, which relate at least some variables together; profiles are stark specifications of a few trends or end states. Scenarios also differ from **Vignettes**, which are more or less detailed accounts of particular features of a scenario, often constructed in the form of a localised "story" or sequence of events (e.g. how a particular technology might be used, what a specific lifestyle might be). Vignettes are often used to provide a more in-depth and vivid account of how a scenario might feel. In areas like information system design, the term "scenario" is often applied to vignettes of technology use constructed to aid the design process. Occasionally in ForSTI we find several vignettes set within essentially the same scenario, but that are described as "multiple scenarios". [Examples include Scase (1999) and Coates et al. (1998)]. In this chapter, we will also sometimes refer to "**Sub-scenarios**", by which we refer to discussions of the implications of a particular scenario for some specific area of the focal topic—for instance, for one set of applications of a new technology (Example: in a scenario study of nanotechnology, we worked with break-out groups in a scenario workshop, these groups focusing on application areas like nanoelectronics, tissue engineering, and the like). If scenarios are accounts of the whole "body", then a profile is like the skeleton, while vignettes and sub-scenarios are like specific limbs or organs.

Scenarios can be produced in many ways; and, whatever some futurists and consultants may say, there is no single right way of developing scenarios. There is a diversity of possible approaches, and on occasion unfamiliar approaches may be most relevant.[2]

Scenario workshops gain a great deal of attention, and rightly so, because they are valuable ways of provoking creative inputs and engaging relevant people. But scenarios can be constructed from small group discussions, deskwork, or even survey analysis or computer modelling. We outline some of the alternatives, and discuss some key practical issues, in the following discussion.

Probably the best-known approach in the ForSTI area is to construct a 2×2 scenario matrix; this may be developed by experts or (commonly) in a group

[2]There are many partial discussions of scenario approaches—for a rare presentation of a range of views from established practitioners, see the special issue of the journal *Technological Forecasting and Social Change*, vol. 65, no. 1, September 2000, edited by Godet and Roubelat.

workshop, on the basis of an analysis of major uncertain drivers.[3] This method, which we will describe in more detail later, can build on prior horizon scanning and assessment of drivers influencing the focal object. But some scenario exercises examine alternative futures associated with multiple uncertainties around each of the critical influences—there might be several scenarios generated around each driver. Wild cards or weak signals, too, may be used to generate scenarios. Yet other approaches involve exploring scenarios that are built around end-states rather current uncertainties—how might we evolve toward futures of particular kinds that are of special interest, towards one or other profile of the future in the terminology introduced above.

A long-established, distinction in futures and forecasting studies is between approaches to scenario development (and futures work in general) that are commonly (though problematically)[4] labelled:

Exploratory Approaches These start from the present and posing "what if" questions: What if the growth rate is $x^{\%}$ or $y^{\%}$? What if events W or Z happen? What if this set of drivers gains in strength, while another set diminishes? What if the government or the competitors pursue one or other strategy?

Normative Approaches These start with an idea about future developments (e.g. a profile) and asking "how" questions: How could a particular future or trajectory of development come about? What would it have taken to have reached a future where the parameter of interest is x% greater than its current value? What would have led us to situation Y? (Sometimes this is called "backcasting".[5] Note that "Normative" approaches need not mean looking for positive images of the future—they can also include possibilities that we will want to avoid, though often the approach centres on an aspirational scenario).

Figure 7.2 graphically contrasts the two approaches.

In practice, these approaches are often used in combination. A set of exploratory scenarios may be developed in a first workshop, and then used to inform a second, normative workshop, or a roadmapping exercise (see Chap. 9 for roadmapping). Some scenario methods are in effect a mix of the two approaches.

---

[3]In at least one case , a 2×2 matrix was formed by a statistical appraisal—factor analysis—that grouped survey responses to a range of questions into two main dimensions that captured much of the variance (Rush and Miles 1989).

[4]To continue a discussion of the exploratory-normative distinction, begun in Chap. 2: all scenarios are full of normative content—including the choice of "what if" and "trend rate" variables. Hopefully, too, they will encourage the analysts to explore options. Thus the terminology is misleading, but alternative descriptions such as "outward-bound" and "inner-directed", have not taken root.

[5]However, again the term has other meanings. For example, a computer simulation's validity may be tested by a form of backcasting, where we take the data on the current situation, and run the model backwards to see if it accurately depicts historical events.

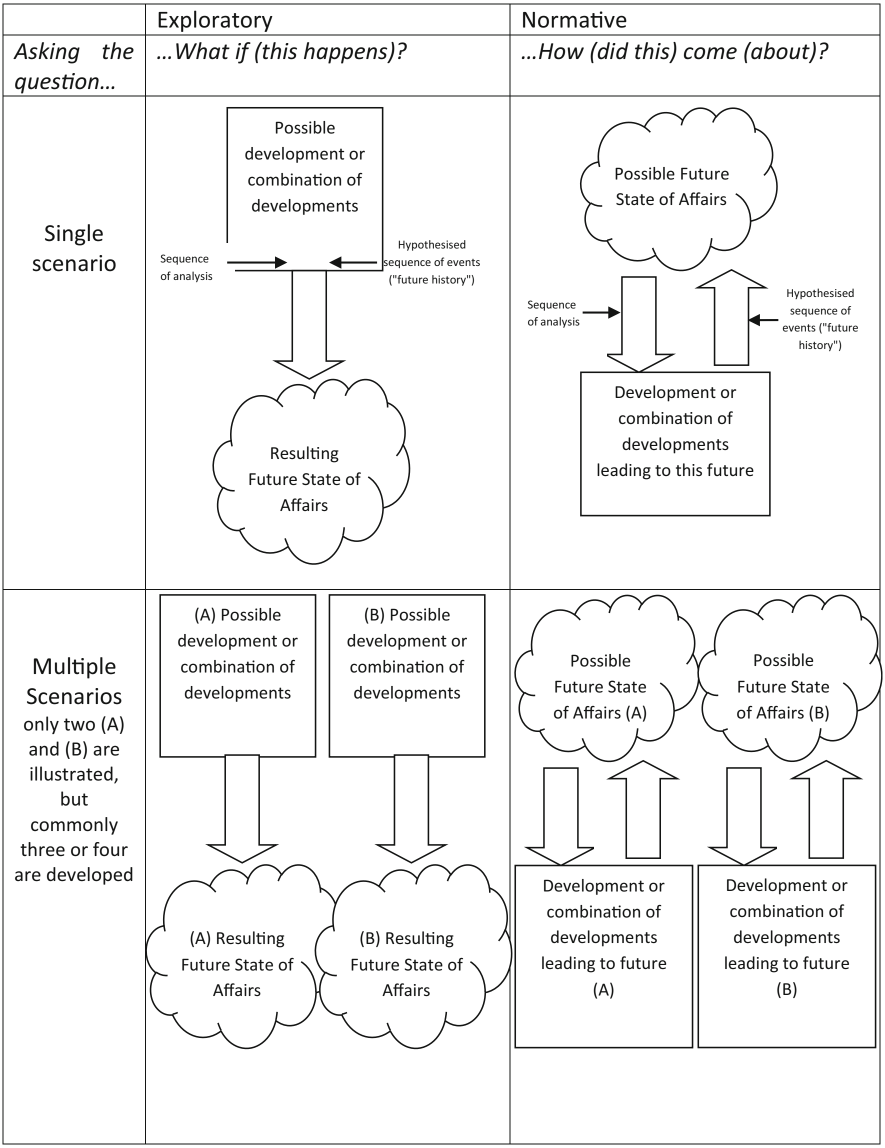


Fig. 7.2 Contrasting exploratory and normative approaches

7.3 Scenarios: One or Many?

Some ForSTI work focuses on a single scenario—often because it has been decided to focus on one desirable and feasible set of possibilities, and to consider how this could be achieved. This is at the heart of aspirational and "success scenario" approaches, and most roadmapping exercises, where we may estimate the effort required achieving positive change, and seeking to mobilise and coordinate the inputs required from various stakeholders. But with the complex focal objects and circumstances of ForSTI, it is important to conduct a wide-ranging review of alternative possibilities, wild cards, and uncertain influences. Given that the future is uncertain, examining alternative prospects is required to develop and share understanding about the range of opportunities and challenges that are liable to confront us, and that our actions may help create or reduce.

Thus multiple scenarios are often developed for ForSTI work, for example:

- A useful and relevant set of alternatives can be applied to examining and assessing the plausibility of several, possibly diverse, futures. This may be important for expanding horizons—not only for warning about challenges that may be confronted. An example of this is a scenario workshop that applied several profiles for participants to explore, based upon a simple set of alternatives for applying technologies. One option was initially felt to be outlandish, since it required extensive capital investment. By the end of the workshop, most participants had come to believe that high-value (if low-volume) production would be the way forward; the "outlandish" scenario was seen as not just feasible, but as desirable (Institute of Innovation Research 2003).
- Multiple scenarios can give more sense of how different trends and countertrends might unfold and interact. They encourage expert teams or workshop participants to examine how different driving and shaping forces may be related to each other, where one trend might undermine another or provoke a countertrend, etc. This means that we have to elaborate our mental models of the situation or system we are confronting: often this requires people to share their implicit mental models, and thus to explore where these contradict, or complement, each other (scenario development can be accompanied by a more formal effort at qualitative or quantitative modelling, as discussed below in Chap. 8).
- The use of more than one scenario allows for a test of the robustness of policy and strategy conclusions across different paths of development (e.g. Ringland 1988, discusses this use of scenarios for examining alternative company investment strategies). This is sometimes known as "windtunneling".
- Multiple scenarios can be elaborated so as to provide guidance as to signals that we are on one or other path, signposts as to possible turning points, etc. Such applications were highlighted in much of the earlier work of scenario development for military/security purposes, but often come into play in ForSTI studies.
- Finally, different scenarios may be built around substantially different mental models. This can be a way of admitting unpopular views into the debate, and of facilitating dialogue among proponents of different viewpoints. The different scenarios then reflect distinctive "paradigms", "worldviews" or "ontologies"—perspectives on what the fundamental drivers of change are and how they interrelate. Freeman and Jahoda (1978) and Wagar (1991) build scenarios around contrasting radical, reformist and conservative perspectives, for

example; though it is not common to find such explicit use of this approach, probably because it runs risks of getting bogged down in political arguments.

The question arises, then, of how many scenarios should be used. There could in principle be an almost infinite number of scenarios, varying in minor details as well as in fundamentals. The answer depends on user demand and practitioner supply issues.

On the demand side, sometimes a sponsor will already propose a number of scenarios that are required, though this is not often explicitly the case (and when it is, it seems to be mainly a matter of how many scenarios were being presented in previous studies). More commonly, ForSTI practice needs to take account of the attention span and absorption capacity of the sponsors and audiences of the work. Practitioner lore suggests three or four scenarios are about as many as can be absorbed by most managers and policymakers—and these are the numbers common across most exercises. However, if the exercise is addressing different sets of users, there might be a case for having different scenarios for distinct groups. For example, when specific intended audiences have responsibilities that bear particularly on specific trends and drivers, we might design scenarios that focus on these influences.

On the supply side, scenario development takes time and resources. Thus, there are practical limits to a ForSTI team's ability to develop and depict multiple scenarios in sufficient depth and at sufficient quality. Even if a computer is used to generate numerous alternative futures from its core model,[6] there is still the task of interpreting them. So, while more scenarios may be generated than are actually deployed for users, there is bound to be a process of selection of those to be articulated and applied. The key issue is selecting scenarios that can help explicate major driving forces and the different futures that these can create, and be useful for tasks such as windtunneling as described above.

7.4 Methods for Scenario Development

Scenario methods are extremely wide-ranging, and can range from completely informal approaches, close to science fiction, through to highly codified and systematic teamwork or modelling activities. Scenarios of many kinds can be generated through deskwork. Here, individuals elaborating their informed speculations about the future ("genius forecasters") may use scenarios to illustrate and enliven their accounts—sometimes as brief and casual afterthoughts, sometimes implanted more deeply into their accounts; or, expert panels prepare

[6]RAND researchers suggest (and provide some case studies to support the idea) that it is becoming possible to generate huge numbers of scenarios using computer models, and then to automatically examine how robust policies would be across different scenarios, and to find the most policy-relevant scenarios in terms of challenges posed. See Groves and Lempert (2007) and Lempert et al. (2003).

scenarios to communicate their work, or to provide a more systematic comparative appraisal of different possibilities. In these cases, the framework of scenarios may be derived from intuition, discussion, literature review or conceptual analysis. Survey results can be analysed to determine if there are different clusters of views about the future that can be considered representative of different scenarios.[7] Cross-impact and similar methods can be used to identify the scenarios possible from a combination of variables (and estimates of the mutual influences, again derived from expert judgements, may be used to associate probability estimates with the different scenarios). Computer simulations of various types can be employed—"Monte Carlo", for instance, involves repeated runs of a probabilistic computer model, while another approach is to request a model to calculate what the results would be when a few key parameters are varied (this is commonly used in sensitivity analysis, for instance). Workshop methods are often used in ForSTI, and we focus especially on these below. Workshops can construct or elaborate on scenarios, with a structured process of dialogue that enables creative exchange of views and information among workshop members. We examine the methods used here in more depth below.

7.5 Scenario Workshops

Scenario workshops are frequently used to build scenarios, sometimes "from scratch", sometimes by further developing scenarios created, in at least a rough form, in an earlier step. The workshops bring together a range of knowledgeable and experienced participants, usually stakeholders of one kind or another, within a structured framework of activities. Scenario workshop methods allow for sustained analysis of alternative futures that are relevant to the key decisions that are confronted, and allow for the generation of reasonably articulate and consistent visions of these futures. They can be used to trigger such inputs to planning as identification of priorities, setting of objectives and targets, defining useful indicators of progress, etc. While a major aim is liable to involve creating a communicable finished scenario, there are also benefits from involving members of an organisation or community in the activity.

Workshops bring people together and can allow them to achieve some integration of the knowledge that they possess. When key actors are involved in scenario generation, they should gain deeper understanding of the underlying processes and key strategies, and a sense of identification with the choice and elaboration of the scenarios. This allows the participants—hopefully some of whom are, or can influence, decision-makers, to:

- exchange information, views and insights
- identify points of agreement, disagreement and uncertainty

[7] For example Tapio (2003) and Rush and Miles (1989).

- create new shared understandings
- develop action plans and other instruments so as to help mobilise future activity—with greater legitimacy than those produced by a smaller expert group or visionary guru (this requires the workshop to have drawn upon a reasonable range of participants appropriate to the decisions in question)
- have “ownership” of the scenarios, in terms of understanding their internal logic, having deeper insight into the considerations that have entered into the scenarios, and being equipped to be “carriers” of the scenarios to the outside world by virtue of having such background knowledge

There are a range of scenario-building techniques in use in workshop settings, and variations on these are developed quite frequently. For convenience we will discuss the workshop process in relation to four sets of approaches.[8]

7.6 Scenario Approaches

Approach 1: Cross-cutting Drivers (the 2 × 2 Approach)
This approach, pioneered and promoted by the Global Business Network (Schwartz 1991), can be seen as largely an exploratory, “what if?” approach. The key elements involve determining critical drivers of change whose future development (or impact of expected developments) is extremely uncertain. Two main drivers, or two main sets of drivers that can be aggregated together, are selected, and each is dichotomised into two major paths of development. By cross-cutting each of these, a 2 × 2 matrix of possibilities is arrived at.[9]

There are many examples of such an approach in ForSTI activities. One example is the scenario development undertaken as part of an examination of prospects for the development and deployment of Personal Health Systems (PHS) to the year 2020. PHS involve application of new IT for monitoring, communication, assistance and other services related to healthcare. Codagnone (2009) reviewed a large range of drivers of change in the PHS context, before elaborating four scenarios, set out in the 2 × 2 matrix in Fig. 7.3 (The accompanying discussion draws to a great extent on Codagnone’s account).

The scenarios are created by cross-cutting two axes designed to capture many of the drivers that may change the wider context of healthcare provision, the context within which PHS may be applied. The ongoing development of the technological capabilities was seen as fairy certain. The uncertainties are more a matter of how PHS will be applied and adopted—for example will they be mainly used by elites,

[8] A useful guide to several approaches, and to overall organisation of the approach, is provided by Rhydderch (2009).

[9] A detailed and free guide to this approach has been prepared by Waverley Management Consultants (2007).

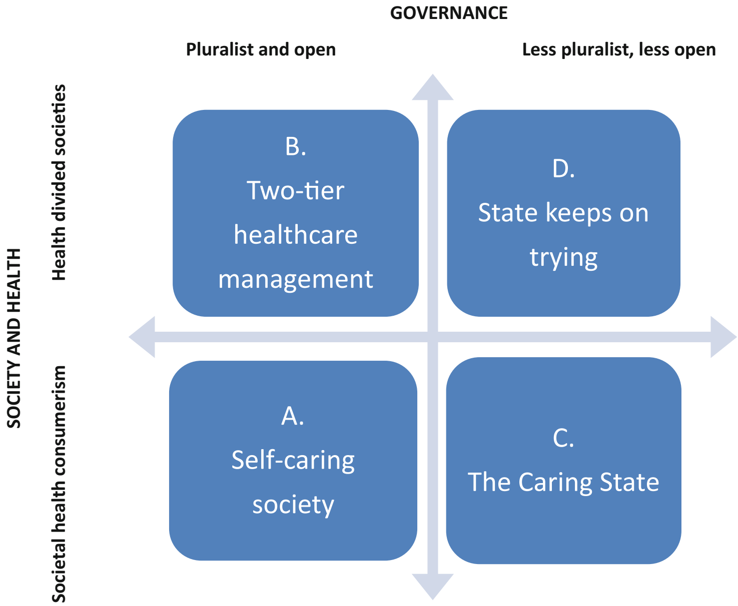


Fig. 7.3 Four scenarios for the future of health systems. *Source:* based on Codagnone (2009)

rolled out on a mass scale, or some mixture of these developments in relation to different qualities of PHS?

The first axis is **Governance**: The issue is whether or not drivers operate so as to push governments to play much reduced roles in production and delivery, control, standards-setting and financing of health services, and in seeking to shape the attitudes and behaviours of consumers/patients. If this happens, these roles are taken on to greater or lesser extent, by new players; if not, these players involvement in healthcare remains limited. One possible extreme pole is a ***more pluralist and more open*** governance and delivery of health care—where the government will focus mostly on policy making and monitoring of healthcare outcomes, will reduce its direct financing role, will introduce regulations and measures leading to new financing and business models, will stimulate public healthcare organisations and professionals to relinquish their full control on service provision, creating many new spaces for third party players to operate within. At the other pole is a ***less pluralist and less open***, and more government-dominated, governance—where the state and its network of healthcare organisations and professional remain the dominant players, where public financing will continue to be the main source of funding along already existing output based models and with third party players confined to very limited niche markets (The terminology of open/closed, pluralist/government-dominated is that of the original report: we would note that other terms might be used to refer to democratic accountability versus private markets, which might give the scenario accounts a different flavour. These "exploratory" scenarios thus have a rather "normative" feel).

The second axis is **Societal Differentiation**. This reflects uncertainty as to how far various drivers promote a fairly homogeneous society, with some tendency for individual attitudes, behaviours and capabilities in relation to health (and also to technology, and to payment) to converge; or instead promote increasing social differentiation, well beyond today's levels. One extreme pole is ***Societal Health Consumerism***, where high levels of confidence in technology prevail,[10] including acceptance of PHS providing remote treatment with little intervention from health professionals; at the other pole ***Health Divided Societies*** feature persistent and even exacerbated social differentiation, with serious problems of social exclusion.
Four scenarios were derived from examination of the combinations of these drivers, of the evolutionary paths that might result from their operating in different ways. In Scenario **A**, "**Self-caring Society**", government withdrawal and an open and pluralist framework of governance coexists with a health consumerist society which poses relatively few social exclusion challenges. In Scenario **B**, "**Two-tiers Healthcare Management**", there is also a lighter touch government, but this is confronted by a split society: a two-tiers management is chosen, with a plurality of delivery players and models for the health consumerist segment of society, but with government traditional delivery of health services where social exclusion issues persist. Healthcare's tiers result from conscious political choice. In contrast, in Scenario **C**, "**The Caring State (Good Big Brother)**" government retains full control and leverages social conditions to fully develop and use selected technology-driven PHS. The diffusion of such technologies, and strong lifestyle guidance, help contain rising healthcare costs and can produce positive outcomes for citizens/patients (though some consumers find their choices more limited than they desire). Scenario **D** is closest to a simple extrapolation of the current situation, where there has been failure to cope with its more problematic features. The "**State Keeps on Trying**", but difficulties in leveraging technologies and shaping attitudes and behaviours result in both steeply rising costs and *de facto* tiered healthcare system(s), with a worsened quality of publicly provided healthcare and social gaps between those who can or cannot pay for better and more sophisticated services, including PHS. The tiered nature of healthcare here results more from exacerbating trends, while in the "**Two-tiers Healthcare Management**" Scenario B, it results more from a conscious choice to cope with social exclusion issues.

Approach 2: "Archetypes"

Various organisations have applied one or other version of the "archetypes" approach.[11] This approach involves proposing a set of possible futures, defined only in terms of very abstract profiles, and asking workshop participants to consider

[10]These attitudes have permeated as much as 95 % of the adult population, implying that potential problems of social exclusion are not a matter of concerns about PHS.

[11]The authors have been very much inspired by work carried out by the Institute for Alternative Futures, using their versions of the archetypes approach. There are various ideas of where the approach was first developed, with the Hawaii Research Centre for Futures Studies suggested as a major influence in the 1970s. C.f. Bezold (2009).

what drivers would plausibly create a scenario aligned with each profile, and what this scenario would look like in more detail. Usually three or four profiles are provided, with various combinations. Sometimes one profile might be “Business as Usual”, a (usually broadly optimistic) extrapolation of trends with few disruptions. But there are almost certainly going to be factors reshaping business as usual, and scenarios resulting from this profile are unlikely to be very provocative; they run the risk of reinforcing the mainstream view that progress can be expected without need for structural change or adaptation to discontinuities. They may also be rather attractive to managers who prefer to emphasise them at the expense of other plausible futures—as a result, so some ForSTI practitioners (the authors included) prefer to avoid them.

A more challenging set of archetypes involves three or four non-business as usual profiles. For example, we may pose two profiles that challenge expectations, such as having the focal topic develop *better/worse* or *faster/slower* than expected. This of course means discussing what such terms mean, which is itself a worthwhile exercise. It is possible to introduce a profile that resembles the “success scenario” approach discussed below—for example, asking participants to envisage the “*best feasible*” scenario. Likewise we could request a “*problem-plagued, hard times*” profile; though there can be problems of acceptance of really grim scenarios, even if these display vividly some of the contradictions of business as usual. However, negative scenarios may be exactly what are needed when the ForSTI activity is intended to contribute to risk assessment.

Often the most interesting results emerge from asking about profiles that are “*different from*” expected. This encourages creative thinking, and can be pushed more by deliberately proposing that scenarios be built around profiles involving “*transformative change*” or “*paradigm shifts*”. While such scenarios are typically going to imply longer-term futures, they may be inspired by weak signals that are already attracting attention—or represent creative thinking based on historical analogies, cases of past paradigm change, for example. It is possible, too, to specify that the profile involves progress—just that progress here is taking on different features to those generally expected. In one workshop on the focal topic of e-science in Europe, the scenario of radical change created from this profile came to be seen as a particularly telling one. Better-than and worse-than scenarios basically involved different speed of roll-out and extent of uptake of the systems now under construction, led by the public agencies who are now in charge. The idea that new private sector actors could well disrupt this ongoing public sector led development of systems and infrastructures, was seen to be especially persuasive. Many of the participants concluded that even if the particular scenario developed—some Google-like firm, perhaps from an emerging economy, offers free or very low price access to massive data storage, sophisticated scientific programs, and supercomputer-like data processing, challenging the plans of the science establishment—failed to emerge, the chances of some disruption from external forces was rather high.

Another workshop using an archetypes approach of this kind was for a British Research Council: the focal topic was the possible contributions of, and demands upon, social research, posed by the rapid development of genomics STI.[12] The participants in four break-out groups explored the implications of each scenario for social research, and developed possible signpost events that could indicate movement towards each scenario.

- In **Genomics, Inc**. "better than expected", the benefits are primarily for the developed countries, the affluent, and corporations. Social science would need to consider impacts of genomics on various sectors of society, concepts of well-being, ethics and NHS use of genomics, the new industrial structure and property rights, as well as the growing divide genomics would contribute to. Signposts that this scenario is coming would include continuing mergers, increasing divide between public and private sectors, and growing inequalities among individuals (a genetic divide alongside the digital divide?).
- In **Genomics for All**, "positively different than expected", sees genomics developed to increase equity and sustainability. Social science research would support the development of international institutions that can regulate, for example, bioweapons; identifying genomic products and applications that will support equity and sustainability; comparative analysis of scientific and political change, using ICTs as an example, historical research on international institutions, understanding how "cultural creatives" unite politically and affect corporations, developing value impact assessment for new technologies. Signposts indicating this emerging future include international agreements on genomics treaties and standards, intellectual property concessions for developing countries, and new potentials being established through genomics for orphan drugs.
- In **Broken Promises**, "worse than expected", genomics works poorly, with applications developing slowly and having fewer benefits than anticipated. Social research contributes to re-evaluations of the notion of progress; reflexive social science would research alternative lifestyles and product use; better understanding of political change; the new approaches to risk are established that include the inevitability of "normal" disasters and the need to prepare for them. Some of the sorts of event that might constitute signposts on the road to this future include Greens winning in Tunbridge Wells (a conservative small British town), the biotech/agribusiness firm Monsanto facing bankruptcy, and Golden Rice being burned in India because of unforeseen side effects.
- In **Out of Our Control**, "radically different than expected", genomics STI is highly effective (for good and ill), but its applications are a destabilising force internationally and environmentally. In the scenario that was elaborated, China takes the lead in genomic STI, in the face of more stringent regulation in developed countries. Social research would consider the comparative

[12]This exercise is documented in a series of articles in a special issue of the journal *Foresight*, vol 4 no 4, in 2002 (Available at: http://www.emeraldinsight.com/toc/fs/4/4, accessed on: 21.01.2016).

advantages and disadvantages of nation states, their relations to transnational corporations, and the nature of international organisations. The sorts of events that could be signposts supporting this scenario include a Chinese body buying Monsanto, and European protestors attacking Greenpeace for obstructing their access to GM products.

Approach 3: Profiles and/or Starter Scenarios

Profiles may be developed that represent end-states of particular interest for those concerned with the focal area. For instance, they may be constructed around a particular set of possibilities that reflect the concerns of managers or policymakers—what would futures look like when one or other power is dominant, for example, when one or other technology path is closed off or proves unsuccessful, and so on. In a workshop, participants are requested to consider what forces might plausibly create such profiles, and what the resulting scenarios might look like.

Two examples illustrate that such an approach can be applied in various ways, adapted to the focal object and stakeholder concerns.

- The first example is a workshop whose focal topic was the application of Bioscience to Non Food Crops (NFCs) (Institute of Innovation Research 2003). Debate about the use of Genetically Modified Organisms (GMOs) in agriculture has almost entirely involved food crops and public concerns about health (at least in the UK, where food and related health scares have been prominent since the 1980s), with environmental issues and concerns about corporate control of agriculture also being raised. Four profiles were developed by the ForSTI team, all assuming that bioscience will continue to develop and widen its range of applications. The profiles varied in terms of the extent and style of development of applications of bioscience to NFCs in the UK, in particular the extent to which GMOs were allowed in agriculture. They ranged from Scenario 1, where regulatory and other developments making it possible to exploit the new technologies on a wide scale, to Scenario 4 in which there was practically no commercial use of GMOs in agriculture, though bioscience is still applied in other novel ways in crop breeding, etc. The other profiles suggest some use of GMOs in contained environments (not open fields), such as greenhouses, sealed polytunnels, etc. Scenario 3 restricts GMO use for NFCs to contained environments; Scenario 2 is one where some limited development of "open" GMO-based agriculture accompanies these contained methods. These profiles were developed into fleshed-out scenarios by break-out groups, who considered prospects for different types of NFC in each profile. The discussion led participants to conclude (to the surprise of many) that the most desirable and viable future would be likely to involve contained agriculture of high-value NFCs—not bioenergy or large-scale oilseed production, for example, but rather things like biopharmaceuticals and cosmetics).

- The second example derives from SANDERA, a study of possible future relationships between the European Research Area (ERA) and defence STI; ERA research and innovation activities have predominantly involved civilian activities, but technology spill-overs, new security issues, and other developments could destabilise this (James and Miles 2010). Four profiles were established, representing different types of relationship between ERA and security/defence research (Fig. 7.4). These profiles, focusing attention on different relationships between the major sets of activity (from indifference to close cooperation), proved a useful framework for exploring the dynamics that might lead to these different outcomes.

In contrast to such skeletal profiles, some workshops use "off the shelf" scenarios prepared in other work, possibly even published ones, as a starting point for the workshop activity. This could be used, for instance, to provide the workshop participants with a base against which to frame their own scenario(s). They may proceed to develop them in more detail ("What would this mean for my particular objects of concern?/for my particular communities of interest?"), to interrogate them more thoroughly ("How could this really come about? Would these resources be made available?" etc.), to criticise them ("fails to take into account....", "misrepresents the technical feasibility of...." etc.). Earlier scenarios may be used as a launchpad for constructing aspirational scenarios or the roadmaps associated with these. A workshop would be organised to systematically appraise the received scenarios and their scope for reuse.

Fig. 7.4 SANDERA's four profiles. *Source:* James and Miles (2010)

Some scenarios have been used in a succession of workshops, sometimes with the aim of deepening the content and/or elaborating implications for specific sectors or regions. This was the case for a set of scenarios developed in the UK Foresight Programme around the turn of the century (cf. Berkhout and Hentin 2002). The initial scenario framework has as its focal topic environmental issues and climate change, but it was subsequently used for studies with a variety of other focal topics. This 2×2 framework of these scenarios dichotomised developments in social and political **values** and the nature of **governance** (see Fig. 7.5). The 'values' dimension ranges from an 'individual' pole private consumption and personal freedom dominate, to a 'community' pole emphasis concern for the common good and future generations, with stress on equity and participation. The other parameter is 'governance', involving political and economic power structures. Its 'interdependence' pole involves power away from the national state level to more international governance, its 'autonomy' pole sees high exercise of economic and political power at national and/or regional levels. The intersection of the two dimensions affects how far governance is seen as a matter of regulating free markets and securing law and order, how far civil society plays a strong role, etc.

Berkhout and Hentin (2002) summarised a wide range of studies and policy activities in which these scenarios were used (and they appeared subsequently in several other ForSTI studies, being elaborated to throw light on, for example, issues of flooding); they remained a point of reference within several UK policy bodies for several years, and seem to have inspired scenarios developed by subsequent European projects. We know of work at the city level in 2015 that clearly draws on this framework.

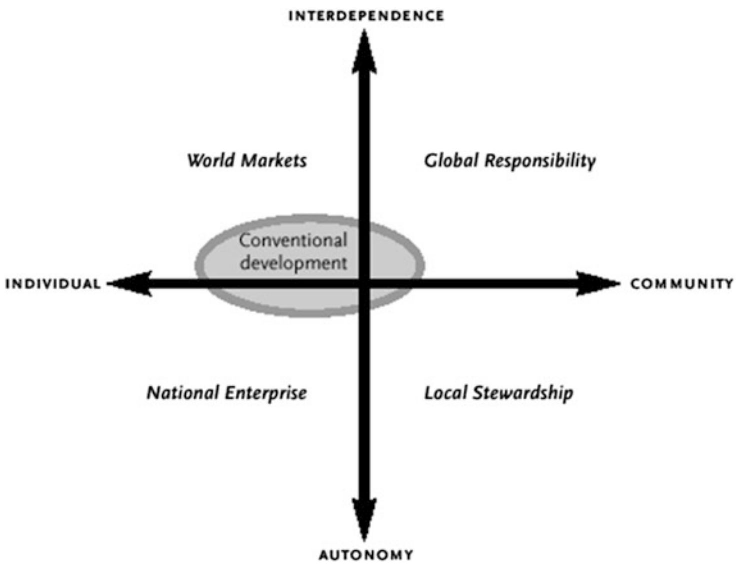


Fig. 7.5 UK Foresight "Environment" scenarios. *Source:* Berkhout and Hentin (2002)

In another example of reuse of existing scenarios, the PHS2020 scenarios from Codagnone (2009), mentioned above, were employed in 2013. This was in a scenario workshop seeking to extend the time horizon from 2020 to 2030 and examine business models and occupational roles that might be confronted. PHS2020 was an impressive study, and it had been expected that its scenario results would remain relevant. Thus the Codagnone scenarios were used as starters for the workshop discussion. However, perhaps because of the rapid changes underway in public health and in technology, and accumulation of experience in the PHS field, this was only partly true. The starter scenarios were not readily appropriated by the break-out groups to whom they were assigned: each group was quite critical about its scenario. The demarcation between a world of high state control versus that of a high measure of privatisation was seen as being too stark: a wide constellation of different public-private mixtures, varying across countries and health-related activities, was probable. For a longer term view—the horizon was now 2030—the starter scenarios were seen to be unstable, and ultimately to have been replaced by different models. The break-out groups proceeded to reformulate their starter scenarios to what they considered more plausible forms. Even while PHS were very likely to be introduced on a large scale over the coming decade and a half, they anticipated relatively incremental change in health systems and institutions. Nevertheless, they did generate rather different accounts of business and service models, the key actors organising PHS, the roles of various organisations and occupational groups, and the outcomes across society. The groups' proposed names for the three scenarios they generated—"The Dream Scenario", "Transitional scenario", and "Shared responsibility for a healthy society"—convey something of the flavour of their work. Despite the substantial revision of the starter scenarios, rich accounts of possible future developments were yielded, and the workshop could further explore how particular types of medical pathway would be transformed in the various futures.[13]

Approach 4: Aspirational or Success Scenarios

More obviously "normative" approaches usually focus on a desirable state of affairs (though it is possible to warn against particular negative outcomes, as well). An aspirational approach will attempt to identify the outline of a future with specific desirable features (how these are determined is, of course, very important) and then map out the routes whereby this may be achieved, and provide a more detailed appraisal of the nature of this future.

These approaches ask "how" questions. They were classically developed in the context of large programmes—such as that aimed at getting the first American on the moon. Bezold (2009) argues that the aspirational approach "involves understanding what might happen (likely and alternative futures) and a clear, shared commitment to creating the community or organization's preferred future. Both the

[13]See the report of the PHS scenario workshops at http://www.phsForSTI.eu/reports (accessed on: 09.09.2014).

understanding of the future and an effective commitment to creating it are essential… Being aware of the 'plausible' and the 'preferable' is critical. The plausible considers what might happen, the preferable what we want, often with some degree of commitment to making it happen… We acknowledge the power of scenarios to explore plausible future space. We add that the plausible space scenarios explore should include paths to visionary outcomes" (p. 81).

The "success scenario" approach typically develops a single scenario, and may well follow on from an earlier phase of multiple scenario workshops. The aim is to explicate a plausible and desirable course of development that stakeholders can broadly sign up to; to identify the steps required to get onto this pathway, and the indicators of progress in the right direction. The success scenario combines:

- **Desirability.** The scenario captures a vision of what could be achieved or aspired to, by the sponsoring organisation or a wider community that it represents.
- **Credibility.** The scenario is developed with the assistance of, and validated by, a sample of experts in the area, chosen to reflect a broad range of interests (and usually including both practitioners and researchers).

The scenario is described in terms of a set of goals that can be achieved, forming a "stretch target", challenging those concerned to aim for excellence, and to think beyond the boundaries of "business as usual". The development of indicators moves the scenario beyond vague aspirations, and allows for clarity as to what precisely is being discussed and whether and how far goals are being achieved. Action points are developed and priorities may be established, with the merit of having been derived from a participative process. The scenario is a communicable, tangible product of the process, which can be used to share the vision and mobilise other actors. The workshop process itself—discussing background inputs, debating and agreeing upon goals and indicators, and identifying feasible actions is valuable for creating mutual understanding and sharing of knowledge. This can establish platforms for putting in place the actions proposed.

Success Scenarios can be regarded as a hybrid of conventional scenarios and some elements of roadmapping. While systematic roadmapping (described in more depth in Chap. 9) often requires several workshops (in which participants determine the key events and actions, and fit them together across different layers of the roadmap), Success Scenarios usually involve more rapid and less structured appraisal. A success scenario activity may be the prelude to a roadmapping exercise–or actually draw upon the results of roadmaps generated in prior deskwork or workshops.[14]

[14]For instance, a series of basic roadmaps for specific applications of nanotechnology were developed before the main SSM workshop on this topic was conducted; they outlined the likely global development of these technologies, and enabled discussion in the workshop as to what might be accomplished within the UK. See Advisory Group On Nanotechnology (2002) *New Dimensions for Manufacturing: A UK Strategy for Nanotechnology*. London: Department of Trade

7.7 Scenario Building and Analysis in Workshops

We have just outlined some variant approaches to developing scenarios, and the examples used to illustrate these approaches largely involve their application in workshops. Across this range of techniques, a scenario workshop activity typically has a number of key steps, much like the overall ForSTI process itself; these are outlined in Fig. 7.6, with Table 7.1 summarising key elements and the ways in which each of the scenario approaches differ in the way they take these steps.

It is easy to forget that the workshop itself is not the only part of the exercise: there needs to be much planning before it, and ideally there will be a programme of follow-up activities. We include these phases in the outline that follows.

The Pre-workshop Phase

Before the Worksop can be conducted, a number of activities should be undertaken in the **Pre-Workshop Phase**. We follow Fig. 7.6 in discussing these:

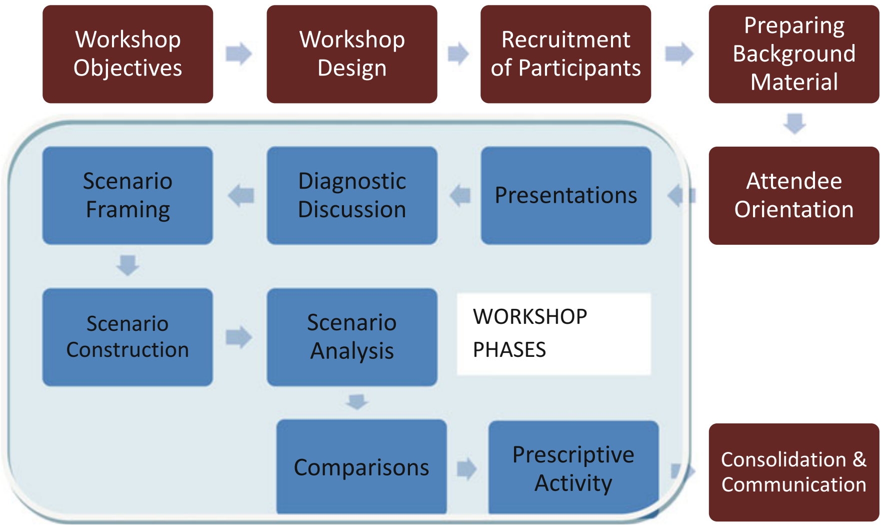


Fig. 7.6 A scenario workshop exercise

and Industry, DTI Pub 6182 2k/06/02/NP, URN 02/1034, Originally published online at http://www.dti.gov.uk/innovation/nanotechnologyreport.pdf (but removed); now available at http://www.innovateuk.org/_assets/pdf/taylor%20report.pdf; and Miles, I. & Jarvis, D. (2001), *Nanotechnology – A Scenario for Success in 2006*. Teddington, UK: HMSO. National Physical Laboratory Report Number: CBTLM 16 (available at: http://www.npl.co.uk/publications/nanotechnology-a-scenario-for-success-in-2006, accessed on: 14.01.2016). The initial roadmaps were regarded as confidential, and are not reproduced in these reports.

Table 7.1 Steps in workshop activities in different types of scenario workshop

	Scenario types			
Workshop Steps ↓	"Classic" 2×2 approach	Archetype profiles	Other profiles/ Starter scenarios	Success scenario
Introductions and presentations	Begin with a review of the aims, purposes and programme of the workshop. Participants often introduce themselves (briefly!), though this may be handled in smaller groups, perhaps with some ice-breaking exercises. Some presentations on the main objects of concern, and related background material, provide participants with further orientation and some common information.			
Diagnostic discussion	Typical activities here involve identifying most important drivers that are shaping the system, and exploring views as to how these may operate and change into the future. In many workshops there will be an effort to target the levels of uncertainty associated with each of the main drivers; this is an essential step in the 2 x 2 approach.			This step may be curtailed, e.g. if the background presentations have already adequately discussed key stakeholders' broad strengths or weaknesses.
Scenario framing	Two highly important drivers, whose future development and operation is highly uncertain, become the basis for the 2 × 2 matrix of four scenarios. This step will often involve some work amalgamating drivers identified earlier, so as to reduce the numbers involved and capture wider change processes.	Current trends and future prospects are discussed, and the archetypes introduced and explored—what would it mean to be better than/ worse than/ (radically) different from/ expected? This may lead to discussions of "success" (cf. the success scenario); if several versions of "different" are proposed, select a plausible and issue-raising example.	Here it may be a matter of introducing a set of predetermined profiles with relatively little content associated with them, or of reporting on the "starter scenarios" developed in an earlier exercise (which may have more content, but will need elaborating and perhaps updating or critical revision in the current workshop).	Framing here concerns the meaning of "success"—how is it to be understood? For example, does it involve research excellence, commercial exploitation, large-scale adoption of innovation? What is the importance of policy goals such as regional and social inclusion, or protection of environment, civil liberties, etc.?

(continued)

Table 7.1 (continued)

	Scenario types			
Workshop Steps ↓	"Classic" 2×2 approach	Archetype profiles	Other profiles/ Starter scenarios	Success scenario
Scenario analysis	The participants are split into four groups, and each is assigned one scenario from the matrix. Each break-out group is invited to consider "what if" the drivers were to operate as specified in this cell of the matrix, what sorts of event might unfold and what scenario would follow. Actions required to make the scenario more or less likely and/or to cope with it are identified.	The participants are split into groups corresponding to each of the profiles developed in the previous step. Each break-out group is invited to consider "how come?"—what drivers had to operate in what way to lead towards this profile; what developments could plausibly have taken the future in this direction, what implications follow about what the scenario would look like in more detail. Actions to promote more desirable futures and to avoid or ameliorate less desirable ones are identified.		With only one scenario to work within, break-out groups are typically invited to consider what success would look like in each of several areas/subtopics, and what would be needed to achieve this. Usually there will be efforts to suggest targets and indicators of progress.
Scenario (or sub-scenario) comparison	Scenarios are presented to a plenary session, where their plausibility can be debated. Some effort may be made to render the scenarios more distinctive, so that the polar opposite scenarios differ from each other in terms of secondary drivers and not just the two major ones forming the matrix.	Scenarios are presented to a plenary session, where their relative plausibility can be debated. One question to ask is how far drivers that are taken to be decisive ones for each scenario are similar (drivers operate in different ways) or distinctive (different drivers are coming into play). This allows for the scenario narratives to be developed so that a wider range of drivers and their possible roles is encompassed.		The work of the break-out groups is presented to plenary, and efforts are made to detect common issues and possible contradictions across the treatment of various elements of the scenario.

(continued)

Table 7.1 (continued)

	Scenario types			
Workshop Steps ↓	"Classic" 2×2 approach	Archetype profiles	Other profiles/ Starter scenarios	Success scenario
Prescriptive phase	All scenarios are plausible, though some may be seen as likely to be closer to the eventual future than others. Likewise, they vary in desirability. The actions suggested by each group can be viewed in this light—are they trying to create, change, or cope with a possible path of future development?	The "better than expected" scenario is liable to involve too many elements falling into place to be completely convincing, but actions to help realise it—and those welcome aspects of "different" scenarios, and those that help to avoid, or help to cope with, the "worse" scenario should be accumulated.	Some revision of starter scenarios may have taken place, with modifications of ideas as to key drivers. There may be some amalgamation of, or move away from, initial profiles/ scenarios. Otherwise, the points made in the "classic" 2×2 approach apply here too.	Each break-out group should have generated a number of proposals for action based upon requirements of its area. These can be regrouped in terms of key actors addressed, timespan, etc.
	The proposals deriving from each break-out group are brought together, new proposals generated (and proposals organised into categories—e.g. actors—and related to targets) by group brainstorming, "carousel method", etc.			
	Subsequent approaches to selection or prioritisation of proposed actions range from simple methods—participants may vote for preferences, or rate each proposal in terms of feasibility/cost and of benefits/impact—through to more complicated multicriteria analyses or roadmapping efforts.			

Objectives

The purpose of the scenario work should be established, the people responsible for conducting the activity should be commissioned, and initial decisions about financing, location, timing and required outputs established. For example, how far is the aim to gather in a wide range of opinion from external sources, and how far to build shared understanding within an organisation?

Design

Workshop design is an important task. Most often it is a matter of the core team discussing the best approach among themselves and perhaps with the sponsor. In some cases, a scenario design workshop, drawing on a range of expert and interested parties, may be constituted before the main scenario workshop, and view of (for example) other futurists and users of the work may be drawn upon. The design tasks include:

- Identifying participants for the scenario workshop—it is vital to include the right range of knowledge and expertise, and as far as possible key end-users of the results
- Determining what background research might need to be conducted, what background materials collated, to provide participants with some common informational resources
- Defining the workshop procedures (what scenario methodology is to be deployed; what areas of study within the domain of interest should be selected, what specific questions might be used in the workshop)
- The design tasks should result, too, in specification of who is going to do what (presentations, facilitation, etc. at the event), and also of the facilities required (rooms, computers, flip-charts, post-its, etc.).

Recruitment

The nature of the participants required should be established (see also Chap. 4). Typically various types of expertise are needed, often with different types of stakeholder (e.g. researchers, business communities, policy communities, civil society) engaged. However, it is important that the participants should be open-minded people who are prepared to dialogue, to listen and to present their ideas in relevant ways (not just to give standard lectures, not just to present their organisations' current standpoint). If there is a design workshop, potential participants may be discussed there, along with good ways of motivating their participation.

Preparation of Background Materials

It is common practice to provide participants with some shared information, terminology and the like. Texts may be mailed out and/or weblinks supplied to relevant resources. There will need to be some specification of the project and its main areas of concern, for example. Typically such material will have been prepared for the workshop and/or the wider ForSTI programme of which it is part. But material may also derive from other ForSTI or similar exercises, from routine reports on competitive or strategic circumstances, and the like. In business settings, SWOT analysis of the organisation's position in the area of concern is often used; policy analyses also use SWOT or benchmarking inputs to compare the region, country or organisation with relevant others. Other material may involve academic or consultancy analyses of relevant trends and problems, statistics of research related to this area; relevant Delphi material; results of computer simulations and econometric analyses. It is probably better to avoid apparently definitive claims about future eventualities, and instead to indicate what available literature and thinking suggest might be possibilities, challenges and opportunities.

Attendee Orientation
A brief programme of the event, with specification of objectives, desired outcomes, and suggestions as to how the work is to be conducted (e.g. what degree of anonymity can be involved, how participants will be asked to contribute). People who are being asked to make presentations or play other roles should be briefed about this. Facilitators should be provided with a clear understanding of their roles (for example, they are usually encouraged to join into discussions, but have important functions to perform in terms of ensuring that discussions are kept to time and remain focused on the intended mission). It is helpful to prepare a highly detailed version of the programme for facilitators, with suggested timing for different steps of the discussion, examples of tasks and questions that may prompt discussion or provide ways around difficulties (for instance, if a groups discussion is failing to reach consensus on a point such as the most important drivers, suggestions can be provided about ways in which voting can be organised).

7.7.1 The Workshop Itself

A scenario workshop may be undertaken in a very short time period (a matter of hours—in which case some of the activities discussed below may need to be truncated or dropped altogether), or extend over a day or several days. The workshop may involve from 10 people upwards—it is common to engage 20–30 people (with "break-out groups" of say 6 to 12 people exploring different scenarios in detail), though we have experienced workshops with up to a hundred participants (which requires a great deal of planning, since there is not usually time or energy for listening to reports back from a large number of break-out groups).

Scenario workshops typically feature periods of extensive exchange of ideas and debate about them, and periods where ideas are being written down and listed, where different lists are combined, and so on (This is a familiar evolutionary process—there is exchange, generation of novelty, selection among options). The process usually involves much dialogue, and use of such instruments as whiteboards and flip charts, though computer-based ("groupware") tools may be used effectively (The danger with these tools is that participants spend much time staring into their screens, and not enough in dialogue with others. The tools can overwhelm the important face-to-face interactions, so they need to be used carefully, for specific activities). The workshop will be conducted with inputs from at least one facilitator each, and often other helpers will be engaged to take notes, record material from flip charts, and deal with logistic issues as they arise (for example, it may be necessary to reschedule lunch or coffee breaks, to shift activities from one room to another, to replace flip charts or pens…). Typically such facilitators have acquired their skills through involvement in these and similar group activities; they may have received some training in other workshop methods (from T-groups through management workshops to academic seminars).

There is often a degree of improvisation in workshops, as activities overrun their estimated time, events (such as fire alarms) intervene, new options are posed by participants, and so on. The convenors should maintain a relaxed composure when experiencing such pressures. Steps taken in the **Workshop Phase** include, in roughly the typical order: Introductions and Presentations, a Diagnostic Discussion, Scenario Framing, Scenario Construction, Scenario Analysis, Scenario Comparisons, and a Prescriptive Activity. We discuss them sequentially below, with Table 7.1 summarising the main steps and the variants taken by the four workshop types outlined earlier.

Introductions and Presentations

Usually participants will be asked to briefly introduce themselves—though in a large workshop introductions may be saved for break-out groups. Sometimes, ice breaking exercises will be employed, or the group will have shared a meal and got to know each other to an extent before the real work begins.

The scenario workshop will typically begin with a presentation from the convenors and/or sponsors, about what the purpose of the activity is, and the programme that is to be followed. Some ground-rules will usually be explained, usually involving anonymity if people do not want comments attributed to them, the need for open-minded and nonaggressive conversation, and so on. There will then often be some presentation of background material that has been prepared especially for the workshop, or perhaps material concerning the focal topic drawn from the wider ForSTI exercise. Examples could be: a SWOT analysis of the organisation's position in the area of concern, a benchmarking input that compares the region or country with relevant others, a summary of a research project, of a set of interviews, or a literature review. Other inputs might include statistics or other data related to this area; relevant Delphi material; results of computer simulations and econometric analyses—even roadmaps or other peoples' scenarios! The material should help participants establish common understandings of terminology, trends and dynamics; it should be prepared in such a way as to indicate what informants and available literature suggest might be possible.

Diagnostic Discussion

STEEPV (see Chap. 5) is one tool for eliciting ideas and grouping material, often used in the workshop or in the preparation of background material. Participants are asked to identify factors and issues under the headings Social, Technological, Economic, Environmental, Political, and Value-Based factors.

This forms a useful prompt to make sure that a comprehensive range of issues are covered, and to permit a division of labour across subgroups, rather than necessarily providing a framework for categorising drivers and shapers for further work and communication purposes. Often the approach adopted will involve break-out groups identifying a small set of key drivers and shapers and bringing these back to be presented in a plenary session. One group may be asked to consider drivers associated with S and T, for example, one with the two Es, and one with P and V. Sometimes different "prompts" and categories will be employed, for example in one ForSTI study we looked at such headings as public attitudes, skills and training, regulatory and institutional environment, scientific capabilities, market environment, etc. Box 7.1 reproduces the definition of STEEPV categories and the working instruction issued to groups in one large-scale scenario workshop, for the work of break-out groups and the subsequent plenary discussion.

The workshop itself may go on to grouping of "driving" factors. Typically there will be a plenary in which each break-out group presents its complete set of drivers, or probably some reduced set—its "top ten" for example. These will be discussed and clarified, and any overlaps may be grouped together. Then some procedure—usually voting (especially in a large group), using computer tools or techniques as simple as allocating votes via post-it notes or pen marks against the list of drivers assembled on a wall or a set of flip charts. Thus a "hit list" of factors that the workshop has identified as critical influences on which path of development is taken is created.

A useful adjunct exercise, particularly important for the 2×2 approach, is to have the most important drivers also rated in terms of uncertainty—how far development of a particular trend, for example, can be taken for granted, or is a matter of considerable conjecture; or whether a particular trend might result in one set of changes or in another completely different set. This highlights key areas where early warning of potential breaks may be required, where research into possible reactions could be helpful, where strategies need to be robust, etc. The plot of uncertainty against importance can often be very revealing, and even if it is not used as a starting-place from which to develop scenarios, it can help demonstrate how far members of the workshop share similar views about major issues and debates.

Box 7.1 displays the instructions used for a low-tech voting method used in one workshop to elicit ratings of importance and uncertainty. The end result was a visually compelling clustering of stickers, and of stickers of different colours, across several flip charts that had been attached to the walls of the meeting room. This provided an excellent focus for subsequent discussion.

Box 7.1: STEEPV and Group Instructions Used in a Scenario Workshop

Break-out Groups

We suggest three break-out groups of approximately 8–12 members each. Each group will address two of the STEEPV categories. (These categories have been introduced in the presentations, and are explicated a little more below.)

YOUR ROLES:

Each group should appoint a chair and a rapporteur at the outset.

Chair's role: to keep the break-out groups to their tasks; to ensure that all participants have a say and that people are not being excluded due to other people's forcefulness or superior status, to defuse conflicts. To prevent people giving long lectures and not engaging with the task or listening to others.

Rapporteur's role: to keep notes on the process and decisions, and be prepared to report these back to the workshop, in a succinct way. To prepare a 5–10 min presentation. It helps to write down ideas as they emerge onto a whiteboard and/or flip charts, etc. This demonstrates that ideas are being captured and gives a point to reflect back on. They may also be useful for the plenary presentation.

Everybody's role: Remember that you are being asked to participate as an individual, not a representative of an organisation. Please talk on the basis of your views, your knowledge—not just echoing the "line" of a particular organisation. One ground-rule of Foresight work is that remarks are not attributed to individuals, and people should be free to express their views, and to debate each other's views, in the spirit of constructive dialogue!

TASKS:

For the first part of the morning, we will identify a wide range of **influences** that are liable to shape the topic. What are the factors that are liable to speed up / slow down / change the direction of a path of development? These could be trends or events. They are **not** the end-points of a path of development (e.g. social goals like better health in 2020). But peoples' aspirations for such goals (e.g. political pressure to improve health or living standards) can be an important influence. Early moves in the direction of a particular goal could also be an influence (e.g. better health outcomes over the next few years could have effects on people's attitudes and behaviour towards innovation, reforms, etc.). In later parts of the morning, we will group and select among these drivers, considering which ones are most important to the topic considered, and which ones are least certain in terms of future development.

TASK 1: STEEPV Brainstorming in Break-Out groups

(Note that each group should have appointed its chair and rapporteur at the outset!)

Time allocated: First 45 min of the morning break-out (10.14–11.30)

(continued)

Box 7.1 (continued)

The immediate task is to brainstorm drivers that are liable to be important influences on the development of your topic over the time period in question. Breakout groups will focus on sets of drivers as follows:

Group I—focus on factors S and T

Group II—focus on factors E and E

Group III—focus on factors P and V

Each group should use flipcharts—begin with one of the two categories and brainstorm ideas, then move to the other.

First of all, spend **20 min** on each of your STEEPV factors, aiming to come up with a list of bullet points representing different drivers that could be important for your topic.

STEEPV is the acronym for the categories Social, Technological, Economic, Environmental, Political and Values. These form an aide-memoire for classifying relevant trends or drivers influencing the topic we are looking at. We would like you to use these categories to make a note of factors which you think could be major influences on the topic over the *next decade* or 15 years. The set of categories is intended to be sufficiently wide-ranging and comprehensive so that we are encouraged to consider a wide range of topics (perhaps a wider range than is habitual), and to provide a convenient way for grouping them together.

The list below provides examples of the sorts of things that can be grouped into each category. Do not feel constrained to cite only items from this list! And do not send a lot of time fretting about which category an issue belongs to: to first important step is simply to generate lots of influences on the topic.

TASK 2: Working with the outputs of STEEPV Brainstorming in Break-Out groups

Time allocated: Second 30 min of the morning break-out

The task now is for each break-out group to work through its suggestions. The aim is to come up with the top *3 to 5 MOST IMPORTANT influences* under each of your STEEPV drivers.

This means discussing the drivers, combining those that deal with essentially the same idea, explaining why they are more or less important. You may well discover that several of the ideas that have been generated are very similar or closely related, so it may make sense to group them together under a new heading

Write the main ideas very briefly (a few words per driver) in large and legible text, onto a set of flip charts (one for each category—one S chart, one T chart, and so on).

You may well want to further group drivers under new headings: form any such groups if they apply to drivers that you think are important.

(continued)

Box 7.1 (continued)

Now the difficult bit: Select your top 3–5 drivers for each STEEPV area by group discussion: try to reach a consensus.

What if this is taking too long? Remember, you only have 15 min per category! One solution is to take a vote. For example, if you are divided about which of two drivers should stay on the list and which go, you could take a show of hands. If things are more messy (they often are), or you simply have not had enough time to explore everything, then you can vote onto the flip charts where the drivers are listed. Each participant can be given three votes to nominate what they think the most important drivers are. These votes may be made with a marker pen, or by sticking post-its against the topic. We count up all the votes and choose the top 3–5 items for further work.

Finally: Your rapporteur should now have a set of flip charts, each containing a list of 3–5 drivers under an individual STEEPV heading, on which they can report to other groups in the plenary that follows. It is convenient if these drivers can each have a succinct label!

TASK 3: STEEPV Reporting Back to Plenary

Rapporteurs: Each rapporteur should report back to the plenary group on the set of drivers that they consider most important in influencing their topic area. Please try to make a strong case for these being important drivers. Please make brief presentations—5 min at the absolute maximum.

Put the flip charts up on to a wall, or set of stands, so they are clearly visible. Discussion at this point should be mainly a matter of clarification and points of information.

It is just possible that some items from one group will be seen as highly relevant to influences mentioned by another; it is possible that the same basic driver has come up in more than one STEEPV category—in which case, we may well want to combine these (if possible) into a single driver. We should put all the flip charts up next to each other for comparison purposes.

TASK 4: Reviewing STEEPV Issues (Plenary)

Time allocated: 15 min

Each participant is allocated three post-it notes to stick against most important influences—or asked to register three votes by marking the flip-charts with a pen (or by voting by sticking post-it notes against the influences).

At the same time, we want to capture ideas about how much uncertainty there is about how the influences will develop or shape the NHS.

Each participant: Your task now is to use these as “votes” to nominate which of the drivers you believe to be most important in shaping the pattern of development of the topic.

You vote by sticking the post-its or making pen marks next to those drivers that you consider most important. You can put all three votes against one

(continued)

Box 7.1 (continued)
topic is you think this is overwhelmingly critical, or distribute them in some other way.

But there is an additional element to this task: we also want to get a sense of how uncertain you feel about how the influence might evolve. We would like you to use different colours to indicate whether you feel:

(Red) = highly uncertain about how the influence might evolve or what influence it might have;

(Yellow) = moderately uncertain about how the influence might evolve or what influence it might have;

(Green) = see the influence as fairly predictable.

Scenario Framing
The structure of Scenarios may be created during the workshop on the 2 × 2 basis, given the importance-uncertainty votes acquired by the procedures outlined above. In this case, the challenge is liable to be that of choosing between, or compositing, a number of different highly important/highly uncertain parameters. While the organisers may well use their experience to move this process along, it is often possible to ask workshop participants themselves for views as to which would be the most interesting and/or informative parameters to select, or whether it is possible to step back a little and see two broad classes of parameters as being linked together in some larger set of variables.

On occasion, it may be that the range of alternative courses of development associated with a single parameter or cluster of parameters is so regarded as being important by the workshop members that scenarios can be constructed around this parameter alone.

Other approaches to scenario involve applying more a priori frames and profiles. We may re-use scenarios developed in earlier studies or workshops. In such a case, these “starter” scenarios need to be introduced, and the break-out groups assigned one or other to consider. Whether they are encouraged to be critical of the scenario or simply to work on deepening it or extending it to a specific focal topic or subtopic, will depend upon the mission of the workshop. We may take this as an opportunity to introduce the archetypes or success scenario profiles as the frame for scenario construction, in which case there will be need to discuss the content of the terms in question mean (see Box 7.2). Whose expectations are being “bettered”, and what does this mean? What is really “different”? What are the key criteria of “success”—for example, if we are talking about some set of innovations, is success a matter of invention, production, diffusion, or application . . . being a matter of a particular social or geographic unit? In some cases it may be possible to employ a set of descriptions of such characteristics, and ask the workshop members to discuss or vote on which are the critical ones for the scenario.

This is an important discussion in its own right, but it will be necessary to reach some compromises—there are liable to be more objectives, interests, alternative circumstances to consider than can reasonably considered in depth in one workshop. It is worth making a note of topics that have been put on one side, for further discussion, and including these in reports that are circulated more widely.

Box 7.2: Introducing Profiles

Brief instructions as used with the "archetypes" approach

We will form three break-out groups. Each will be given a "Profile" to work with. The three profiles are:

α—"Better than expected": things develop very well for the focal topic that concerns us, so that current goals are substantially exceeded (quantitatively or qualitatively).

β—"Worse than expected": things develop very poorly for the focal topic that concerns us, so that achievements fall well short of current goals—though this is not "falling off a cliff", total abandonment of efforts to manage the focal topic.

γ—"Different than expected": things develop in directions that represent a new paradigm of development, a substantially different context for the focal topic.

Brief instructions as used with the "success scenario" approach, when applied to the success of a particular country in successful application of a specific set of innovations

We will shortly be working in a set of break-out groups where we will be considering various aspects of this focal topic. In each case, we want to be considering what would be a desirable, yet feasible, state of affairs for [our organisation/country/etc.]. [For example, w*hat would it mean for our country to be a world leader in the development and application of at least some areas of this set of technologies?*]

Before we do so, we would like to briefly consider what success might mean. Do we mean success in social, commercial, environmental terms? Should success for the whole country/organisation mean that different parts of the community are participating to more or less equal extents? How far are we talking about widespread or routine use of these innovations, how far about their effectiveness in achieving the intended aims?

When we are focused on a "success scenario", we may want to characterise this success in terms of various possible goals and elements of success. In the FISTERA project (Pascu et al. 2005) the success scenario could be viewed in terms of various goals laid out for the European Union in its statements about a desirable future (e.g. the Lisbon Objectives for Europe in 2010). Having considered the alternative scenarios generated in an earlier workshop, participants in this workshop outlined the features of a success scenario (by rating it in a computer-based system).

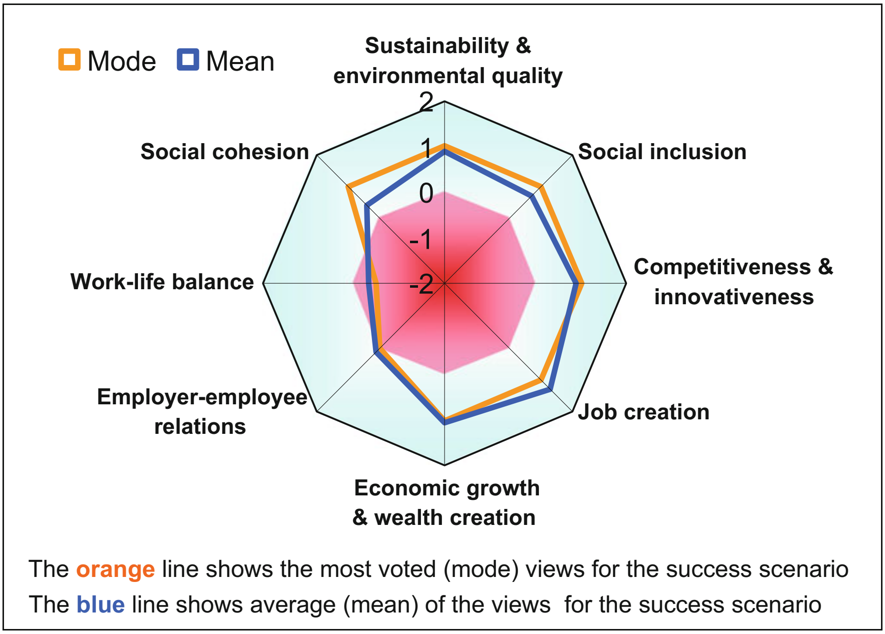


Fig. 7.7 Profile of a success scenario. *Source:* Green et al. (2005)

Figure 7.7 displays the results. It will be apparent that the goal whose attainment was least plausible in this scenario was "work-life balance".

Scenario Construction

This activity is usually undertaken in small break-out groups of 4–10 people. It is helpful to have a facilitator, to explain the task to the group; often this person can help move things along by making notes of points raised on a flip chart (This provides a point of reference for participants, and shows clearly that ideas are being listened to and registered). The facilitator will be provided with a detailed set of the activities that the group is to undertake, with suggested timings and types of outcome. Larger groups should appoint (or have appointed) a chairperson, too, to moderate discussion—in particular, ensuring that proceedings are not dominated by one loud person and that all participants have a voice, and to help keep the group on track. A rapporteur is needed to report back to plenary sessions.

Whatever the specific mission of the group and the overall workshop, a first task will be that of achieving familiarity with the profile or starter scenario they have been provided with. Often what happens is that a first working consensus is reached on the main features of a plausible scenario that may arise from the set of drivers or the movement towards the profile suggested. It can be helpful to prepare a succinct statement of just what the scenario is (30 words maximum); and create a (catchy and telling) name for it one that communicates some key features, providing an aide memoire to help identify the scenario, to distinguish it from alternatives, and to communicate it better to others.[15]

The overall task is to put flesh on the bones the group has been given, to define and describe a plausible scenario corresponding to the operation of drivers or the profile in question. This needs to be a realistic prospect, not one that requires too much good or bad luck, or that is contingent upon unexpected positive or negative wild cards. The scenario is then developed, for example by examining such questions as:

- What is the role of the various **drivers** in promoting the development of the scenario? Can we piece together a story of the scenario's evolution and its outcome in terms of these drivers?
- What would the role of the key **actors** be in this future history? (An indicative list of actors relevant to the focal topic can be provided)
- What are the main events that are likely—can particularly resonant examples be suggested? (It can be helpful to capture such events in terms of newspaper headlines)
- How would we know whether or not we were on this path of development? What are useful **Signposts and Indicators** of movement toward the scenario? Can we express these in terms of statistical trends or, again, as headlines in the media?
- What does this future look like in more detail—how does the focal topic appear in this future, what are the achievements and problems of the organisations or social groups that most concern us?

Each of these tasks should result in the collection of many points on flip charts or computers/projectors. The main points of the discussion, and especially the conclusions reached (for example, the top three points in the answers generated for each of the questions) should be summarised in a coherent form, for rapporteur to present to the plenary, when they will only have a few minutes in which to explain the group's thinking and to "sell" the scenario to the plenary as presenting a significant plausible future that needs to be considered seriously.

Some workshops will now move directly to the task of comparing scenarios, which is then followed by a consideration of implications for action. In some workshops there is first a period of "touching base" with the plenary, so that participants are aware of the different scenarios (or sub-scenarios) that are being considered, and can reflect on whether there are challenges raised for the assumptions that they have been working on. In some workshops the break-out groups continue to develop implications for action of their specific scenario (or sub-scenario) and bring these back to the plenary as part of the presentation and subsequent discussion.

If the break-out group continues to work on the implications of its scenarios for the policy or business strategy areas related to the focal topic, there are a number of

[15]This naming of the scenario is less relevant in the success scenario approach.

approaches to pursue. One interesting issue is how far thinking through the alternative scenarios challenges the assumptions under which the organisation has been used to working? Then, for each scenario we need to examine what key issues arise for the organisation: for example, what are the 3–5 top priorities in terms of issues that demand further study, where there are challenges for received wisdom and routines, what practical issues may arise concerning who should take what action. The workshop will typically be organised to move from analysis of multiple scenarios one by one, to achieving an overview across the scenarios.

Following this activities are typically introduced that elaborate implications of the scenarios for the policy or business strategy areas under consideration. One interesting issue is how far thinking through the alternative scenarios challenges the assumptions under which the organisation has been used to working? Then, for each scenario we need to examine what key issues arise for the organisation: for example, what are the 3–5 top priorities in terms of issues that demand further study, where there are challenges for received wisdom and routines, what practical issues may arise concerning who should take what action. Box 7.3, below, reproduces instructions used to orient a break-out group in one workshop to develop its ideas for actions.

Box 7.3: A Break-Out Group, Developing Action Implications from Its Scenario

We now move to examining the points for action that could be implied by, or deduced from, the scenario that has been developed by your group.

First task:

Brainstorming of main actions that are required to meet the challenges of this scenario (feel free to include actions that may have been provoked by the other scenario presentations).

- What actions could help avert or cope with the dangers and difficulties foreseen?
- What actions could increase the positive opportunities available in the event of these future developments?

It may be helpful to organise brainstorming around a series of broad classes of action—for example (this is merely a suggestive list) those connected with:

- Skills and training, professions and professional bodies
- Management and organisation
- Regulation and legal issues
- Funding and financing
- Public relations, marketing, lobbying, relationship with other bodies, etc.
- Technologies and infrastructures

(continued)

Box 7.3 (continued)

In the brainstorming stage, we do not try to assess the suggestions, the important goal is to collect a wide-ranging set of suggestions. So do not spend time critiquing each other's ideas, and if the flow of ideas is faster than one person can put onto a flip-chart, make use of post-its to jot down and add further ideas. (These are the "WHAT actions" points.)

Second task:

You should now have a good range of ideas; we suggest you transcribe these to a new flip-chart (or set of charts), grouping them in terms of the key actors that would be needed to implement the activity. (These are the "WHO acts" points.)

Now discuss the WHY, WHEN and HOW points. Which actions will have the biggest effects? Which ones are absolutely necessary and which ones are more debatable? Which actions have to be undertaken immediately, or require prior action to prepare the way for their introduction and successful implementation? What problems and difficulties might be confronted in trying to put the actions into place?

Third task:

Select those actions that you consider to be BOTH feasible (especially if they are relatively easy and inexpensive!) and to have high positive impacts. We propose that each group select 5–10 actions at this stage (please keep a record of other suggestions). Write a note on each action, saying what it is, and who should do what (and when).

Scenario Comparison

The next step is for the various scenarios, or sub-scenarios, to be presented to the entire workshop in a plenary session, and discussed. The rapporteurs who make the presentation should explain why this course of events and outcomes is a plausible one, and make a strong case for the need to take this seriously. They should offer the opportunity for other members of their group to add any points that they have missed, and to clear up any misunderstandings; they should take questions and provide answers to the other workshop members, about ambiguities or unclear rationales. This process may take from 5 to 20 min.

Having presented all (sub-)scenarios, these can now be compared more systematically. Are there inconsistencies? In the case of sub-scenarios, inconsistencies may involve the various elements not fitting together well (e.g. being reliant on different assumptions as to framework conditions and policies, or conflicting in terms of where resources need to be allocated). Where different scenarios are contrasted, there may be drivers or actor choices introduced across the narratives that suggest that earlier discussions about uncertainty of drivers have been overturned, or it may be that supposedly contrasting scenarios are beginning to look very similar (as was the case in the PHS scenario exercise mentioned above).

Some futurists are keen to assign probability rankings to different scenarios, and users sometimes request this. While it would be very appealing to decision makers to have a good assessment of the likelihood of different outcomes, and thus the risks being taken by gambling on one or other, this runs the risk of false precision. Decision makers may put more faith in one set of outcomes than is warranted. Arguably, no single scenario of the sort described here should have a probability estimate associated with it: the actual future course of events will diverge from, and perhaps be a composite of, all of the options considered. A simple profile may be an accurate description in terms of its limited parameters, but a full scenario is bound to feature some inaccurate details; and with a near-infinity of possible scenario variations, the probability of any particular account being fully realised declines toward zero.

It can be valuable, instead, to discuss collectively which elements of the scenarios seem more or less realistic. Often this discussion can provoke further elaboration of the details of a scenario, of the operations of drivers, and so on.

One approach that can facilitate this discussion is to request from participants, not estimates of the probability of different scenarios, but of other features. One line of enquiry is to estimate how far various normative goals might be realised in each scenario, for example—this can help later construction of a "success scenario". A different approach is to ask **how far** the future is liable to resemble each scenario, how many of the elements described are likely to emerge over the time period in question. This can be done by each participant allocating a set number of votes across each scenario, for example, or by use of a set of rating scales for each scenario. In the FISTERA project (Pascu et al. 2005) this latter technique was used, with participants keying in their judgements about each scenario into a groupware system that allowed for rapid calculation and display of results. Figure 7.8 reproduces the results of this exercise.

Several notable features emerged from this exercise. First, none of the scenarios was felt to be a complete representation of the future. Some mixture of elements was most likely. One of the scenarios (SCEN2 in the table—this was the scenario whose headline title was "Sustainable and Inclusive Information Society"), however, was seen by some participants as thoroughly unrealistic, and few expected many of its elements to be apparent. The other scenarios were seen by most participants as liable to be moderately or considerably featured. These results provoked discussion about possible developments, with SCEN2 seen as being too contingent upon a number of relatively unlikely events. We have experience of other workshops, too, where the "radical transformation" scenario was thought to be only reflected to a small extent in near-term futures: but as increasingly plausible as we move into the longer term. Thus it may be worth delving deeper into these issues in the workshop discussions.

In the "success scenario" approach, a step beyond contrasting sub-scenarios can be further characterising the overall success scenario by specifying concrete ideas about how to recognise that the success scenario (and its sub-scenarios) is becoming, or failing to become, a reality. Some preliminary ideas of the sorts of indicator that might be developed may be provided to kick off the work (for example, we

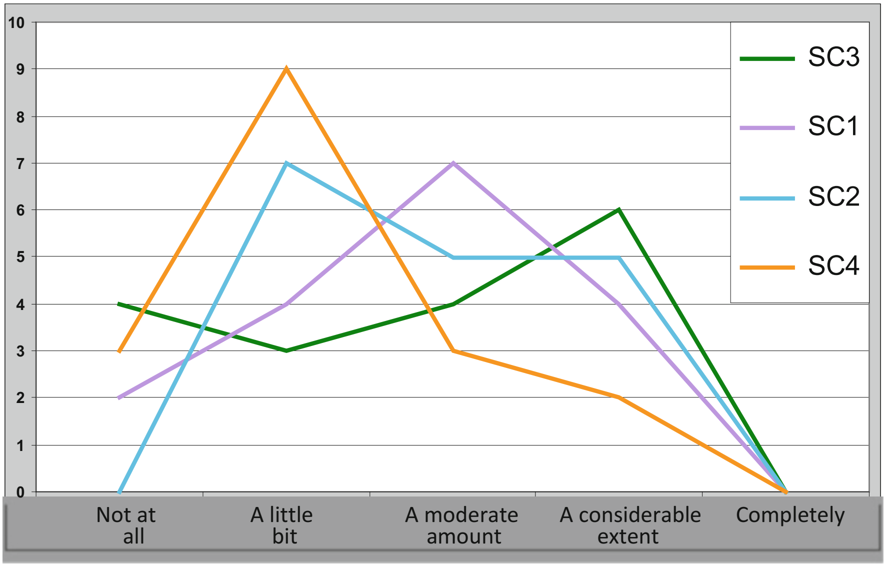


Fig. 7.8 How far the future was seen as being likely to reflect each Scenario, in the FISTERA workshop exercise. *Note:* The figures represent the numbers of respondents rating each scenario in terms of one of the categories on the horizontal axis. *Source:* Green et al. (2005)

might have diffusion levels of an innovation, measures of lives saved or expenses reduced, suggestions about spin-off firms or public attitudes...). The plenary session or subgroups are challenged to suggest plausible quantitative estimates of such indicators—to clarify points of agreement and disagreement, to provide tools for monitoring progress, and to suggest alternatives to the narrow set of indicators that are typically used to drive policies.

Prescriptive Activity

The final element of scenario workshops is usually a session designed to elaborate the implications of the preceding discussions for the actions of various stakeholders. This can be accomplished in various ways, but the underlying activities always involve generation of a series of proposed interventions, rendering these more concrete in terms of who should do what, when, with what objectives, and some process of assessment and/or prioritisation and selection among these.

In this step, it is very helpful to draw upon the expertise of people who have been involved in the policy-making or strategy formulation activities of key sponsoring/stakeholder organisations. They will be able to contribute their understanding of the language and rationales which can be used to “sell” specific policies, the timetables of decision-making systems, existing initiatives that might be used or complemented, and so on.

As discussed above, and illustrated in Box 7.3, one option is for the break-out groups to consider what actions are implied by their specific scenarios—to help create, change or cope with the developments outlined. A slight variant on this, which has the virtue of introducing a different flavour to the activity, and getting people on their feet, is the "carousel method" (also known as the "samba"). Here, the team members have put a series of flip charts on the wall or on stands around the rooms being used, and the break-out groups (or new groupings of participants, if this makes sense) are encouraged to process around these (each starting at a separate point). They can see the points made by previous visitors to each poster, and comment on these and add new ideas of their own. The various posters may cover *specific themes*, such as research, training, public attitudes, international relations.... in which case the task is to specify what interventions should be made, and who would be responsible for these. Or the posters could cover *various stakeholders* and actors, such as government ministries, Universities, scientific associations, financiers... in which case the task is to specify what interventions they should make, when and with what objectives. It might be useful to assign flip charts to different types of policy instrument, too, though this might constrain creative thinking as to possible actions.

The resulting lists of actions can be transcribed onto a common poster or set of posters), a whiteboard, or a computer/projector system. If time is short, these can be briefly discussed and then voted upon (e.g. each participant allocating a number of votes across a set of actions). If there is more time, rather more sophisticated assessment of the interventions can be made. For example, there could be ratings of the actions (or a set of priority actions chosen through the voting procedure as mentioned above) in terms of the perceived benefits and the likely costs or difficulties associated with them. This can be a relatively simple assessment, or a more complicated one—for example, in a FISTERA "success scenario" workshop, the actions were rated in terms of the participants assessed each proposal in terms of feasibility captured by PREST headings—Political feasibility, Resources (i.e. economic feasibility), Ethical constraints and values (i.e. social feasibility), Sustainability (environmental feasibility) and Technological Feasibility. The various feasibility measures were combined and plotted against an "importance" measure in an approach familiar to strategy analysts. This let us see how the various actions were located in terms of feasibility and importance, and to home in on those that are "immediate" (high importance and feasibility), and those that are "intermediate" (important but less immediately feasible).

It is normal courtesy, of course, to conclude the workshop by thanking participants, and explaining how the organisers will feed back the workshop results to them and to the ForSTI process more generally. This can be a good moment for some words from the project sponsor, for engagement of participants into further activity—and for soliciting any thoughts about issues that have been neglected in the workshop and that demand fuller recognition in future work. On one occasion, the opportunity was taken by a charismatic sponsor to provoke a discussion in the concluding plenary of what the one key message to take away from the workshop would be, and what the single most necessary set of actions would be. Whether or not this is appropriate will be determined by many factors—not least how tired people are!

7.7.2 The Post-workshop Phase

Finally, after the workshop, there will usually be **Post-workshop** activities, which we group here under the headings Consolidation and Communication.

Consolidation
At a minimum this requires preparing a report on the main activities of the workshop and their results, and circulating this to participants for corrections and comments. This can be an opportunity for people to (be asked to) suggest ideas for narratives, newspaper headlines, early warning signals, and other material that can add to the report. Clarifications can be gleaned about formulations that are found to be ambiguous when trying to write them up; it may be possible to get some sense of whether people approve one or other reformulation of statements that is made in the interests of clarity or precision. On occasion, there will be continuing discussion from a subset of participants, who may (for example) prepare a more impactful scenario narrative.

The sooner this feedback process is accomplished, the better. Memories are liable to fade, motivations to dissipate. The report, and consultation about what to report and how to report it, can help keep things fresh.

Communication
With the exception of work carried out to effect change within a particular organisation, there is usually an intention of reaching a wider audience, one going beyond the participants and immediate sponsors. Apart from presentations made face-to-face with sponsors and perhaps other organised stakeholders, the main form of such output will be a published report, outlining the results of the scenario workshop (e.g. in the form of elaborated scenarios, lists of key drivers and shapers, indicators, activities that need to be undertaken, etc.). It is also common to explain the context of the workshop and present dome of the background material. Historically this has mainly taken the form of a published document (and associated abstract, press releases, etc.), with add-ons such as dramatisations or illustrations of scenario elements being rather a luxury. With web publication and the scope for social media to enable other parties to input, this is liable to change—though the results may not always be easy to manage, unless a moderated forum of some sort is employed.

Material can, of course, be presented in many different ways—and different audiences may respond best to one or other approach. The systematic nature of the approach can be communicated by tables (for example comparing a set of scenarios in terms of key parameters), by timelines of events, even by use of graphs. Some audiences will be more convinced by vignettes, looking for plausibility in narratives. Illustrations of activities in an imagined future context can be very telling (but often date rapidly, as clothing and other design elements can vary rapidly).

Other outcomes of a scenario exercise will take more the form of decisions about follow-up meetings, about topics where further research is required, about issues to raise with stakeholders, etc. It may feed into other scenario exercises in this, or other, ForSTI activities. Box 7.4 presents a further case study on the use of scenarios in ForSTI.

Box 7.4: Scenarios – Case Study

This case study concerns a study aimed at *Identifying Future Opportunities for EU-Russia STI Cooperation* (2009–2013). A scenario analysis was part of this study, which also included a two-stage Delphi study and a set of thematic workshops.

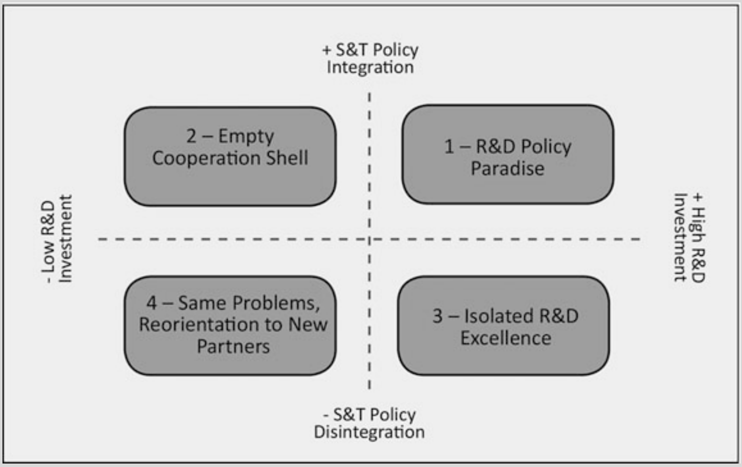
The starting point for scenario development was a "***creativity workshop***" held at the Institute for Prospective Technology Studies (IPTS) in Spain. It was devoted to discussion of critical variables and definition of the dimensions of the structural scenarios. A joint scenario grid was established and scenarios located in the grid. On this basis, small expert groups developed different scenarios and sketched out first scenario descriptions. The key dimensions considered within the scenario workshops were: R&D investment (low-high); S&T policy (integration-disintegration); key players (public-private); and performance (low-high).

The creativity workshop was followed by a series of **scenario workshops** with participation of policy makers from EU member states and associated countries and from Russia, along with experts and researchers in STI cooperation. The scenario workshops explored policy measures that would assist in STI cooperation—**these** "discursive spaces" enabled the exchange of information and of (converging and diverging) views on the structural arrangements for, and thematic orientation of, R&D and innovation cooperation. In turn, this facilitated the building of partnerships among the stakeholders—a process outcome of the work, along with the actual scenarios as products of the exercise.

Four scenarios describing potential EU-Russian S&T and innovation cooperation were selected for consideration by the participants—they outlined one optimistic, one pessimistic and two intermediate scenarios, and provide some narrative to describe these. Expert workshops with policy makers, representatives of funding organisations and researchers were then conducted to validate the scenarios and flesh them out in more detail, and the likelihood and desirability of the scenarios was assessed as part of the subsequent Delphi survey. The four scenarios are displayed below.

(continued)

Box 7.4 (continued)



Briefly, these scenarios were:

1. **R&D Policy Paradise** (assessed by participants of the Delphi study as rather unlikely but very desirable)
   (a) a decade of prosperous cooperation
   (b) Russia's successful and deepening participation in Horizon 2020
   (c) formation of a free-trade zone
   (d) Russia's joining the Organisation for Economic Co-operation and Development (OECD)
   (e) establishment of a joint EU-Russian research fund
2. **Empty Cooperation Shell** (rather likely but undesirable)
   (a) low and decreasing investment in R&D cooperation
   (b) lack of qualified personnel despite a strong interest in cooperation
   (c) draining of key human resources for public research centres by private Russian firms
   (d) discouragement of participation in R&D cooperation due to inadequate incentives
3. **Isolated R&D** Excellence (probable but very undesirable)
   (a) scientific isolation accompanying economic globalization
   (b) attempted creation by every macroregion (e.g., the EU and Russia) of the best "ivory towers" and centres of excellence to remain competitive in their specialties
   (c) R&D cooperation limited to specific areas
   (d) Russian focus on topics such as nuclear fission and defence, EU focus on different topics such as green energy and aging

(continued)

Box 7.4 (continued)

4. **Same** (i.e. Persisting) **Problems, Reorientation toward New Partners** (probable but undesirable)
   (a) because of limited EU enthusiasm to promote joint research projects, a shift in R&D cooperation by Russia toward the Eurasian Union
   (b) by 2020, continued third-country status for Russia in Horizon 2020
   (c) uncertainty persists in R&D governance issues, including Russian intellectual property rights policies, visa procedures, and convergence of standards (e.g., Bologna Process)
   (d) little improvement in quality or scale of cooperation.

The Delphi survey revealed wide agreement on the relevance of such broad topics as energy, transport, health and nanotechnologies, for STI cooperation between the EU and Russia, and the study ultimately resulted in a joint research call.

For more information on the project see Haegeman et al. (2015) and Sokolov et al. (2014).

7.8 Conclusions

We have reviewed a range of scenario methods, and focused particularly on the practicalities of Scenario Workshops, illustrating these with material drawn from a number of exercises. These workshops are intended to contribute to decision processes, and in conclusion we should note that there are several elements to this:

- The activity brings a wider span of knowledge into the process. Participants share relevant thinking in new ways (they are discouraged from delivering their conventional speeches, for example, and asked to relate their expertise to the points that others are bringing to bear). As in ForSTI more widely, the benefits of this can be viewed technocratically (as increasing efficiency by accessing more knowledge), or democratically (as enabling wider participation through deliberative means).
- The scenarios should provide insight into how the focal topic is influenced by various driving forces and their interactions, what some of the major uncertainties may be, and what sorts of contingency may need to be addressed. Often the activity will provide new insights and bring together material that has previously been compartmentalised. The participants will improve their understanding of each others' points of view, and how different stakeholders might respond to various contingencies.
- The workshop is likely to arrive at suggestions of possible actions, and some assessment and prioritisation of these; results developed from such a process

can be more valuable to decision-makers than the established opinions of a few (possibly self-serving) individuals. Of course, such lists are not translated automatically into policy actions—the decision makers have their own judgement to exercise and choices to make, though there is now a reference point at which the decisions can be compared.
- These inputs may serve to provide sponsors with huge amounts of intelligence which they previously lacked. Or they may serve to confirm what the policy expert already believed, but legitimise this by validating the views by reference to a wider set of experts and stakeholders.

As in many other ForSTI activities, client involvement often proves vital in the design, conduct, and eventual use of the scenario workshops. Without such involvement, the exercises would not have been adequately tailored to the decision-making needs of the sponsors. Client participation in the activities helps ensure that there were "champions" for the scenario work within the sponsoring organisation, who could take the messages of the study further. This could be seen as a matter of disseminating the products of the exercise further. Equally, it can be viewed as a matter of extending the process of the exercise. Design to allow both of these dimensions to be maximised is needed to make sure that scenarios effectively contribute to decision making.

Integration: Modelling 8

8.1 Introduction

The integration phase in ForSTI involves examining the models underpinning the alternative futures and their appraisals. This follows the construction of alternative scenarios in the Imagination phase, mainly with the use of future scenarios (Chap. 7). Models used at the Integration phase depict how things are related together—or, more accurately, how we think they are related together. Thus, models illustrate how components of future systems are seen to be interlinked and interdependent, and to examine what kind of synergies they may create through their interaction. The relationships between components may be derived from logical or theoretical analysis, or using statistical estimation techniques[1]; the results of interactions, however, may be quite unexpected, especially in complex systems.

Whatever the focal topic of a ForSTI exercise, models of some sort will be used—in our thinking and discussions about this topic, in our development of appraisals of future prospects, in our construction of strategies. Models may be spelled out in some detail, or remain largely implicit. The question is not **whether** to use models: it is whether we are aware that we are doing so, and that we are using some models and not others, and thus that we need to be aware of the validity and limitations of the models we develop or choose (or refuse). How fit for purpose are our models? This chapter examines how the modelling process can be made explicit and subject to analysis—whether and how we spell them out, including whether we put them into mathematical language. It will thus begin with a fairly extensive discussion of qualitative and quantitative approaches and tools.

Following the explication of the models, several steps may be undertaken. The consequences of different actions and events can be explored—as can the

[1] Despite some claims about "big data", where computers may search for relationships among large numbers of variables, even statistical estimations will require some theoretical analysis and selection among variables (whose data in any case will have had to be generated by some observational mechanism).

I. Miles et al., *Foresight for Science, Technology and Innovation*, Science, Technology and Innovation Studies, DOI 10.1007/978-3-319-32574-3_8

implications of experimenting with different initial assumptions as to the values of variables or the strength and direction of relationships.[2] This can be one way of establishing a range of possible alternative futures. But it can also contribute to more normative analysis. Different actions and strategies can be considered, and their effects in isolation and together can be estimated. The chapter will thus go on to examine some modelling approaches that contribute to activities that bring us closer to prioritisation, planning and policy analysis, which are the topics of subsequent chapters.

8.2 Becoming Aware of Modelling in ForSTI

In some ForSTI exercises models are expressed in highly formal terms, and documented with illustrations or equations (Often, parts of the exercise may draw on the results of such models that have been developed and applied elsewhere, for example to outline economic growth possibilities, or the employment implications of new technologies, and so on. Sometimes an existing model will be modified to take into account the focal object). In many ForSTI exercises models are less explicit, being most evident in the arguments that participants and rapporteurs are making. (They may well be making use of some broad frameworks that have been developed elsewhere, and often these will be ones that are in wide circulation as commonplace economic, management, sociological thinking.) When several models are drawn upon, their mutual coherence may not be taken for granted. For example, economic models that assume no structural change may be employed alongside forecasts of sweeping social or technological change: the projections of the former are liable to be undermined by the latter. This is just one reason why it is important to reflect upon the adequacy of the models that are used.

Let us put to one side the use of the word "model" to describe the people whose job it is to pose in the clothes that fashion houses launch on the world with the hope that the rest of us will aspire to look like (or at least dress like) these people. Otherwise, in everyday speech a "model" most commonly refers to a scaled-down three-dimensional depiction of some three-dimensional object. Common examples of such models include miniature versions of buildings or townscapes, of ships and aircraft, and model railway systems. Some of these are actually four-dimensional—the model trains may move around the tracks, for example. Some are toys; some have more practical applications in education, design, and research. The aim is often just to create a sense of how the various components of the system or structure that is depicted relate together; miniaturisation, like distance, can provide perspective. We may be given a sense of how things work, as when the model aircraft's propeller enables the craft to lift off, and its ailerons are used to control its trajectory. We can experiment with different circumstances, testing things to breaking point or finding more efficient ways of arranging things.

[2]It is common for statistical data and relationships to feature error margins.

A general point about these—and many other—models is that very often they do not have to be composed of the same materials as the structure that they are intended to represent, nor do their power systems and other operations have to follow those of the original. (Electric power will often be used in models of steam railways and aircraft that use aviation fuel, for example.) Different sorts of models will be used when we want to demonstrate the properties of building materials or the operation of various types of engine—and such models are built for such relatively specialised purposes.

The word ‘model’ is commonly used in scientific discussions, reflecting the impact of twentieth century developments in the philosophy of science. These can be summarised (with huge simplification) by the contrasting positions of Karl Popper (we cannot prove a theory and thus know the truth, we can only test and sometimes disprove one or other theory) and Thomas Kuhn (we see the world in the frame of different paradigms, which not only provide present different explanations of events, but also tell us what problems are interesting and what evidence is relevant). The result has been that researchers in natural sciences as well as social studies will often talk of their task as basically being that of formulating and testing models (this probably underplays the role of research in discovering unexpected things via serendipity). Sometimes ‘models’ are held to very highly specified versions of ‘theories’—a given theoretical statement can be represented by numerous models which only differ minimally from each other, and models may take different forms as we have seen.[3]

Models are efforts to represent structures and systems. Various forms of representation can be devised—and are more or less tailored to particular purposes. A street map is a 2D (scaled-down) model of a city, and is much more useful to carry around for navigational purposes than a 3D construction of balsawood and Plaster of Paris would be. A conventional map is not very dynamic, but it can be used to plan or record journeys over time. This can be accomplished manually—and now online maps can suggest optimum routes and predict the expected duration of a journey. The online map goes beyond the traditional paper-based map: geographical positions have been translated into coordinates, and we are dealing with something closer to a mathematical model from which visual representations (the map) can be derived as well as texts describing routes.

Richardson (1984) discusses some 12 different approaches to modelling. Modelling by changing scale is just one approach; others range through categories like analogy, simplification, sampling and (mainly mathematical) symbolism. The term “simulation” is generally used where we are talking of models of *processes*: models that seek to represent the way in which a system operates over time. “Simulation models” are generally understood to be computer-based models, however; “simulation games”, in contrast, usually refers to games that human players

[3]However, models may also be seen as almost the opposite thing: as analogies or weakly developed ideas of how a system behaves, that precede more formally elaborated theories.

engage in, for example taking the roles of different stakeholders in the system being modelled.

Physical models are still often used, for hobbyist and educational purposes, for testing physical structures (e.g. wind tunnels for testing aircraft design and pylon stability). But models may be expressed in words, as mathematical statements, in the form of graphical illustrations (e.g. flow diagrams and other visual depictions of phenomena) and so on. This chapter contains two long sections, discussing respectively qualitative models—expressed mainly through words and diagrams—and quantitative models—using the specialised words and logic of mathematics (and usually computer simulation) separately.

Whether qualitative or quantitative, the critical feature of a model is its underlying conceptual frameworks—what elements, and what relations between elements, are invoked to represent the system or structure of concern? The particular language and terminology, tools and techniques that are used to elaborate this, and to derive analyses and even forecasts from it, can be highly significant (not least because they may conceal these conceptual underpinnings!). But it is the underlying framework that constitutes the model that we need to be able to (de)construct. Just what variables, and what relationships between variables, are being taken into account? Are these borrowed from previous work (and if so, what, and how has it been selected?), or developed by an expert group and/or a team working at their desks. Is there opportunity for different stakeholders to examine and comment on the key assumptions? Are we relying upon some standard theories, are relationships evidence-based (and on what evidence)?

Human beings are always using implicit or explicit models in viewing the world and deciding what actions to take. The focus of the discussion below is on modelling as explicit practice in ForSTI work. Here we may be dealing with innovation systems, with particular STI organisations, with specific technologies or application areas, with topics like skills or risks, and so on. A system involves various elements (often called "nodes") and the relations between them. These elements may be rather abstract phenomena (e.g. demand, employment levels), or actual actors or actor groups. The system also has boundaries, though it may be affected by, and have its own impacts upon, its external environment. Much conventional modelling deals with fairly abstract variables, but it is possible to have actor-based approaches (e.g. a qualitative approach is simulation gaming; a quantitative one is agent-based modelling).

What may be harder to deal with are the *emergent* properties of systems—the ways in which new actors, behaviours, and of course innovations may arise. This reflects a critical limitation of many modelling efforts. Our focal object (or some related topic) is being modelled. The model treats it as a system, a set of relationships among elements. One issue then concerns how well the description of elements and relationships serves as a description of key features of the focal object or topic. Over time the relationships, and the elements themselves, are liable to change (for example, new social actors, economic sectors, new behaviours may emerge; quantitative changes may turn into qualitative ones—like ice turning to water turning to steam, as the temperature rises; relationships may become unstable as they mature). Often the whole point of a ForSTI exercise is to get a better grasp on such potential changes, and the threats and opportunities they may present. Before placing too much reliance on models, it is important to consider whether their fundamentals may be disturbed by new phenomena, which we have not been able to identify, and build into the models.

Before discussing the main qualitative and quantitative types of modelling, we should briefly consider just what modelling is being used for.

- **Examination** of the behaviour and future prospects of the focal object, and of the consequences of action.

  The model may be taken to be the most realistic view of the forces acting on and within the focal object, and thus providing a guide to how it will evolve over time (and in response to various policy interventions or actor strategies). Models can be used in "exploratory" or "normative" modes, the former asking where current developments may take us, the latter asking how we might get to particular future states. In policy and strategy formulation for ForSTI, as elsewhere, one or other model (or sometimes a melange of elements drawn from different models) will always be underpinning and proposing decisions. Modelling may be used to help structure strategies and choices, not least by allowing for some estimation of the consequences of taking different actions (and also, of course, the consequences of unplanned or ongoing exogenous and endogenous influences).

  As noted above, modelling may be limited in various ways—by addressing only a few parts of a large system, by failing to capture emergent phenomena, and so on. Even a huge model that has been developed with the aid of many experts feeding in much data is still only a model, and the conclusions that we draw about its behaviour should not be assumed to be automatically accurate accounts of how the focal object could behave.
- **Testing** of assumptions—as when researchers specify what might be expected to apply in particular empirical circumstances, given the theories we are bringing to bear.

  This is more of a general application of modelling than one used extensively in ForSTI. However, in the course of conducting ForSTI work, we may need to test some of our assumptions against data (or against expert opinion). For example, if it is being argued that a particular innovation is going to bring about massive efficiency gains, or reductions in jobs or energy use, can we examine this claim in the light of early data on the innovation, or data concerning analogous innovations in earlier periods (often it may be concluded that such claims often prove to be substantially overstated, or at least to anticipate a much more rapid rate of change than actually materialises). The results of such tests may also prompt further elaboration of theories, for example with proponents of the case for rapid and large changes having to articulate why it is that they believe the future will differ from the past. Modelling may push practitioners and researchers to clarify their thinking, with more systematic specification of theory and of data requirements. It may allow for detailed analysis of the consequence of minor differences in assumptions (the values of variables or the form of the relationships between them); and of more major changes in assumptions, applications to different situations and data, special cases, etc. One role often played by numerical models is rather basic accountancy—simply telling users that there will need to be choices made between investment decisions, for example, because the costs of various proposals do not add up.

- **Communication** of assumptions, and of the implications of applying these assumptions.

  Model-building involves explicating and formalising understanding of how a system works—and often this understanding is largely implicit and has been only partly spelled out. The task is to (more or less systematically) determine the main elements of the system to be modelled, and the main relationships between these. Undertaking this task provides an opportunity to discuss points of view on these issues. This can allow for debate within the ForSTI team, and between the modellers and the audience of this part of the ForSTI work. It may involve tricky matters of operationalisation and approximation—for example, about how far existing available indicators can serve as measures of the model parameters. Often the discussions are mainly conducted within an expert group, and are then relayed to a wider audience only in the context of the whole model—where it can be difficult to identify the main assumptions, and how far and in what ways the results are driven by these. Time pressures in ForSTI may limit opportunities to critically reflect upon the models used, but discussion of assumptions can be a real learning experience for experts and wider stakeholders alike.

- **Obfuscation**

  Hopefully, it is rare that a modelling activity deliberately aims to conceal its designers' actual view of the focal object. There may be a conscious decision to omit some issues from the analysis—often because they are hard to deal with (for example there is no good data on trends that can be drawn on), but sometimes because they could be embarrassing. This is rather frequent in the mobilisation of statistics to make a political case, but can also apply when a model is used in the course of making the case for an STI programme of some sort (for example, some portions of the population may suffer from a major infrastructure development from which most are expected benefit—this can be obscured by using only population averages for costs and benefits. In 2014, there was controversy in the UK over the planned construction of a new High Speed railway line, and efforts were made not to keep details of cost-benefit modelling secret, since these pinpointed some substantial losers). Even when obfuscation is not the intention, complex models may be very hard for non-experts to assess. Some people find visualisations difficult to follow, for instance, while many find it hard to follow elaborate mathematical formulations.

  It would thus be helpful for communication and education purposes to have key assumptions of the model spelled out. Unfortunately, the modellers themselves may not always be aware that some of their assumptions are debatable, rather than the logical statements they assume them to be (In Kuhnian terms, this is because they are working within an unquestioned paradigm[4]). Often, for example, simplistic economic arguments are assumed to be uncontroversial, when in fact they are very problematic (because the neoclassical framework they derive from itself involves all sorts of problematic formulations[5]); or indicators are assumed to be adequate for purposes far from original intentions or actual capabilities (example: the use of per capita GDP as a measure of social wellbeing). Model results may provide dramatic presentations that can "wake up" audiences to important ForSTI issues, as has recently been the case for climate change forecasts. But highly technical language and displays of expertise with sophisticated techniques may create a mystique which leads to uncritical attitudes or apathy on part of audiences.

A model may be intended to fulfil more than one of these functions. Furthermore, it may be that a model is applied to purposes remote from those it was originally designed for. Since some forms of modelling can be quite costly to undertake, it is not unknown for an established model—developed for other purposes—to be used to set some parameters for a ForSTI study, without its numbers being taken too literally.

8.2.1 Qualitative Modelling Approaches

This section will outline a number of approaches to constructing and using models that do not depend on elaborate mathematical analysis. In practice, such approaches often involve some simple arithmetic—for example, score-keeping in games; and qualitative approaches may be a first step to quantitative modelling. As computer analysis of texts becomes more familiar, powerful and user-friendly, we may also expect to see normal speech and writing more often rendered into quantitative forms—word counts and concordances, for example.[6]

[4]Thomas Kuhn (1962) argued that scientific enquiry tends to be framed within paradigms that constitute accepted theory for their adherents, and that are used as guides to relevant models, data, evidence, and so on. A paradigm is disrupted when, for example, evidence piles up that can only be interpreted in very contorted ways, and some completely different account seems to provide a more lucid explanation. Social research is often held to be in a preparadigmatic stage, or to feature rivalry between alternative paradigms. The term technological (and by extension technoeconomic) paradigm is used to indicate the situation when a set of given technologies is employed as the solution to socioeconomic problems, and R&D is framed around expectations as to the next advances in these technologies (cf. Drechsler et al. 2011).

[5]Not least in that assumptions are made about market functioning and equilibrium that make little sense when the process of technological innovation is taken into account.

[6]Modern computer technology is being employed to aid these activities, with tools to support many of the methods used, for instance, mind-mapping and flow diagram creation. The development of "artificial intelligence" and "expert systems" can involve the creation of software that can work with qualitative reasoning. Complex applications of formal logic, mathematics, and computer software are also coming into use. The result is that the distinction between qualitative and quantitative approaches may well become even more blurred. See, for example, Forbus (2008).

8.2.1.1 Gaming

A game is a sort of model; a game consists of a set of rules which players should follow in order to achieve their objectives. In simulation gaming, participants are assigned roles to play—they may be, for example, consumers, financiers, policymakers, pressure groups, companies etc. They are presented with an outline scenario of the situation they find themselves in, and with specifications of their interests and goals, their resources and capabilities. The designers of the simulation game have prepared these materials, and also created (1) a process whereby "actions" (or "moves") undertaken by the players result in changes in the situation; (2) a structure for the players to make their moves and interact with each other, over the course of a session of role-playing that is intended to represent a period of time in the real world (potentially years in the case of ForSTI); and often also (3) further interventions in the form of changes in the situation (e.g. wild cards to introduce). Some games are "turn-based", with players taking it in turns to choose their moves; some involve periods where they come together and periods for reflection or discussion within groups. The moves permitted may be completely open, with the players needing to communicate or expose what they are doing (to all, or just to selected others); they may be highly structured, e.g. when the moves are limited to making investments or casting votes. Alliances are often permitted, with players pooling some resources and acting together for periods of time.

Simulation gaming has a long history of application in military contexts—war gaming—and was used in RAND and other environments alongside scenario planning and other forecasting tools, by Herman Kahn and his colleagues (cf. Kahn 1960; Wilson 1970). It may be accompanied by the use of elaborate models representing armies, navies, etc., and as such it was often used for educational purposes; indeed, education and training is a common arena for application of simulation games more generally. Business games—often continuing the metaphor of warfare into the commercial environment—are also used in management and management training contexts. Because of the strong element of novelty and change in most ForSTI studies, and the long time horizons often considered, there is relatively little use of such games in this context.[7] However, role-playing games may be valuable in scenario development. For example, we might ask workshop members to play various roles as they would be confronted in a specific scenario. This could be a stimulating approach for eliciting ideas about the responses and counter-responses of various stakeholders in the context of, for example, breakthroughs in technological potential, or large-scale development projects. It might be particularly useful to examine the possible "reinvention" of technologies for purposes other than those they were originally intended, for example.

In its applications for training and decision making simulation gaming is often known as "serious gaming", drawing on the terminology used by Clark Abt in his

[7]The main exception of which we have first-hand experience is in Foresight training courses, where participants may be asked to play the role of sponsors and designers of a ForSTI exercise, so as to gain experience with the various choices and tools that are available.

1971 review of the topic.[8] Such games have been extensively documented in a variety of guides (The journal *Simulation and Gaming* is devoted to the area[9]). One set of practices that has received less attention is "New Games", which are designed to promote cooperation and learning, as well as fun. There may well be scope for making use of these ideas in the ForSTI context, too [see Fluegelman (1976, 1981), PGP (n.d.) and Yehuda (2008)].

Role-playing games have entered popular culture on a grand scale in recent years, in the forms of board games (e.g. **Dungeons and Dragons**) and Live Action Role Playing, and in computer games. Often the latter are set in science fictional scenarios—most frequently apocalypses or dystopias of one sort or another—and while they occasionally display flashes of creativity and originality, they rarely deal with plausible near futures, and mainly focus on combat situations. Some games involve multiple players, perhaps large numbers of them interacting in an environment that they can largely construct themselves. There is clearly scope for designing futuristic scenarios within such environments, for example **Second Life**, as well as simply using them as places to hold discussions.

Another method, which is widely employed in ForSTI projects for modelling, is mind-mapping, which was presented in Chap. 4 as a method of interaction along with Brainstorming.

8.2.1.2 System Mapping

A wide range of approaches can be applied to visually depict a system's component features (elements or nodes) and the relationships between them. Usually the features are represented by icons or text boxes of some kind, and the linkages by arrows.[10] System mapping is concerned with causal relationships, as the arrows imply. Usually these are fairly simple relationships: an increase in feature A leads to an increase or decrease in feature B (for example, if an innovation becomes cheaper, it is liable to be adopted more rapidly). Sometimes there will be a U-shaped relationship, as small amounts of A lead to increases in B up to a threshold, after which more A means less B. There may be reciprocal causality: feature B may exert influence back onto feature A (for example, higher levels of adoption of the innovation lead to increased production which leads to economies

---

[8]See http://www.seriousgamesinstitute.co.uk/ for current research on the topic, much of this involving computer-enhanced gaming. In the last decade of the twentieth century, *The International Simulation and Gaming Research Yearbook* (a series published in London by Routledge, under various editors) featured volumes devoted to such themes as Emergencies and Crisis Management, Strategy and Policy Making, and Transition and Change; these are still good overviews, but practice has moved on.

[9]An extensive bibliography of the field is available at: http://www.coulthard.com/library/bibliography%20-%20simulation.html (accessed on: 09/09/2014); its creator provides a helpful review (Coulthard 2009).

[10]Arrows are used, since system mapping deals with causal associations, whereby one factor influences the other. In contrast, in social network analysis and some other techniques, simple lines are often more appropriate, since these approaches are more likely to be focused on the closeness of elements—their similarities or interactions.

of scale and decreasing costs). If each element influences the other one positively, then we have a situation of growth of both, usually known as a virtuous cycle or an example of positive feedback (In reality, the outcome may be far from virtuous, of course, because unrestrained growth is often harmful to other elements of the wider system). A system map will contain more than two variables, though a good place to begin constructing such a map can be one such relationship.

A system map can be created in desk- or group-work by using a structured form of mind-mapping. The central starting point is the focal object. What are its important features—and how stable are these? The focal object can be represented as a set of boxes. What factors are influencing, or could lead to (or impede) changes in these features? These are represented as further boxes, with their influences on the focal object indicated by arrows linking them. The next step is to consider what factors might be influencing these influencing factors, and so on. This approach diverges from standard mind-mapping in that the links between the various branches of the mind-map are explored. Factors that are influential in one causal chain can also be influential in another (as opposed to being only related to one chain). As factors and linkages between them accumulate, discussion of which factors are most influential in shaping the system's evolution may mean that the diagram can be simplified, without great loss, by excluding the less important factors.

Beyond simple arrows, more elaborate analysis of the scale of influence can be provided. For example, estimates of the direction of, and scale of, influence of each factor on the node that is being influenced can be made using, say, 5-point scales (ranging from $+1 =$ small positive influence to $+5 =$ very high positive influence, "positive" meaning increasing the size or likelihood of the nodes influenced; and $-1 =$ small negative influence to $-5 =$ very high negative influence, "negative" meaning decreasing the size or likelihood of the nodes influenced).

An excellent example of system mapping comes from the UK Foresight Programme, in its project "*Tackling Obesity: Future Choices*". Obesity may seem to be an unusual focus for ForSTI: but it is well-known that obesity has become a highly problematic issue in Western societies especially, with huge ramifications for their populations' well-being and the load on health services in particular. It is also a classic "wicked problem", involving different sorts of professional knowledge and organisational responsibilities. It is, for example, of relevance to the several departments of government and public services concerned with education, food, nutrition, sports, as well as with health, as well as to private and voluntary organisations. Among the ForSTI issues that arise here are, for example, ones concerning bioscience (e.g. individual propensities to gain weight), medical treatments (from surgical to pharmaceutical interventions), food and nutritional sciences (analysis of the impacts of foodstuffs and dietary patterns of various kinds), and matters of education, lifestyle and exercise.

Box 8.1 reproduces the broad principles under which this exercise operated. It provides a helpful account of the background to qualitative system modelling, and thus we quote at length from the original text. The stress very much is on "causal loops", in which (sets of) variables are mutually reinforcing each other, giving rise to long-term trajectories of change (in this case, the result being increasingly obese societies). The thinking of this project on the value of causal loop approaches is reproduced in Box 8.2. These models were constructed through groupwork during the course of the project, as outlined in Box 8.3.

This exercise was very time-consuming, and drew on a large number of expert and stakeholder inputs: group processes generated ideas as to key variables and relationships; the project consultants worked these up into more systematic and evermore elaborate versions of the system map. The consultants also input many ideas about variables and relationships, deriving from a series of reviews of the various scientific literatures bearing on obesity (Projects in the third cycle of UK Foresight, like this one, generally commissioned such reviews of the "state of science" at an early stage of investigation of the focal topic). The eventual map developed and used in the exercise had over 100 variables, with over 300 relationships. It was used as a framework for discussion (not just within the exercise, but in later rolling-out of the results to a wide range of interested parties), in the development and assessment of scenarios, and for other purposes.

The system map (over 100 elements with over 300 arrows linking them) may not do complete justice to the complexity of obesity in modern societies: there could always be important factors that are not recognised, for example. But it succeeds in foregrounding the interdependencies among highly diverse variables (ranging from industry strategies to consumer habits and behaviour change). The dialogue is reported to have helped to exchange insight and forge relationships across stakeholders and disciplines, and that this provides support for more "joined up" policymaking.

(It should be noted that regulation of the food industry and its products remains highly controversial in the UK. Arguments have erupted over the years about food labelling, about the use of sugar and hydrogenated fats, about school meals, about the industrialisation of farming, and about many other related topics. There is widespread suspicion that successive governments have been unwilling to challenge major corporate interests and to support adequate inspections of food supply chains. Difficulties here demonstrate a basic point—policy decisions are ultimately political ones, and influential lobbies may be more important than the best available evidence. Many STI policy decisions are relatively apolitical, in the sense that there is little conflict between major political parties about them, and major lobbyists are less prominent than in many other areas of policy. STI related to food is one of the exceptions,[11] with debates about introduction of GMOs in agriculture being a hot issue at the time of writing).

But the model is highly complex; indeed it is difficult to represent on a two-dimensional surface like a (very large) sheet of paper. This is a common problem with large-scale system maps. As noted, there are over 100 variables ultimately influencing energy balance; each is interconnected with others. They have varying numbers of inputs and outputs from each; there are feedback loops

[11]Energy and security affairs are among other notable exceptions.

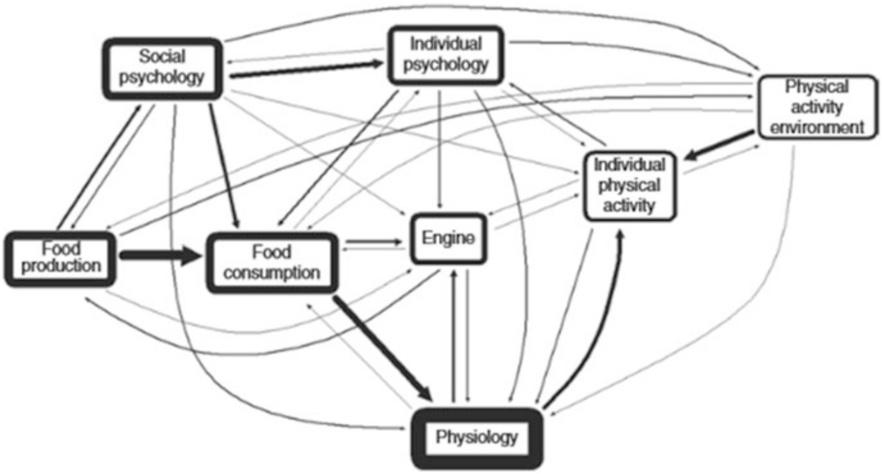


Fig. 8.1 Network diagram of the obesity system map. *Source:* Finegood et al. (2010)

where merely two variables are mutually influencing each other in positive or negative ways, and feedback loops that encompass numerous variables. In one sensemaking effort at simplification, the variables were clustered into seven themes ranging from Food Production to Physiology.

Another approach was also taken, as a response to concerns that such a complex map is not just difficult to assimilate, it may actually deter or disempower some of the intended audience. (People may not know where to start; or they may feel that any action at one point is liable to be overwhelmed by the large number of influences that are depicted.) Finegood et al. (2010) suggested that one way to overcome the problem would be to group elements from the Foresight system map into various themes or clusters, as mentioned above. A quick overview of the map is then created by counting the connections within and between the themes (the numbers of linkages between individual variables situated in the same theme, or each of the other themes), and applying social network analysis software to these counts. The outcome is a simplified map, depicting the strength of linkages within and between themes (reproduced in Fig. 8.1).

In this simplified map, the thick border around Physiology reflects the numerous (33) interconnections among the variables within this cluster on the original Foresight map, whereas the thin border around Physical Activity Environment reflects few (8) interconnections within this theme. The thick arrow from Food Production to Food Consumption reflects the large number (22) of direct influences from Food Production variables on Food Consumption variables—while no variables in the latter cluster impact directly on the former. The complexity of the visual image has thus been reduced, while much critical information is summarised and some key relationships among clusters are highlighted. It makes a great deal of sense for ForSTI exercises to experiment with approaches like this one for simplifying complex maps—and they could be applied to computer simulation models, as well—in order to communicate assumptions and results more intelligibly.

Box 8.1: System Mapping for UK Foresight Obesity Project

"The system under study in the present project is the 'obesity system'. Obesity is an attribute of a human being. For a given individual, obesity is associated with being over a normal body weight for their gender, age, height and build....

The key assumption underlying this qualitative mapping exercise is that obesity is the result of the interplay between a wide variety of factors, deriving, for example, from a person's physical make-up, eating behaviour and physical activity pattern.

The obesity system, therefore, is pragmatically defined here as the sum of all the relevant factors and their interdependencies that determine the condition of obesity for an individual or a group of people.

- What has been called a 'factor' is an attribute (characteristic) of a person or their environment that has an influence on that person's level of obesity. 'Factors' are often referred to as 'variables'. . . The term 'variable' suggests that the corresponding attribute is measured against a qualitative (ordinal) or quantitative scale and can vary over that scale. Some of the factors are fairly straightforward to describe in measurable quantities (for example 'energy density' of food), whilst others are psychological, cultural or environmental attributes that are more difficult to quantify (for example, 'walkability of living environment', referring to a physical environment's suitability for movement on foot). As many of our variables are not readily quantifiable, we do not attempt to use the model to draw quantitatively-based conclusions, rather we consider overall trends and direction.
- 'Relevance' is a pragmatic criterion for deciding which factors belong to the system:

In this project, relevance was chiefly determined by judgments of academic experts. The particular representation of the obesity system that has been developed constitutes our best understanding of the system within the given constraints of time and other resources in the project. . .

- The interdependencies that the definition refers to are of a causal nature. In other words, the obesity system is a set of relevant, causally linked variables that determine the condition of obesity. So, any link between variables a and b in the system needs to be interpreted as 'the level of a is causally linked to the level of b.' A distinction will be made between positive and negative linkages.
- The obesity system can be scaled at various levels of aggregation (individual, group, society), depending upon the level of aggregation of the constitutive variables. One can think of an obesity system operating 'around' an individual or a group of people. In the latter case, the variables represent average values for a given group. . .

(continued)

Box 8.1 (continued)

The causalities discussed so far are linear causalities (from a' to 'b'). Circular causalities (e.g. from 'a' to 'b' to 'a') in systems maps are called feedback loops. They are an important feature of causal loop models because they help to explain the dynamic behaviour of the system.

There are two kinds of feedback loops: reinforcing (or positive) and balancing (or negative) loops. Reinforcing loops encapsulate exponential growth whilst balancing loops push the system towards an equilibrium value:

- An example of a reinforcing loop from the obesity system map is the following: if the 'demand for convenience' by consumers increases, the 'convenience of food offerings' from food manufacturers is likely to increase in response. If consumers then become habituated to these convenient products, their cooking skills are likely to diminish. Hence, an increase in the 'convenience of food offerings' triggers 'de-skilling' of people. And this, in turn, can be expected to increase the demand for convenience. And so on, until compromises on taste or price will flatten the dynamic.
- A balancing loop is at the very core of the obesity system: when human beings' 'level of available energy' decreases, they experience a 'physical need for energy'. The stronger that need is, the more effort will be invested in 'acquiring new sources of energy' or to 'preserving the energy' that is already available. This, in turn, will lead to a higher level of available energy, which will finally dampen the physical need for energy. By this means, the system remains in equilibrium. The primary purpose of this exercise is to understand how the broad range of variables influences energy balance, leading to it becoming imbalanced. . .

The key purpose of building a causal loop model is to gain insight in the underlying structure of a messy, complex situation. A system map shows how 'variables interrelate' and where there are opportunities to intervene in the modelled system to influence its behaviour. A secondary objective could be to impart that insight to a wider audience. System maps are arguably one of the most effective tools with which to visualise complexity. In short, the essential contribution of a causal loop model is to summarise and communicate current trends, relationships and constraints that may influence the future behaviour of a system.

However, a causal loop model is not a predictive model. It does not allow future levels of system variables (and, hence, prediction of the level of obesity at a given point in the future) to be foreseen."

Source: quoted from Vandenbroeck et al. (2007) Chapter 2 (p2 *passim*)

Box 8.2: The Use of Causal Loops in System Maps (UK Foresight Obesity Project)

"A causal loop model is a device to describe the systemic structure of a complex problem. As such it serves three very general purposes:

- to make sense of complexity: individuals who have been deeply involved in the construction or study of a causal loop model will appreciate its considerable heuristic power. In particular, once the top-level architecture of a model (rather than its fine detail) has been thoroughly absorbed, it becomes a powerful filter for identifying relevant variables and an aid to thinking about the issue.
- to communicate complexity: the anatomy of a system map—particularly with a fairly large number of variables and many causal linkages between them—is a clear confirmation of the inescapably systemic and messy nature of the issue under study. This approach highlights the need for broad and diversified policies or strategies to change the dynamics of the system.
- to support the development of a strategy to intervene in a complex system: careful study of a causal loop model will reveal features that help in deciding where to intervene most effectively in the system... leverage points, feedback loops and causal cascades....

Decision-makers need to focus on a system's leverage points if they are to effect change. Leverage points are variables in a system map that have an important effect on the system's behaviour. They can be recognised as 'hubs', where many arrows are leaving from and coming into different variables. Leverage points pick up changes from many variables and transfer these on to other parts of the system (first to those variables linked directly to the hub, and then further afield). Particularly important are those leverage points that are directly connected to the system map's central engine. These are called key variables. They will be sensitive conduits of change to the system's basic dynamic architecture. In the obesity model, four variables have been identified as key variables:

- the level of psychological ambivalence experienced by UK citizens in deciding lifestyle choices (food, exercise)
- the force of dietary habits preventing UK citizens from adopting healthier alternatives
- the level of physical activity UK citizens engage in
- the level of primary appetite control in the brain.

(continued)

Box 8.2 (continued)

These four variables impose themselves as crucial elements of any obesity policy portfolio. It is perhaps noteworthy that there are four key variables rather than just two (eating and exercise) and that the key food variable focuses on habits rather than actual intake.

Feedback loops are a defining feature of causal loop diagrams as they determine the dynamics of the system… Focusing, for example, on undesirable positive feedback loops may suggest useful options for policy by evaluating where balancing loops can be imposed or where linkages in reinforcing loops can be broken. Similarly, inflexible situations which are in equilibrium (lockins) could be countered by removing bottlenecks and restrictions in resources or by stimulating new reinforcing loops to undermine the status quo…

Studying feedback loops and leverage points in system maps can be a fertile basis for developing policy options. However, maps can also be used to study how a given policy option might affect the system. First, an inventory is made of the variables in the system map that are apparently affected by the policy measure. Secondly, verification of how these measures causally propagate through the model and how they affect the feedback loops driving the system. By mapping out these causal cascades, it is often also possible to verify whether a given measure may at some point result in unintended consequences in another part of the system…"

Source: Vandenbroeck et al. (2007) Chapter 2 (p8 *passim*)

Box 8.3: Development of the Obesity System Map

Vandenbroeck et al. (2007, Appendix B) explain that the development of the obesity system map involved two main phases of work, which are summarised below.

Phase One: involved focused work undertaken by the Belgian consultancy group facilitating the project (**WS**—now **shiftN**), accompanied by four interactive workshops. These involved experts (from a variety of disciplines) and individuals from stakeholder groups, including policy makers and representatives of business and civil society. The workshops generated and evaluated ideas that were formalised by the consultants.

- The **first workshop** laid the foundations of the system map. This involved identifying the system map's nodal variable, which was defined as 'energy balance': the difference between energy intake and expenditure. Using the results of this first workshop, WS proceeded to develop the first version of

(continued)

Box 8.3 (continued)

a causal loop model, "the core system engine". WS also put together a preliminary database of causal links influencing the elements of this model, drawn from short science review papers (another part of this Foresight project) and grouped into four sets:

- food and food environment;
- cultural and psychological;
- socioeconomic; and
- physiological influences on energy intake or expenditure, or on obesity.

- The **second workshop** reviewed the draft causal loop diagram, and the database of causal links (considering factors like size and direction of impact, uncertainty about and explanations of the link). Subgroups examined the four sets of influence. Twenty five key linkages were emphasised by the workshop. These were used by the consultants, subsequently, to develop a much more elaborate system map than the draft causal loop diagram the workshop started with, the "first draft model".
- The **third workshop** reviewed this first draft model, discussing whether important variables and relationships were missing. Again, the workshop results were used to build a more elaborate model. However, it was felt that the physiology subsystem was underdeveloped in this version, so a **fourth workshop** was set up to provide further input.

Phase Two: Following these rounds of activity, the work involved gradual "streamlining" of the map into the final version of the model. A version of the map was produced that was circulated together with a questionnaire to experts, in this case asking for views on the relative importance of the causal linkages featured in the system map, not for yet more suggestions about influential variables. An interesting further step here was to ask the experts to consider how far the map varies across social groups: to what extent the influences were subject to gender, age, ethnicity and socioeconomic class effects. Thus versions of the map could be produced for specific social groups. Additionally, sections of the overall map could be "pulled out" as derivative maps for examining one or other set of influences in more detail.

8.2.1.3 Relevance Trees and Morphological Analysis

A number of tools that are often described as "normative forecasting" methods are relevant to long-term STI planning. Many of these tools were developed within the context of large managerial and technological programmes, aimed at specific objectives requiring much effort at development of complex technological systems. Outstanding among these was the US space programme, which in the 1960s was facing such questions as "how can we get an American safely to, and back from the surface of the Moon?" Roadmapping is one such tool, but this is discussed in a later chapter (Chap. 9), since this widely-used technique puts particular stress on the actions that need to be taken to achieve future objectives. The two tools examined here are Relevance Trees and Morphological Analysis. These methods can be applied for various purposes: one of which is to examine a broad range of possible future circumstances and choices, and how different sorts of capability and knowledge requirements would need to be developed and deployed.

A **relevance tree** is, as its name implies, a tree-like diagram—or, when presented so that the "branches" spread out downwards, is more like a diagram of the roots of a tree, resembling a typical organogram to look at. The branches divide a broad topic into increasingly smaller subtopics. Transport might be divided into transport of people and of freight; each of these into land, sea or air transport; and so on. The diagram then represents the various critical aspects of a system—or of a problem and/or its possible solutions. So if the focal object concerned reducing CO_2 emissions associated with transport, attention would be directed towards these different modes and functions of transport. Specific relevance trees could be constructed for specific modes of transport, for example. One relevance tree might consider the different technologies used in one mode, leading to consideration of the emissions (and other costs) associated with different technologies. Thus there are relevance trees outlining different options for solar powered automobiles. Another tree might consider the different purposes to which transport is being put, leading us to consider the various forces influencing transport usage in and across modes. Relevance trees can also be used in the planning and design of ForSTI exercises.

Morphological analysis similarly involves breaking a problem area or focal topic up into various subcategories. A grid structure is created, rather than a tree. In the grid, different options for each of these categories (e.g. land, water, air in the case of transport) form different cells—this is known as the "morphological field". The grid can be used to explore combinations of different possibilities. Some combinations will prove logically impossible, others may be ruled out as too costly or technically difficult. Other combinations may provide possible routes to an objective, or solutions to a problem. The approach can also be used for constructing scenarios, where different combinations are explored as the basis for distinctive scenarios. In a study of futures for agricultural biotechnology in the UK, specifically concerned with crops used for purposes other than food, the Institute of Innovation Research (2003) developed four such scenarios. The combinations concerned two alternatives for each of two issues. First, would new bioscience be applied to create GMOs; or would it be applied only to other purposes, such as improved plant breeding (the use of GMOs being a controversial theme)? Second, if the GMO route were to be taken, would it be used only in "contained environments" (such as greenhouses) or more widely? This is a relatively simple scenario structure—often the scenario definition is much more complex, with numerous sets of options being related together to form a set of scenario pathways.

Much material on morphological approaches is provided by the Swedish Morphological Society.[12] This Society has published accounts of the application of these approaches in a scenario study for the Ministry of the Environment in Sweden, concerning Extended Producer Responsibility (EPR). EPR involves making producers of goods responsible for waste or used products: the products will need to be reused, recycled or applied to energy production. Eight major “external” factors were identified that might influence a Swedish EPR system. Over 20,000 configurations of these factors were notionally possible: of these, around 2000 were believed to be internally consistent and thus feasible combinations—and, in principle, these could be the profiles of alternative scenarios. Ritchey (2009), however, argues that usually some 8–12 configurations can be chosen to cover all of the cells and give a good spread of possible scenarios. In this study, eight configurations were chosen by a working group, with every state of the factors being represented in at least one scenario.[13] Figure 8.2 displays the cells selected for one of these scenarios.

In a further step, different EPR *strategies* were developed, concerning “internal” factors (those that can be more or less controlled); these were then examined for their fit to each of the scenarios, giving an assessment of the robustness of strategies across ranges of scenarios. Figure 8.3 depicts how three strategy alternatives (developed from a strategy matrix) are related to the eight scenarios (from a scenario matrix), together with a fourth alternative—“no strategy available”. Here, strategy B is shown to be able to cope with 3 of the 8 hypothesised scenarios, and 2 of the scenarios (light blue) are beyond any of the strategies.

Both relevance trees and morphological analyses are ways of thinking systematically about the topic of concern. They are used in planning, but are more than just routine planning tools—this process can allow for unexpected possibilities to emerge, new appraisals of the future to be established, and new options to be identified. This process requires some substantial effort on the part of the people that implement them, since these approaches are far from easy to use. They require in-depth analysis, and usually need to be supported by people familiar with the techniques; expertise in the problem fields will be required. Lengthy work may be involved. Numerous alternative elements and combinations of these elements involved may arise. The outputs may be rich in technical detail—indeed they run the danger of being overloaded with it, making it difficult for lay people to fully grasp and use them. The Swedish Morphological Society argues that new computer-assisted approaches may make the process easier and easier to understand. As with system mapping, it is important to maintain the comprehensibility of the assumptions and the results that flow from applying them.

[12]Its website is: http://www.swemorph.com (accessed on: 18.01.2016).

[13]These are really what we term “profiles” in our discussion of scenario analysis in Chap. 7.

EPR rules and regulations	Environmental adaptation of products	Required range of information about products	Waste sorting system	Collection system	Recycling system	Dominant EPR market for waste products	Instruments for deposition and burning
Voluntary, branch regulated	Focus on clean materials	Chemicals Material Energy	> 15 commodity groups	Very near premises	Mechanical recycling	International	Recycling: Up Energy: Down
General legislation toward individual. No monopoly.	Same mix as today	Chemicals Material	> 15 material groups	High density "bring system"	Thermal recycling	National and close international	Recycling: Up Energy: Up
General legislation toward collective Partial monopoly.	Focus on dematerialisation	Chemicals Energy	Same as today	Low density "bring system"	Chemical recycling	Local/regional	Recycling: Down Energy: Up
Finely detailed legislation (who, how & what)		Chemicals only	< 5 commodity groups		Biological recycling		Relative increase of deposition
			< 5 material groups				

Fig. 8.2 A scenario profile identified through morphological analysis. *Source:* Ritchey (2009)

SCENARIO	EPR rules and regulations	Environmental adaptation of products	Required range of information about products	Waste sorting system	Collection system	Recycling system	Dominant EPR market for waste products	Instruments for deposition and burning
Global Crisis (Production gone wild)	Voluntary, branch regulated	Focus on clean materials	Chemicals Material Energy	> 15 commodity groups	Very near premises	Mechanical recycling	International	Recycling: Up Energy: Down
Raw Material Depletion	General legislation toward individual. No monopoly.	Same mix as today	Chemicals Material	> 15 material groups	High density "bring system"	Thermal recycling	National and close international	Recycling: Up Energy: Up
Current policies (Negative trend)	General legislation toward collective Partial monopoly	Focus on dematerialisation	Chemicals Energy	Same as today	Low density "bring system"	Chemical recycling	Local/regional	Recycling: Down Energy: Up
Current policies (Positive trend)	Finely detailed legislation (who, how & what)		Chemicals only	< 5 commodity groups		Biological recycling		Relative increase of deposition
Green-house effect (Stop emissions)				< 5 material groups				
Batman: High-tech solutions								
Dematerialised production (New materials)								
Green market (ideological paradise)								

Fig. 8.3 Morphological mapping of strategies against scenarios. *Source:* Ritchey (2009)

8.2.1.4 Cross-Impact Analysis

Developed by Theodore Gordon and Olaf Helmer in the USA in the mid-1960s, this method has some relation to systems mapping (described above). Its focus is also on interrelations between variables—or rather, on expert views of these interrelations, which we can rarely determine from pure logic or common sense. Cross-impact analysis is labour-intensive. It requires systematic consideration of the links between each pair of variables that are being considered. The more variables that are considered, the more the number of relationships to be examined rises, and rises dramatically fast. Since expert judgement is required to estimate how each variable interacts with each other, and experts time and patience is limited, it is common to work with a much smaller number of variables in cross-impact work than in systems mapping.

While the method may be employed in different ways, the typical approach is to ask first, *how likely is it that A will happen? that B will happen?* etc.; and then to ask *if A were to happen, what would be now the likelihood that B will happen?* and vice versa (ForSTI applications of such analysis often deal with events—e.g. a particular technology being developed, a variable such as the level of adoption of an innovation reaching some threshold value). The result is a matrix of cross-impacts in the form of conditional probabilities. In effect this is a small system map, represented as a matrix, with each variable connected to each other. The matrix can be analysed in various ways. One use may be to see which variables have greatest direct and indirect influences overall. Another use is to see which variables are having greatest impact on a parameter of particular concern. Indirect effects can be determined through this approach, which may be overlooked in less detailed analyses. A further use of the matrix is to examine all potential combinations of variables and estimate the probability of each occurring—these are, in effect, the profiles for a number of scenarios (with some assessment of probabilities).

The cross-impact method thus seeks to apply structured reflection to assess the interrelations between elements of the system we are examining. It has been widely used in the French “la prospective” tradition (and also, apparently, within the CIA and wider US intelligence community), where a high level of commitment has been obtained from participants. Since it involves much estimation of conditional probabilities, the approach can be very demanding of those required to make the judgements. The task requires careful assessment of discrete elements—perhaps too painstaking for some participants’ patience. Cross-impact estimations tend to be completed by means of questionnaires—which reduces the opportunities for discussion and knowledge exchange (except perhaps in the initial specification of key variables).

The approach has the virtue of aiming at a comprehensive mapping of interrelationships, and is thus regarded by some commentators as superior to methods such as Delphi, where individual developments are usually examined in isolation. Just how comprehensive this is may be questioned, however. It is possible that combinations of events will act together in nonlinear ways, even cancelling each other out; in some circumstances one event may shift the conditional probabilities associated with another one. The approach provides seemingly more precise results than a system map, and works with fewer variables. Proponents of the method argue strongly for its usefulness, and again it can be hoped that computer tools will allow for more engaging versions of the technique to be developed. Finally, we should note that in attaching numbers to the various relationships between a set of elements, cross-impact approaches are moving very close towards quantitative modelling, and some of the analytic procedures that are applied to the matrices take this forward further still. We now turn to other quantitative techniques.

8.2.2 Quantitative Modelling

Trend analysis (see Chap. 5) is a basic form of quantitative modelling, though often the only variable that is seen to be influencing the trend is the passage of time. Time is actually the stage on which processes—relations between variables, actions of stakeholders—pan out, and more sophisticated quantitative approaches will seek to explore the effects of actions and interrelationships over time. Already methods like cross-impact analysis involve some quantification of links between variables, but a range of techniques allow for consideration of many more variables than can feasibly be handled by the cross-impact approach.

As with other methods in ForSTI, the assumptions that are used in modelling are critical to the outcomes of the analysis. All models have to make assumptions about what variables (and what sorts of variables) to include, and similarly about the (sorts of) relationships between variables to work with; all have to face the challenge of finding data (or making "guesstimates" to calibrate the model with numbers that it can process. There are, however, fundamental differences in assumptions between broad classes of model. For example, a whole family of economic models is based around the notion that economic systems are fundamentally tending toward equilibrium conditions, and apply computational procedures aimed at finding what these equilibrium states are. Again, some models focus on stocks and flows between variables, while others (games theory and agent-based approaches) try to model the behaviour of actors who influence each other. Within any approach, choices are being made about what factors to treat as important, and which relationships to take into account. Implications of this basic point will be apparent when we discuss major world modelling efforts below.

Ciarli et al. (2013a—and see also 2013b) provide a useful discussion of quantitative tools used in ForSTI exercises, with some 64 tools being identified, and a smaller set of 26 of the most common (and some recent but heavily used) tools being selected for further analysis. The study reviews the advantages and limitations of the tools, which organisations most typically use them, and within what context they are deployed. As Fig. 8.4 displays, the techniques can be characterised by the sort of application they find; some are more about describing and making sense of the current situation of the focal object; some are more used for more or less sophisticated forecasting of the development and outcome of trends; and some are applied more in a fully-fledged ForSTI context. This is a helpful way of considering the range of quantitative tools that may be brought to bear within exercises; and the study provides a provocative and illuminating review of various features of these tools, to which the reader is referred.

It will be apparent that some quantitative tools—such as survey analysis or bibliometrics—are liable to be more about identifying trends or hot issues than to do with modelling as considered here. Models appear in their framework as tools

Descriptive *Extrapolative* *Data gathering* *Foresight*				*Forecast*			*Inference*	*Foresight*	*Prescriptive* *Normative*
Creative	**Monitoring & intelligence**	**Descripive & matrices**	**Statistical methods**	**Trends analyzes**	**Economic methods**	**Simulation Models**	**Quantitative Scenarios**	**Roadmaps**	**Valuing/ decision**
TRIZ	Bibliometrics Conjoint analysis *Social network analysis* *Social Software (Webometrics)*	Bibliometrics Cross Impact analysis State of the future Conjoint analysis *Social network analysis* *Social Software (Altmetrics)*	Cross impact analysis SMIC Prob Expert Scientometrics	Long wave models Trend extrapolation Trend impact analysis S-curves Technology substitution Megatrend analysis Time series / Indicators *Google trends & correlate*	Input Output *Prediction markets*	Agent modelling (Modeling & simulations) (Decision modeling) (Robust Decision Making) System dynamics	*RDM* *Scenario discovery*	Roadmapping	Multicriteria decision analysis AHP Life cycle an. / sustainability

Fig. 8.4 Quantitative methods used in ForSTI and related activities. *Source:* Table 1 (p. 22) in Ciarli et al. (2013a, b)

that are used more when we are considering such things as alternative futures, the results of different interventions, and the like. (Further along the axis that points towards "Foresight" is roadmapping, reflecting both its normative components and its typically involving dialogue within groupwork.)

When we speak of quantitative modelling, we usually refer to the use of computer simulation models of one kind or another. This may be somewhat misleading. Extrapolation of trends, we have argued, is a very simple form of modelling, and it is not difficult to apply more sophisticated methods of trend analysis without use of computers (though these days, just about all analysts will typically be employing at least spreadsheets, if not more complex methods of mathematical statistics, to organise data, fit curves, and so on). For example, it is likely to make sense to employ theories, such as those involved in diffusion analysis or product/industry cycle theories, to model trend data into S-curve or similar "extrapolations". This is a form of modelling, too, but is not strictly simulation modelling, which involves more dynamic approaches.

8.2.2.1 Computer Simulation

Computer simulations represent a system in terms of its key components and the main relationships between these, and to project how the system will operate over time, or how it may respond to specific interventions. Many of the issues that are dealt with in ForSTI exercises are hard to model systematically with quantitative tools, not least because there is often inadequate empirical material to inform the model. Some topics may be relatively easy to examine. Examples include: diffusion patterns of new products and processes, the labour force implications of training programmes, and the costs of cleaning up pollution. Many topics are more difficult to model—such as the pace and location of technological breakthroughs, the outcomes of R&D funding, public responses to new technologies. Being able to reliably forecast the rates of adoption of innovations before they had entered the market, or the likelihood of one or other design framework achieving dominance, would give firms huge advantages.

Computer models are, not surprisingly, used most extensively to simulate systems that have relatively easily quantifiable properties. Economic forecasts (many of which are issued on a routine basis) use models whose key variables can mainly be expressed in terms of monetary values (e.g. investment, consumption levels), or of headcounts (e.g. people in employment in different sectors, people unemployed). Demographic models also use population statistics (which, along with economic statistics, are regularly produced by the government statistical apparatus), and track and forecasts the numbers of people being born, dying, migrating, and so on. Transport and related models draw on data on traffic movements and data on location of dwellings, workplaces, shops, etc. (and specialised "gravity models" are employed here, to reflect the relative attractiveness of different locations). Weather forecasts and climate change projections are based upon meteorological models dealing with variables such as temperature and precipitation in particular areas.

The statistical data produced for governments (and sometimes for private organisations) can be used to estimate the relationships between variables—for example, the effect of price increases in one class of goods on prices in another class, or on the demand for these products. Data analyses involve sophisticated tools of mathematical statistics, though these tools often carry latent assumptions about the sorts of relationship that may be described. The models mentioned usually deal with aggregates—economic sectors, population groups, etc.—and consider actors as behaving in predictable ways within these aggregates. For some purposes this may be quite reasonable. But when we are dealing with STI issues we may well find actors seeking to behave in new ways—to innovate, with or without technological innovation—and to learn from experience. "Game theory" models have become quite popular as ways of accounting for the interaction of different actors whose behaviour will result in outcomes that vary according to how the others choose to act. "Agent-based" modelling is still a fairly novel set of approaches, albeit one with considerable promise: it describes systems in terms of different entities that are interacting (and thus the entities themselves have to be modelled in terms of their goals and capabilities).

Even when there are no obvious sources of evidence with which to "calibrate" a model, trying to create a simulation model can force us to think systematically about our assumptions concerning the dynamics of a system, and make us search for relevant data with which to test, explicate or elaborate such assumptions. It can also allow us to explore alternative starting conditions, events and interventions, and even allow us to experiment with changing assumptions and to compare the behaviour of models of the same system based on different understandings of how it operates. One of the main claims of the modelling community is that we can be enabled to deal with numerous variables simultaneously—to explore relationships and the working out of multiple changes in ways that are quite beyond our normal mental processes. Unless we have made programming mistakes, a computer can perform a huge number of calculations to process the model and its calibrated data meticulously. Finally, quantitative results can be presented many ways—graphs, charts etc.—and allow us to compare results obtained, for example, from different calibrations, for different interventions, and so on.

However, the quality of a model is only as good as that of the assumptions on which it is based (and the data with which it has been calibrated). One of the main drawbacks of modelling for ForSTI is that these assumptions may be obscured—by the technical language that is involved, and the degree of expertise required picking apart an elaborate model. The public may be less inclined to accept computer output as authoritative, even definitive, than previously. But the volume of precise results (expressed in seemingly detailed precision) may well have a dampening effect on critical inspection.

8.2.2.2 Limits to Growth and Global Models

Computer simulations began to attract widespread public interest in the 1970s, when *The Limits to Growth* study of the Club of Rome (Meadows et al. 1972) achieved considerable publicity. The model employed here—quite simple by current standards—employed the simulation technique known as Systems

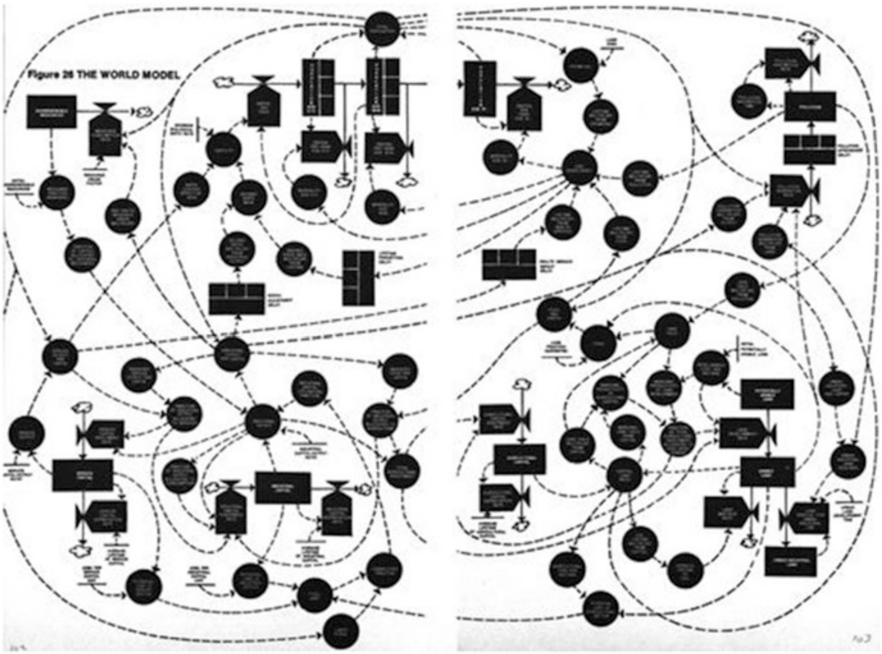
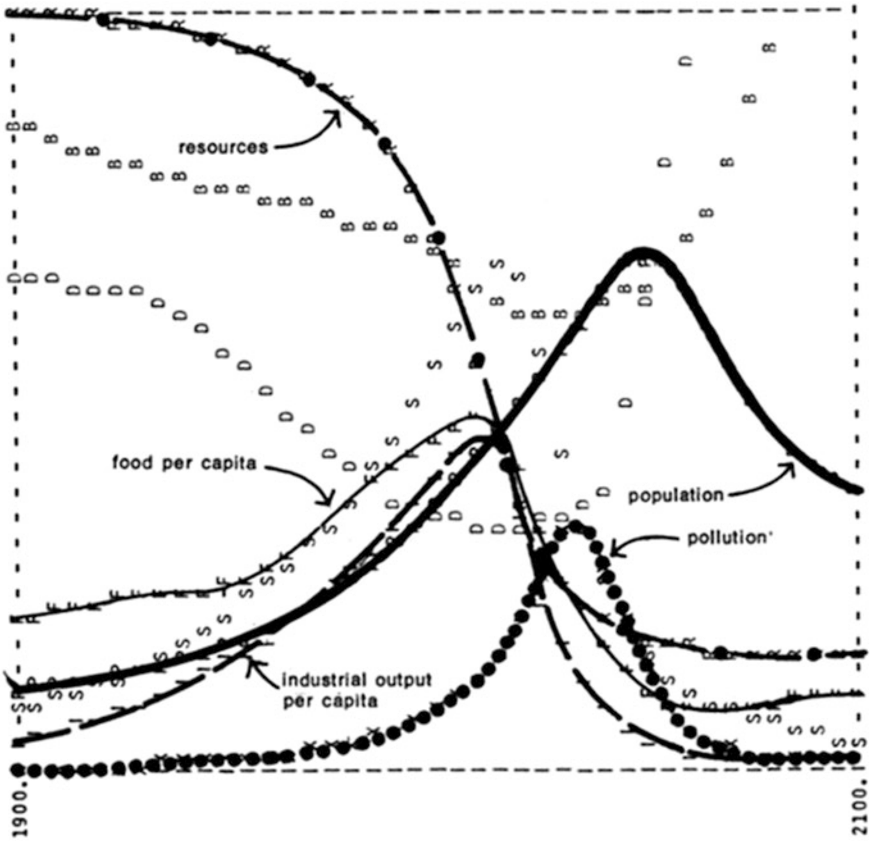


Fig. 8.5 The structure of the Limits to Growth model. *Source:* online version of *The Limits to Growth* (Available at: http://collections.dartmouth.edu/teitexts/meadows/diplomatic/meadows_ltg-diplomatic.html#pg-14, accessed on: 09.09.2014)

Dynamics, in an effort to describe the long-term future of the world system. Introduced by Jay W. Forrester starting from the 1950s (Forrester 1961, 1968), Systems Dynamics allows for nonlinear relations (the impact of A on B can be exponential, for example) and for feedback (A can affect B, B can affect A). In the Limits to Growth model, the world was analysed as one single economy, composed of population, agricultural production (needed to support the population), industrial capital and industrial output, non-renewable resources (consumed by industrial activity), and pollution (generated by industrial production, and reducing agricultural production). Figure 8.5 displays the structure of the model. Economic growth is seen as consuming resources and creating pollution, and ultimately, population growth and the associated demand would outstrip the capabilities of agricultural production, leading to "overshoot and collapse"—a Malthusian disaster, with a crash of world population. The "standard run" of the model, depicting this, is reproduced in Fig. 8.6.

The *Limits to Growth* study came under criticism from various quarters, but intensive marketing, and perhaps the novelty of the approach (at a time where computers were remote "electronic brains", that were often seen as more objective and rational than humans), meant that it was widely disseminated and hugely influential. With translations into more than 30 languages, and extensive media coverage, this was probably the best-known futures study to date. Another factor in



The "standard" world model run assumes no major change in the physical, economic, or social relationships that have historically governed the development of the world system. All variables plotted here follow historical values from 1900 to 1970. Food, industrial output, and population grow exponentially until the rapidly diminishing resource base forces a slowdown in industrial growth. Because of natural delays in the system, both population and pollution continue to increase for some time after the peak of industrialization. Population growth is finally halted by a rise in the death rate due to decreased food and medical services.

Fig. 8.6 The "Standard Run" of the Limits to Growth model. *Source:* online version of *The Limits to Growth* (Available at: http://collections.dartmouth.edu/teitexts/meadows/diplomatic/meadows_ltg-diplomatic.html#pg-14, accessed on: 09.09.2014)

its success may have been the "common sense" view that resources are finite, and that we cannot continue forever creating more pollution. Recently, a number of reports have concluded, essentially, that *Limits* was right. Thus Turner (2014) compiled data suggesting that the main trends depicted in that study were proving uncannily prescient, concluding that resource constraints were posing growing problems for the world order—just as many of *Limits*' supporters in the 1970s believed.

But *Limits* was also subjected to one of the most detailed critiques of any futures study, with Cole et al. (1973) dissecting the model and arguing that it failed on a number of critical points (for a detailed history of the first years of the debate, see Moll 1991). Resource estimates were consistently pessimistic and ignored scope for discovery and substitution. The "holistic" view of the world as a system was achieved by eliding the difference between rich resource-gobbling societies and poor countries where the "population explosion" was apparent. It was based on an embedded Malthusian view that would always generate cycles of growth, overshoot and collapse—in part because there was no scope for learning in the system. Innovations and structural changes that might decouple growth from resource consumption were not considered. The many criticisms led some commentators to dismiss *Limits* as an overambitious attempt to grapple with serious issues, but without sufficient grasp of their complexity. In some quarters this reinforced a view that the global economy would be self-correcting—"if these shortages really were severe, we would see little boys out recycling scrap" as one well-known economists remarked at a meeting attended by one of the present authors. For other commentators, it meant that we had to build bigger and better models as a matter of urgency. For others still, it was an urgent wake-up call that should not be neglected just because a multitude of "technical" errors were pinpointed by (allegedly) more mainstream researchers.

Following *Limits*, there was a wave of efforts to build computer models of the world system, some of them addressing (some of) these criticisms (for reviews see Cole's contribution to Freeman and Jahoda 1978). For example, the Bariloche model (Herrera et al. 1976) took a perspective more attentive to the challenges facing developing countries, while work at IIASA (Mesarovic and Pestel 1974) considered energy options and alternative technologies in much more detail. The Bariloche team set out to demonstrate the physical viability of a more egalitarian world order in the near future, concluding that under reasonable assumptions there was good reason to believe that the basic needs of the population of all world regions could be met without running into severe resource constraints (Herrera et al. 1976). Demonstrating this was taken to be an important task (given the Malthusian controversy) and the Bariloche model accordingly paid little attention to the formal analysis of what we would now call "transition processes" (how such changes are effected in practice). Presumably, models of political and economic affairs would be required for these purposes.

Such "world models" were highly ambitious attempts to simulate economy-environment interactions for the whole planet over decades and even centuries. They involved heroic, and highly contentious, assumptions to be made concerning natural resources, technological change (or its absence) and social affairs. They became extremely complex and demanding of computer resources (and of data with which to calibrate them). This raised another problem, because the structure and especially the behaviour of highly complex models can difficult to understand—sometimes modellers have misinterpreted their own results! (For example, attributing a trend to one causal process, when it is actually driven by another). Often there are a few key relationships that are driving the major results, and it is important to be able to explicate them for example, in the climate models discussed below, global warming is essentially down to greenhouse gas emissions. The volumes of data required are so extensive that it is very laborious to validate them, too.

The world models succeeded in raising awareness of many key issues, their quality as forecasts was highly suspect—one common criticism was that the models had been constructed by general-purpose computer or management scientists rather than experts in economic or ecological affairs. The sustained criticism they received cast a long shadow over modelling efforts, though in retrospect we can see that few critics would attempt to create such ambitious long-term analyses themselves.

More recently, large-scale modelling has attracted a great deal of attention in the context of climate change research. The models used here should not be confused with the models used for weather forecasting by national and local meteorological offices—these are extremely large and complex models developed in efforts to examine and project forward trends in global climate.[14] Since these are the product of large expert teams from many countries, and have attracted the support of many leading researchers in the climate field, the controversy concerning their results has been very different from that associated with *Limits*. The models involved are often massive ones, requiring supercomputers to calculate the evolution of conditions in a vast number of volumes of the global atmosphere (and its oceanic and land interfaces) over many points of time across long durations.

The controversies around climate change models have demonstrated that many people now no longer view computer models as authoritative and objective. They see the models as constructed by "experts" who may be simply incompetent, or who seek to obfuscate reality. Conspiracy theorists see the modellers as acting in their own self-interest (seeking more funding for their research) or else as promoting some elite agenda (e.g. Europeans seeking to curtail American growth). The science may be criticised on the basis of anecdotal evidence (since the weather is cold today, talk of global warming makes no sense). Or there may be argument about the meaning of various indicators or the difficulty in representing, for example, the role of clouds or of microorganisms in the sea. The response to the modelling efforts of the Intergovernmental Panel on Climate Change (IPCC), and others concerned with climate change, has led to much public uncertainty as to the extent of scientific

[14]Beck (2002) provides an interesting review and account of personal experience with environmental modelling.

consensus and the possible role of self-interest in their pronouncements. Critical responses are organised in part through powerful interests in oil and gas industries, so it gets a level of media coverage much broader—and more vociferous—than that accorded the critics of *Limits*.

The early climate models in the 1960s mainly concerned air temperature and precipitation, and began to address the consequences of additional levels of CO_2 entering the atmosphere. There are now actually many different models that seek to represent long-term processes in global circulation; essentially these portray the atmosphere (and ocean) as a large number of interacting cubes. Basic physical and chemical processes are captured in each cube, and relations between them are calculated over successive periods. (See Fig. 8.7: because these models involve huge numbers of relationships between the many entities modelled, it is felt that these visual representations convey the model structure most adequately.) These atmospheric and oceanic general circulation models are combined into global models, also incorporating factors such as land surface, ocean ice and clouds, and the role of aerosols and volcanic activity, together with more detail on the ocean on the carbon cycle with vegetation reacting to regional climate conditions, the role of rivers, and aspects of atmospheric chemistry (cf. IPCC 2007, 2014).[15]

Numerous models of increasing detail and complexity are incorporated into the IPCC's forecasts, but the basic message has remained stable over the four decades—anthropogenic CO_2 emissions are liable to lead to global mean temperature increases; and IPCC work on the impacts of these increases presents us with alarming scenarios (even taking into account the other IPCC work on adaptation and alleviation).

The most elaborate circulation models involve so many calculations that they require huge amounts of computer time to process. It is thus expensive and time-consuming to explore many scenarios with them. "Simple climate models" (reviewed in Harvey et al. 1997) thus provide a great deal less detail, but allow for more exploration of the consequences of different patterns of greenhouse gas emission (e.g. from different levels of use of different energy sources). They relate these and other factors to give estimates of such matters of concern as global mean surface temperature and global mean sea level rise. Harvey et al. (1997) stress that both simple and complex models have their own uses, and contrast the two in the table reproduced as Box 8.4.

[15]IPCC has produced a series of valuable assessment reports, where they have described the various models and other sorts of evidence used to reach their conclusions. Their briefing papers (Summaries for Policymakers) present key results together with assessments of the degree of confidence that can be attached to the forecasts (see material at: http://www.ipcc.ch/index.htm, accessed 09.09.2014).

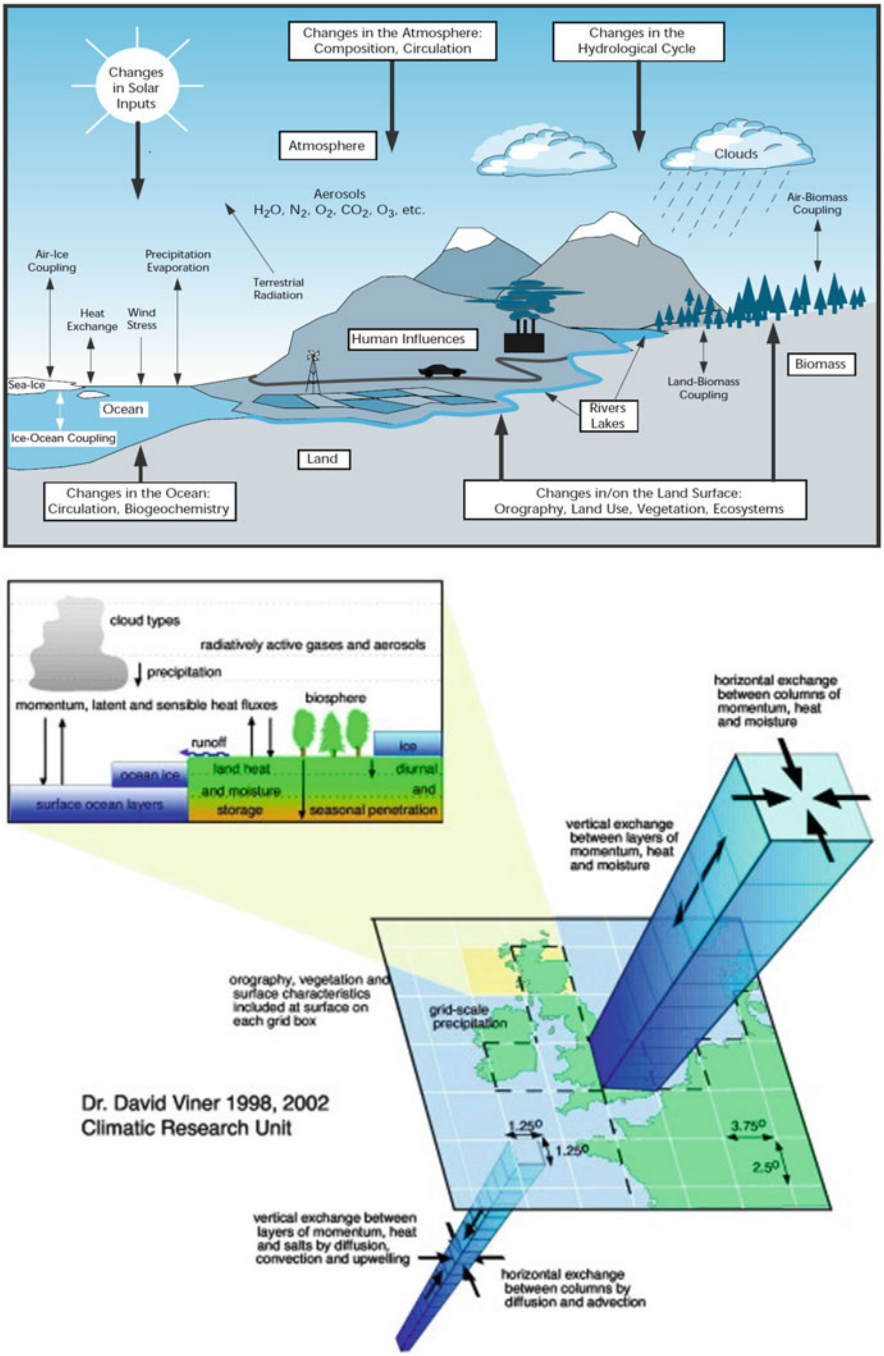


Fig. 8.7 Basic processes modelled in Global Circulation Models. *Sources: top figure* from IPCC SAR WG1 (1996); *lower figure* from IPCC (2013)

Box 8.4 The Use of Simple and Complex Climate Models

Simple Models	Complex Models
Generally produce zonally- or globally-averaged results, and only for temperature and temperature changes, not for other variables such as rainfall.	Simulate the past and present geographical variation of temperature, as well as other variables of climatic interest such as rainfall, evaporation, soil moisture, cloudiness, and winds; and provide credible continental scale changes of at least some of these variables.
Cannot simulate possible changes in climatic variability as output consists of the climate change signal only.	Have the potential to simulate changes in important modes of interannual variability (e.g., *El Niño)* as well as mean values.
The effects of physical processes are approximated based on globally- or zonally-averaged computations with low temporal resolution.	Many physical processes are directly simulated, necessitating the use of a short time-step but allowing resolution of the diurnal cycle.
Climate sensitivity and other subsystem properties must be specified based on the results of complex models or observations. These properties can be readily altered for purposes of sensitivity testing.	Climate sensitivity and other subsystem properties are computed based on a combination of physical laws and sub-grid scale model parametrizations.
Sufficiently fast that multiple scenarios can be simulated, and that runs with a wide range of parameter values can be executed. Can be initialized in a steady state at little computational cost.	Computational cost strongly limits the number of cases that can be investigated and the ability to initialize in a steady state.
Useful for sensitivity studies involving the interaction of large-scale climate system components.	Useful for studying those fundamental processes which can be resolved by the model
Analysis is easy because simple models include relatively few processes. Interpretation of simple model results may give insights into the behaviour of more complex models.	Model behaviour is the result of many interacting processes, as in the real world. Studies with complex models indicate what processes need to be included in simple models and, in some cases, how they can be parametrized.
One-dimensional models cannot simulate climatic surprises, for example sudden ocean circulation changes. Two-dimensional ocean models can give some insight into such changes.	AOGCMs can simulate major changes in ocean circulation but the timing and nature of such changes may not yet be reliable.

Source: Harvey et al. (1997)

The IPCC reports provide scenarios of climate issues (temperature, sea level, etc.) that—at the very least—a majority of experts consider plausible, with negative outcomes appearing to be highly likely (unless dramatic policy measures are undertaken). These results may be uncomfortable, but could valuably be taken into account in many ForSTI exercises. It is not the job of ForSTI to be comforting, especially not when we have many signals of impending crisis. Even if we still have inadequate understanding of global dynamics, the chances of environmental disaster cannot be discounted, and those that would discount them have better come up with their own well-grounded models.

8.2.3 Examples of Models in ForSTI

An example of the use of climate change models to support ForSTI analysis comes from the UK Foresight Programme's project on Flood and Coastal Defence (Government Office for Science 2004). Here, global climate scenarios produced by the UK Climate Impacts Programme (drawing on IPCC work) were combined with socio-economic scenarios developed in the first cycle of UK Foresight. These integrated scenarios provided some quantitative description of both climate conditions alongside the more economic data (e.g. GDP growth), together with less quantitative specifications of such social dimensions as the system of governance (whether power remains at the national level or moving upwards or downwards e.g. to the EU or regional governments), and social values (more or less individualistic or community-oriented).

The combination helped secure wide impact for the study. Maps and charts were used to demonstrate flood risks in the various scenarios (see Fig. 8.8 for example), along with photographic images of possible future landscapes. The report led to considerable media attention, not least because it enabled property owners, developers and insurers to consider the risks associated with building (or living) in particular locations.

Moving on from climate change, it will often make sense to use the sorts of economic and demographic projection routinely produced by national governments and international agencies, to provide at least a context for ForSTI work. Neither type of forecast is infallible, nor economic forecasts—even though they are typically shorter term—can be upset very rapidly by financial and other crises. But they can often provide us with some insight into underpinning trends and/or boundary conditions we should attend to.

With the widespread availability of personal computers and associated software, computer simulations in the form of life simulation games, social simulation games and "God games" have allowed players to experiment with evolving societies (As compared to games where players simply interact with one another or virtual characters—like *The Sims*—or play some kind of military, crime fighting, or other action adventure). *Civilisation* was the first well-known example of these genres of simulation game, emerging in the early 1990s and rapidly followed by other games purporting to have more or less historical accuracy. Some models necessarily underlie these games, though these are not usually very evident to users. At the same time, however, it has become more viable for more people to design and/or modify, as well as to interact with models, using general-purpose software tools (like spreadsheets) as well as specialised simulation techniques (such as the Systems Dynamics). Cole (2008) describes how model-building can be used in educational contexts to deepen understand and communicate knowledge about

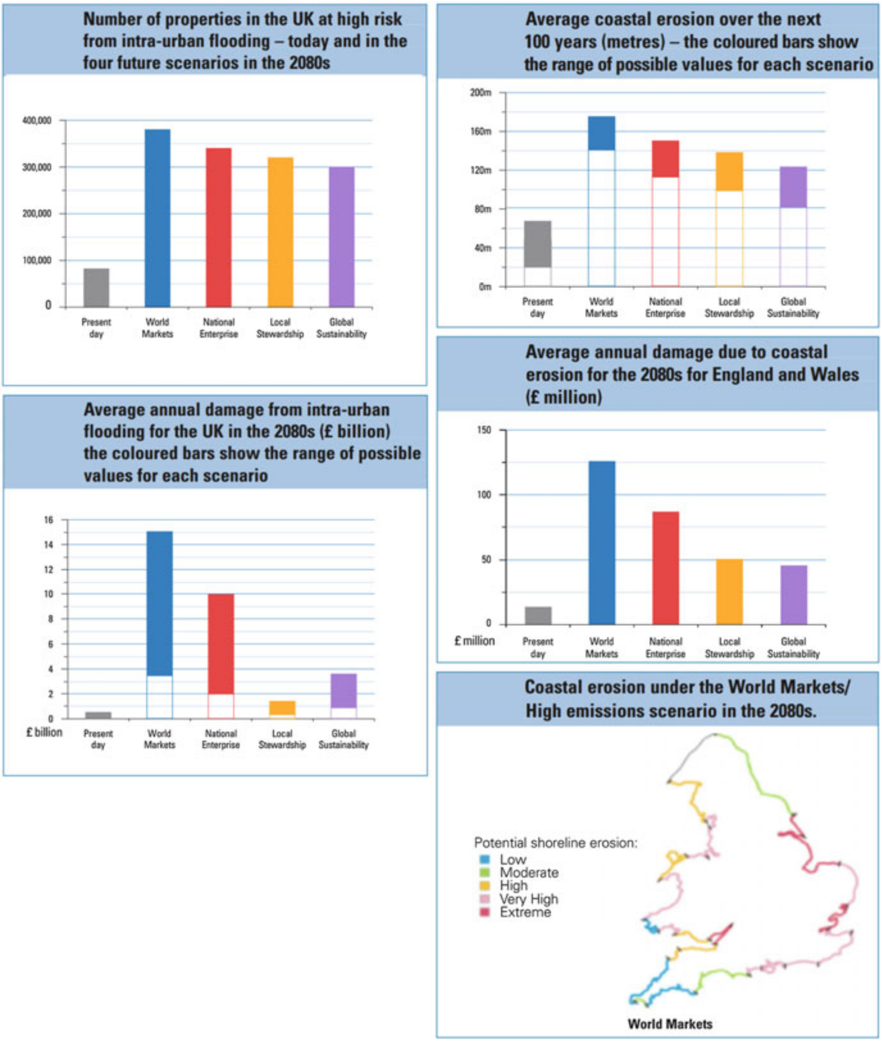


Fig. 8.8 Future flooding and coastal erosion in the UK. *Source:* Office of Science and Technology (2004)

critical issues—such a role is often claimed by proponents of computer modelling, but this is an example of its realisation in practice. Too often, we fear models obfuscate as much as they illuminate—especially when social and political assumptions are built into them.

Finally, we should note that new simulation approaches are being developed which hold considerable promise for application to social and ecological issues. One approach utilises "**cellular automata**", of the sort familiar in the computer *Game of Life*, first introduced in the 1970s. Here each cell in a space filled by cells is seen as behaving according to the cells around it; in *Life* the rules are very simple, cells will live or die according to the prevalence of other cells in their neighbourhood. It is easy to envisage extensions of this, where people's likelihood of adopting a particular attitude or behaviour is determined by how many of their neighbours are doing the same—indeed, models of diffusion of innovations that will be familiar to those involved in ForSTI, essentially take this form. The simple game of *Life* is one in which stable and unstable "social" structures emerge in the space occupied by the cellular automata.[16]

Another (and related) approach goes by the name of **Agent-based modelling**. Instead of treating, for instance, economies in terms of the interchanges between industrial sectors (and a consumption sector), the focus shifts to the interactions of a number of "agents". These may be people or organisations, and the task then is to represent their objectives, patterns of behaviour, and interactions in the model. This approach has attracted much interest in evolutionary economics and among theorists of technological innovation, as well as being applied to a wide range of issues in social analysis, where it is seen to be more realistic than traditional models. Instead of thinking of the word as composed of sectors, it is seen as constituted from multiple actors, agents, each of whom has a measure of bounded rationality and capability to learn about the others and the environment. The agents can communicate (or at least affect each other through their behaviour); they can be quite dissimilar from each other in terms of resources and capabilities; and they can interact in complex ways. Such simulation techniques are being explored across a wide range of ForSTI-relevant fields, with progress in moving from abstract models to representations of actual empirical situations and their possible developments. Among the topics covered are the transitions of energy systems, the migration of populations, the launch of innovative products, and the evolution of economic and innovation systems.[17]

ForSTI addresses very complicated issues, and while models are necessary, the more formalised quantitative models are probably most useful for addressing specific sub-domains of these issues; rather more informal and qualitative models may be required to take a wider and more integrative view. There may be developments emerging from some of the new modelling approaches which will allow us to construct models that can address the possibilities of structural change, for example, the emergence of new actors and institutions bearing on our focal objects. At present, most quantitative models that are used in ForSTI (and forecasting in general) are far more limited, and should be understood as such. They rarely deal explicitly with technology and technological change (this is treated in economic models, for example, just in terms of levels of investment, productivity and relative balance of factors of production). They have little ability to encompass

[16]For more on *Artificial Life*, consult the journal of that name (available at http://www.mitpressjournals.org/loi/artl, accessed on: 09.09.2014).

[17]The literature is already vast, and a small and nonrepresentative sample only can be given here, as a starting point for further exploration: Chappin and Dijkema (2010), Crooks and Heppenstall (2012), Delrea et al. (2007), Polhill et al. (2011), Pyka and Fagiolo (2007).

discovery, strategy and systemic transitions. However, the development and application of these models can be part of a critical and reflective process that helps ForSTI participants better understand the issues we are dealing with, and may allow for improved communication with other stakeholders—as long as we avoid the mystification of modelling! Obfuscation may be reduced by identifying the key relationships that drive the behaviour of the models, and it may be most appropriate to demonstrate this with construct simple models, and allow users to become familiar with how these operate, before adding layers of complexity.

8.3 Conclusions

Models are inevitable in, and intrinsic to ForSTI.[18] To rephrase a point made by J.M. Keynes, even the most influential ForSTI practitioner is usually applying the models of some long-dead economist—unless the assumptions and rationales involved in the models being used are made transparent. The approaches reviewed in this chapter represent ways of making the models that we are employing more transparent—more able to be communicated, critiqued, and further articulated. These approaches may take us further—we may be able to examine the results of complex interactions, we may be able to explore the implications of different assumptions, the effects of small or large variations in the data we input, and so on. As such, they can be valuable aids to the ForSTI process.

As always, the sorts of model we employ will be very much related to the circumstances and contingencies of a specific ForSTI exercise. Some types of model may take much time and require considerable expertise to develop—we may be fortunate enough to be able to apply the models recently developed by some still-living economist or environmental scientist, or have to do with much more limited types of trend analysis. ForSTI activities will often help to tell decision-makers what sorts of model they need to develop to better inform future strategies. In a given exercise, it is likely that one or more models will be developed and applied, however, even if these are far from perfect. The task is to appreciate the inevitable limitations of our models, while deploying them as effectively as possible. Following from this, we should be aware that models are liable to be employed for learning purposes as much as for forecasting.

[18]Indeed, human beings use more or less complex mental models to guide all of their actions.

From Integration to Interpretation: Translating ForSTI into Strategies

9

9.1 Introduction

One of the key features of ForSTI is that it is a policy and action-oriented activity. Therefore, the process does not simply end with the description of preferable futures, but goes to the next levels on the ways of formulating and implementing strategies and policies, and planning and allocating resources for successful implementation.

The task of determining a preferable state of the future, and the ways of achieving this, is a multifaceted process, where there are a variety of worldviews and expectations to be negotiated. This can be considered as a transition from a more exploratory and divergent thinking mode to a more normative and convergent mode of thinking in the ForSTI process.[1] At this phase of the activity, decisions on the desired future system need to be aligned with normative goals and values. An inclusive process, where the creative exchange of ideas and information sharing among participants is experienced, is beneficial. The definition of the 'most desirable' future system is a matter of 'prioritisation'. The end product of this phase is an agreed model of the future. Methods like Delphi (Chap. 6), Cross Impact Analysis (CIA—Chap. 8), Multi-Criteria Analysis (MCA), SWOT and/or Cost/Benefit Analysis (CBA) can be considered among the methods to support this process. Some of these methods have been referred in the earlier chapters of the book. In this chapter, we will particularly focus on CBA and MCA, and then consider the techniques of Critical/Key Technologies, before moving on to the roadmapping approach.

Roadmapping has become one of the most frequently used tools for bridging the future with the present. This is mainly because the method encompasses the key features of ForSTI, including: (1) linking the future with the present, (2) examining

[1] Recall that we do not see exploratory and divergent, or normative and convergent, approaches as inextricably bound together. However, the loose association within each of these "couplets" holds up fairly well as a description of different steps of the ForSTI process.

I. Miles et al., *Foresight for Science, Technology and Innovation*, Science, Technology and Innovation Studies, DOI 10.1007/978-3-319-32574-3_9

multiple alternatives for achieving desired futures, (3) providing participation through an interactive process. Roadmaps are used to ***guide decisions*** on research, development and innovation by providing information through graphics and visualisations instead of lengthy reports—though short reports may always accompany roadmaps for further information on key assumptions, description and elaboration of the components of the roadmap as well as providing policy and strategy recommendations. Thus roadmaps are easily understood by all parties involved and helping ensure discussions are informed, open and objective.

9.2 Assessment Methods

9.2.1 Cost-Benefit and Multi-criteria Analysis

ForSTI activities seek to inform stakeholders about decisions they could be, or actually are, making. While people will generally not want to follow advice blindly, and while policymakers and senior managers will generally want to feel that THEY are the ones making the decision, often they want more than just information about the options that might be available and the advantages and disadvantages associated with them. Decision-makers often demand that advice involves proposals as to what to do, which options to prioritise—even if they may also want to overrule such advice in the light of their own considerations.

Numerous techniques have been developed to help decision-makers choose between alternative options. When we put it this way, it is already apparent that these approaches presuppose that we have a set of alternative options. This may not be the case—or there may be considerable scope for modifying or tailoring options, for combining elements of different options, and so on. (We are comparing Option A against option B, but what about Option A + B—there may be multiplier effects—or some compromise that is 50 % A and 50 % B?) It may also be that options are not strictly equivalent, for example in terms of the level of "granularity" they refer to. For example, comparing Option A (fund research into new approaches to achieving greater energy efficiency) against Option B (fund a single centre to research into the applications of gene therapy to skin cancer), or Option A (undertake wide-ranging public consultations about the desirable future for the health and social care system) against Option B (survey staff attitudes to use of smart cards in electronic patient health records), are not just comparing chalk with cheese—they are more like comparing one piece of chalk with a whole shop full of different cheeses.

Still, decision makers may be presented with a limited range of options, for example a set of priority areas for research arising out of a ForSTI exercise. In many conventional planning exercises, the criteria being employed are strictly economic ones. A **Cost-Benefit Analysis** (CBA) simply seeks to examine what the costs of various options are, and what their benefits are, expressed in financial terms—and with discount rates applied to take into account the estimates as to when expenses will be incurred and when the rewards will become apparent. Many decisions as to (for example) large infrastructural projects, are based on such an approach.[2] The approach has been often criticised for its limitations. (cf. Ackerman 2008—who outlines six criticisms of the approach—Kelman 1981; Rosenhead and Thunhurst 1979). For example, the value judgements necessarily creep in when putting monetary values on, say, ecological damage or cultural heritage, on the time of non-employed people as that of senior managers. Massive future costs may appear negligible simply because they are remote—Linstone (1973) notably showed that the catastrophes predicted by *Limits to Growth* were discounted to being practically meaningless because they would only happen in future decades hence. CBA can be used in more sophisticated ways than simply providing an overall score for each option, though. Costs can be plotted on one axis and benefits on the other, for example, to give a two-dimensional mapping of the alternative options in terms of these two dimensions. The options can be represented not by dots or points, but as fuzzier oval or circle shapes, to indicate the level of uncertainty associated with the cost-benefit judgements. Risks can be indicated, for example by plotting each option in two locations—one of which assumes successful implementation, one which assumes that non-negligible risks of failure (say, those with more than a 1 in 10 chance of happening) do occur. Different discount rates can be employed, with arrows emerging from the dots to indicate the ways in which the cost-benefit ratios would change when future events are valued in different ways. While most CBAs do not adopt such approaches, it makes sense for long-term ForSTI analysis to consider presenting any CBA results in more elaborate ways than simply scoring benefits minus costs. Even so, the methodology is limited by its use of a single criterion for assessing value.

Multiple Criteria Analysis (MCA—also known as multi-criteria analysis and other variations on the theme) is employed when monetary values are not considered to be sufficient for representing the objectives and impacts of decisions. For a description of the approach, and some alternative ways of applying it, see Department for Communities and Local Government (2009). Several techniques are in existence, but in common they involve scoring the alternative options against a series of defined criteria; and having users indicate the relative importance of each criterion in numerical form, so that the scores that each achieves can be weighed in terms of importance. The most common practice is then to use "importance" as the overriding criterion, and reduce assessments on the different criteria to a single measure of importance (as contrasted with CBA's use of monetary values). So what most often is done, is to compute the overall value attached to each outcome (how much will X happen and how important is X), and thus rank the options in terms of their (non-monetary) cost-benefit appraisal. This assumes that the values are computable (what if, for instance, infinite value is placed on some attribute such as "survival of the human race"?). However, the approach does not need to culminate

[2]For a set of resources on using cost-benefit analysis, with worked examples, see the "Green Book" website at https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent (accessed 10/12/2014).

in a single score of options on a single dimension. It is equally possible to contrast a set of options in terms of how each fares in terms of different value criteria. Thus the form that the advice takes might go along lines such as: "if your goal is to maximise this sort of outcomes, then these options look most viable, while if you in contrast prefer these other outcomes, then these options rise to the top". The user can then make decisions that take into account, for example, the need to avoid particular types of extreme outcome, the need to balance between various values, and so on. It is also possible to use some statistical analyses here—which outcomes are more often positively or negatively associated with each other; which options look most similar in terms of outcomes. It is also possible to combine mixtures of options (if they are not mutually exclusive), in the form of different "scenarios" (in the terminology we introduced earlier, we call these profiles) that can be compared with each other, as Gough and Shackley (2006) do.

Gough and Shackley (2006) detail this study's application of MCA to some STI options. Their work examined a number of possible approaches to Carbon Capture and Storage (focusing on ways in which CO_2 might be stored to avoid further climate change hazards from emissions). They aimed at doing more than just selecting the "winner" from a set of options. One feature of their use of MCA was to provide insight into the expectations and preferences of those providing the information for the project; this gave the researchers the ability to better 'map' the key issues shaping the prospects for future development of the technology they were considering—. The MCA study was conducted in two stages.

The first stage was "reservoir assessment", where criteria relevant to assessing a number of options for storage of CO_2 were compared (These options were offshore oil and gas fields; offshore saline aquifers within traps and outside traps; and on-shore sites). These options were assessed against a first set of criteria, dealing with the effectiveness of the technology. This set was developed in an iterative process with expert respondents (geologists from the British Geological Survey). The authors reported that their experts found it much easier to generate ideas when they were commenting on and adding to a list of potential criteria provided to them by the study team. In contrast, having to generate their own criteria on a blank slate was challenging. (We have noted similar tendencies in other contexts. The message is: do some preparatory work and provide your experts with, at least, a few examples!) With the experts, a set of default scores was developed for the reservoir options; disagreements demonstrated where there were areas of scientific uncertainty and controversy. Other study participants, if unconfident or uncomfortable with assigning their own scores to the options, could use these default scores (Most of the non-experts used these defaults, thus being able to assign weights to the value criteria, without needing to have developed their own in-depth understanding of the storage options).

All participants were asked to weigh the criteria in value terms, i.e. how important each was. Thus the relative 'performance' of each reservoir option could be calculated, for each participant, on the basis of the options' scores and weights. This approach is using the value weighing placed on each criterion in a way rather like the use of simple monetary values assigned in CBA. It still requires some assumptions about the validity of the arithmetic operations of multiplication and addition that are employed to reach the estimates of how well, overall, the options perform against the value criteria. It could be argued by CBA proponents that we can be more confident that adding up two monetary values provides a coherent result, than we can about adding up two ratings of importance. However, MCA does at least not assume that everything can be assigned a monetary value, and can be used so that decision-makers can consider what values they would assign to particular criteria—or to particular combinations of outcomes in terms of different criteria. The sort of rationalistic approach used by MCA has been shown to have some predictive utility in examining how individuals' attitudes relate to their expectations and values—attitudes reflect beliefs about the likely consequences of choices for variously valued outcome criteria (Ajzen 1988). But we also know from behavioural economics that psycho-logic is often not a simple mirror of rational logic, for instance when risks are being assessed.[3]

Figure 9.1a, b display some results from this first stage analysis; they present the default assessments of the options in terms of the first set of criteria, and the overall views of the options from different stakeholders.

The study discusses the underlying reasons for the assessments, and the divergence of views. As the lower part of Fig. 9.1 indicates, there appears to have been a moderate degree of agreement as to the best and worst options. In a second stage of the study, alternative scenarios (that were described in terms of different extent of development of the four options) were compared. Further criteria were now introduced, going beyond assessing the effectiveness of the technological options. These were: cost, infrastructure change required, lifestyle changes required, security of supply, environmental impacts, credibility (of the scenario), risk of major disasters, international/distributional effects. Again the study participants assessed the relative importance of the criteria, so that a set of scenarios featuring different combinations of the technological options could be compared. As in many real life situations, some mixture of options is likely—emphasis on a single technological solution typically carries substantial costs in terms of one or other criterion, and substantial risks if things go wrong.

This was not a large scale exercise, but does demonstrate how quite simple methods (the only technical support required was a spreadsheet) can be used to gain insight and provide rich information for policymakers and stakeholders. While in some situations a clear and decisive answer will be sought—which option should we go for?—there are, fortunately, many cases where debate can be furthered, and

[3]The literature on these topics is vast. For an introduction to behavioural economics, see Kahneman (2003); one of many efforts to assess and explain public perceptions of emerging technologies is Kahan et al. (2007); efforts to explicate key risk issues for policymakers is Annual Report of the Government Chief Scientific Adviser (2014) and Williamson and Weyman (2005). Foresight Programme commissioned an excellent "Science Review Summary: Public Perception of Risk" (by J.R. Eiser, dated 2004); this is still accessible online from other repositories, such as http://web-archive-net.com/page/789210/2012-11-29/http://www.bis.gov.uk/files/file15017.pdf

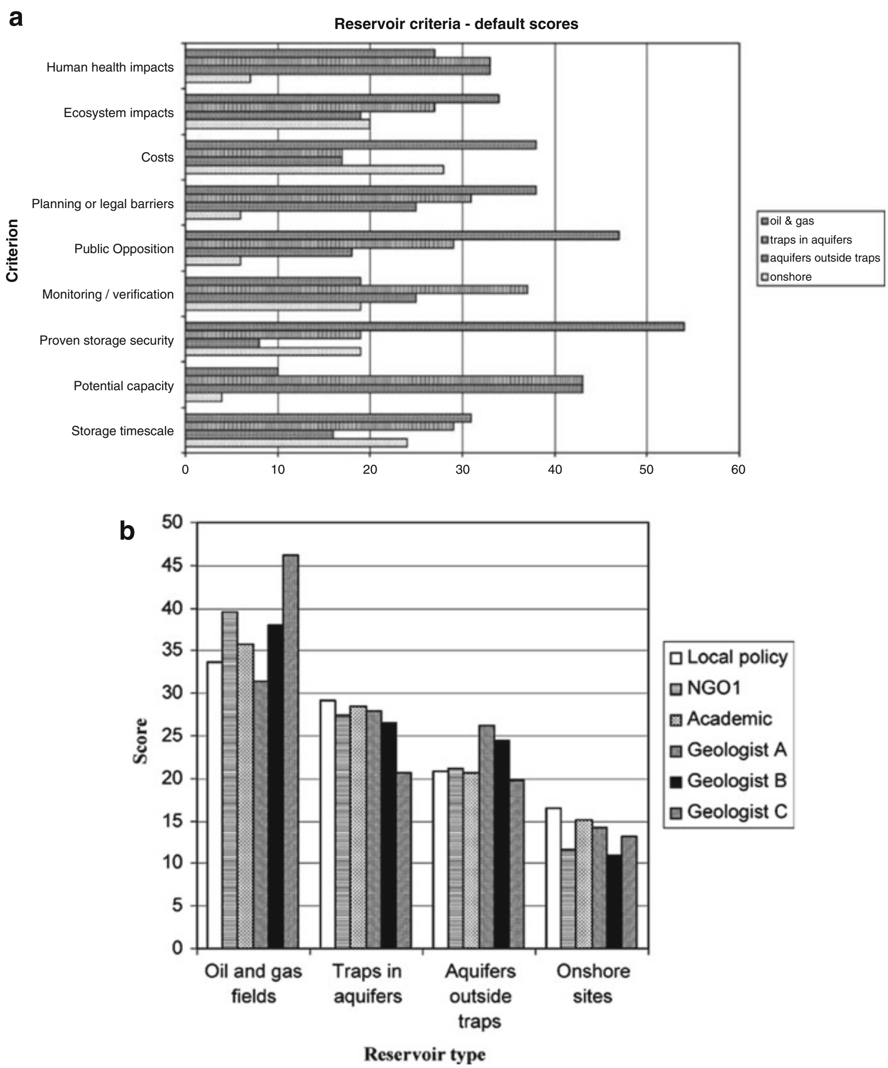


Fig. 9.1 (**a**, **b**) Stakeholder assessment of different carbon storage options

decisions better informed, by systematic provision of evidence about different criteria and outcomes.

9.2.2 Other Assessment Approaches

There are many other efforts to develop tools useful for decision making where we are confronting multiple criteria and (often) some degrees of uncertainty. The field of Operations Research is a rich source of these, along with the fast-evolving area of Decision support Systems. Probably the best-known method after CBA and MCA is the Analytic Hierarchy Process (AHP—see Vaidya and Kumar 2006).[4] Like MCA, this suggests that we evaluate options in terms of multiple criteria. In a twist that makes it particularly suitable for group discussions, the approach usually involves making pairwise comparisons between criteria; how do these criteria impact upon the overall assessment of the option—or, indeed, on some higher-order criterion (For example, we might take economic development to be the overall goal; this is assessed in terms of criteria such as employment, wealth creation, and so on; employment is assessed in terms of job creation, quality of jobs, etc. It is possible to have multiple layers in such an approach—which would then require subgroups to work on them. With multiple layers and such subgroup judgements, though, there is much scope for inconsistency to creep in). Numerical weights are then assigned to the criteria, and the options assessed in terms of their (likely) performance in terms of these. A convenient short description of AHP, some of the main criticisms of the approach, and its relation to other tools is provided by the Department for Communities and Local Government (2009).

9.3 Prioritisation: Critical Technologies

This section will outline the Critical Technologies approach, which has been one of the most common ways of undertaking ForSTI in a number of countries—notably France and the United States. In some languages, the word "critical" implies "catastrophe", and therefore the wording "key technologies" is used instead, for example Technologies Clés in France (Louvet 2000) or—Schlüsseltechnologien in Germany (BMBF 2003). Despite the name, the meaning is always the same—technologies which have a strong potential to influence national competitiveness and quality of life. Thus the approach involves applying criteria to measure the relevance or criticality of particular technologies to these goals (The term springs from the American identification of strategic and critical materials in 1940, referring to materials needed for the US Army which were either not produced at all or produced in inadequate quantity, respectively, in the US (Miller 2007). The term continued to be used, for example in the 1950s it signified materials where 5-year stocks should be held in the case of military conflicts. In the 1980s the idea began to be applied to materials that critical to some economic sectors, and to technologies as well, that were widely used across the economy).

In the ForSTI context, we are concerned less with those technologies that are of current importance, and more with those that are liable to be of high significance in the future. Resources that are invested in such technologies are anticipated to lead to significant returns in various applications in the future—they represent

[4]Some similar approaches in ForSTI work are reviewed in Lee et al. (2008); see also Martin and Daim (2012) for application in a roadmapping context.

technological opportunities to create beneficial products and/or processes in terms of economy and/or quality of life outcomes. For example, we can anticipate that some developments of so-called generic technologies (those that are widely used, that underpin many sorts of applications, that provide key components for more complex products and systems) are liable to be critical. Prospective developments in artificial intelligence may be critical, for instance, to a wide range of Information Technology (IT) applications—from autonomous vehicles and robotics, through to decision support systems and ways of providing cognitive support to people confronted with more real-time data than they can process. So when there is rapid technological development in a generic technology—like new IT, genomics and biotechnologies, nanotechnologies, etc.—there may well be many critical technologies emerging.

9.3.1 Critical/Key Technologies

Bimber and Popper (1994) suggested that three criteria would need to be met for a technology to be considered as critical. It should be:

- **Policy-relevant**—policymakers should be able to see to what the technologies are critical for, and where there may be points of political intervention that would increase capacity vis-a-vis the technologies and the needs they address. Bimber and Popper mention paying attention to such issues as R&D, commercialisation, dissemination and utilisation of technologies. They note that some technologies upon which countries rely may nevertheless not be critical is they are easily obtainable on the world market: lack of self-sufficiency is only grounds for concern if there is a realistic prospect of lack of access to commercially available products in the global marketplace.
- **Discriminating**—though "grey zones" are common whenever we are confronted with uncertainty, Bimber and Popper argue for a clear distinction between critical and non-critical technologies, and application of methods that will place candidate technologies clearly in one or other group. This reflects their concern that every advanced product or process might be touted as critical, and perhaps the fear that things that have been hyped in the media might be automatically assessed in this way. Many things that attract media coverage will only be important (if at all) in the very long-term, or in very specialised applications. (Likewise, technologies that are "state of the art" may not be relevant to policy, even though they attract a great deal of attention.) Bimber and Popper also draw attention to the need to consider the level of aggregation (or granularity) that we are using. A grouping that is too broad is liable to include non-critical developments of a generic technology, for example, alongside more critical areas of application or technological progress.
- **Reproducible**—a transparent methodology should be used to develop results, so that it would in principle be possible for others to follow the same procedures and reach similar conclusions. (In practice, this may not always be possible,

simply because experts might not want to answer the same questions twice—or they might be influenced by the published results of an earlier exercise.) A clear exposition of the methods employed is important for giving confidence in the results, in learning from any problems that were encountered, and for being able to compare the outcomes of different exercises.

The critical technologies approach, then, typically aims at generating a list of such technologies, a justification of this list, and clear specification of related policy actions that follow from this. While the basic outcome is a prioritisation of critical technologies, the assessment of what is and is not critical, and what the action implications of this are, inevitably implies some analysis of the national innovation system (or of the system for whatever unit of analysis is being considered – it would even be possible to do city-level analysis, and there are many regions in some countries that are larger in demographic and economic terms than the smaller countries of the European Union, for example).

Prioritisation of R&D fields has long been an objective—often the leading objective—of ForSTI exercises. The goal may be simply that of deciding where to allocate public funds, or it may involve stimulating wider awareness (especially in industry and the research community) of key technologies. Identification of policy measures can be a valuable input to discussion of STI policy mixes, as could be the discussion of what criteria are relevant for assessing priorities.

9.3.2 Applying the Critical Technologies Method

As with most ForSTI methods, there are many ways in which this approach can be implemented. Almost invariably they depend, however, on consultation with experts in order to form judgements. Often a relatively informal method has been used—a panel has selected the key technologies, after some discussion of criteria, usually drawing upon some overview of developments in different technology fields (such overviews prepared in the course of UK Foresight are the Technology and Innovation Futures reports, which drew on interviews with a range of experts).[5] More formal approaches typically involving surveying experts, and the first tasks will thus be (a) designing the survey and (b) locating key experts to whom the survey should be sent.

Even in the case of a panel-based approach, involving a limited number of experts and a narrow consultation approach, the sponsor will need to choose panel members. If there is broader consultation, for example by a survey, then some core group will still need to locate key experts and interpret results. Broader consultation typically takes more time, but the loss of speed may be offset by the gain in legitimacy from examining wider views.

[5]Available at https://www.gov.uk/government/publications/technology-and-innovation-futures-uk-growth-opportunities-for-the-2020s (Accessed on: 02.11.2015).

The survey (or even the discussion within a small group) needs to work on the basis of some initial list of technologies. In a Delphi-type approach, this list may be derived from a more open-ended survey, or by other approaches such as using lists developed in previous ForSTI studies (especially those conducted fairly recently in similar territories), from interviews, or via a wide-ranging review of literature; in any case it will require fine-tuning by a core group or expert panels to develop a list that is clear and concise, readily understandable, and at the right level of granularity.

The survey (or group discussion) will need to embody some criteria for prioritisation—and again, in a survey these will need to be very clear and concise. Thus in the Delphi study of the first UK exercise, respondents were invited not only to indicate when they thought particular technologies would be realised, but also to rate each example in terms of its contribution to "wealth creation" and "the quality of life" (to be precise, respondents voted about specific "topics", most of which involved STI, but a few of which dealt with topics such as regulations, social developments, etc.). A rating scale was employed with four scale points ranging from "negative", through "neutral" and "positive", to "very positive". Once survey results had been accumulated, each topic could be located on a two dimensional graph comparing the average ratings on each objective (In some STI areas—such as health—the two tended to be highly correlated, e.g. high contribution to wealth creation was associated with high quality of life impact. In some areas, such as transport, the association was much lower). The plotting of topics on these dimensions clearly informed the final judgements of the Foresight Steering Group as to priority fields for study; since technologies were considered in terms of "attractiveness", reflecting the score on these dimensions.

However another variable comes into play—how feasible it is that the technology can be developed within the national innovation system. In the current approach adopted in France, key technologies are defined as being those that are 'attractive' (have a potential for practical implementation in 5–10 years ahead) and where France has competitive advantages (in terms of the presence and performance of enterprises or research laboratories, the development of innovation ecosystems, and so on).[6] The UK Delphi solicited ratings about the level of capability (or feasibility) in the UK to undertake the science and the commercial exploitation of the various topics considered, and this also informed the final judgements. A representation of the prioritisation scheme is given in Fig. 9.2.[7]

A two-dimensional plot could be obtained, using a combination of the impact and the capability scales (Fig. 9.3).

In the figure, critical technologies are located on the top right corner of the figure. These are the technologies with the highest Attractiveness/Importance and Capability/Feasibility rankings. As they are both attractive/important and at the

[6]France has had earlier rounds of "Key Technology" exercises in the 1990s and at the turn of the century—see Barré (2008). For the recent exercise, see Ministere de l'Economie, de Finance et de l'Industrie (2015).

[7]This scheme was also used in the Czech ForSTI exercise, which will be mentioned briefly below.

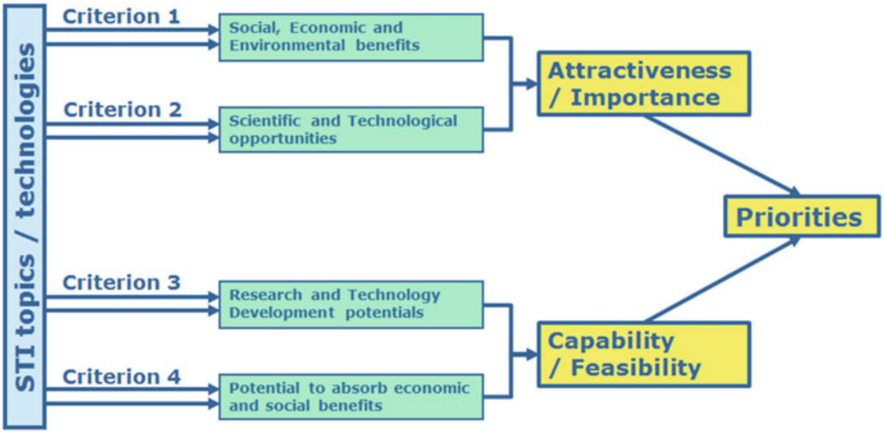


Fig. 9.2 Prioritisation scheme. Adapted from Klusacek (2003)

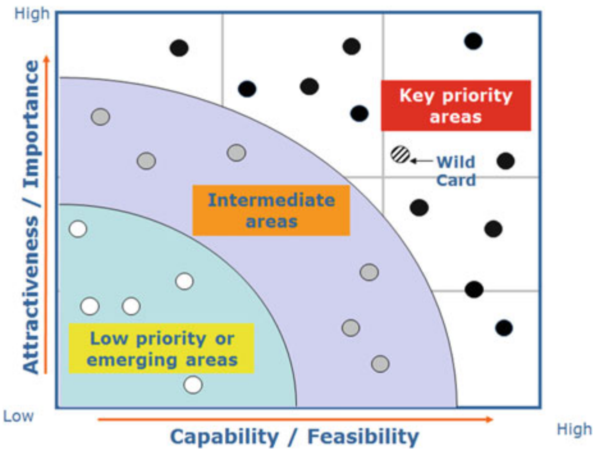


Fig. 9.3 Attractiveness/Feasibility matrix

same time feasible, they are the first group of technologies to focus on. Here, there might be some of those unexpected or surprising Wild Card technologies emerge. These may provide additional added value for ForSTI. Regarding the other quadrants, the figure also shows technologies, which are highly attractive/important, but not feasible, meaning that there are not enough resources (e.g. time, skills, funds etc.) to exploit them, and they currently remain under-exploited. Strategies can be developed to make these technologies more feasible through allocation of resources. There are also technologies with low attractiveness/importance and high feasibility (bottom-right corner). Resources used for these technologies can be directed towards the under-exploited technologies to increase their feasibility and eventual exploitation as critical technologies. The bottom left corner consists of technologies, which have both low attractiveness/importance and low feasibility.

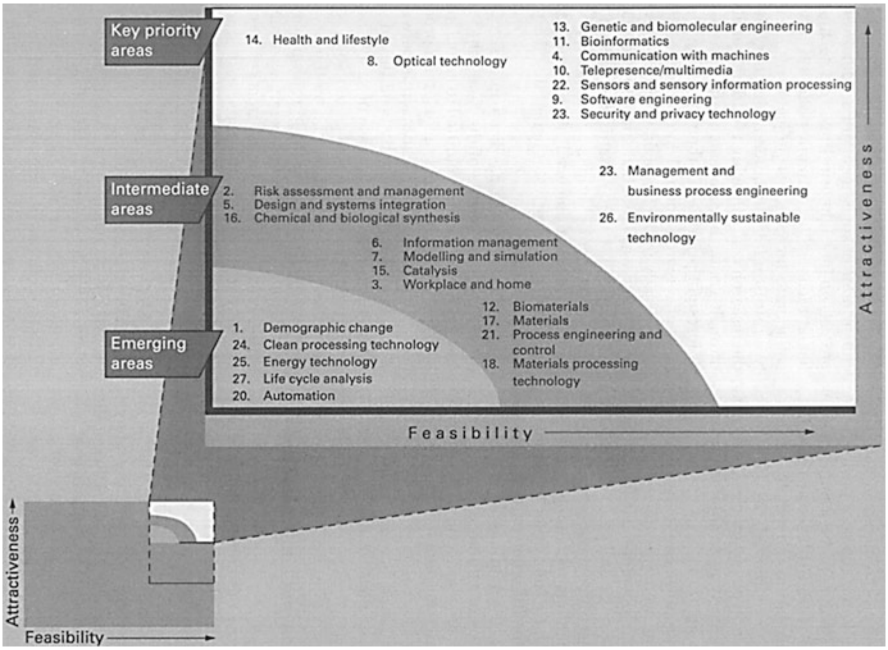


Fig. 9.4 Priority areas in UK Foresight. *Source:* Steering Group of the Technology Foresight Programme (1995)

This may be due to two reasons. On the one hand, these technologies may be considered as low priority technologies and do not require immediate resource allocation. On the other hand, they may be considered as emerging areas, which may require particular attention in case they may become attractive/important in the future such as demographic change and clean processing technologies identified in the first UK ForSTI exercise. In the UK case, the precise way in which attractive and feasibility combinations were achieved remains somewhat obscure, and the results for each of the over 1000 topics considered were not published; but a broad overview of priority technology areas was presented, and this is reproduced in Fig. 9.4.

Prioritisation essentially involves reducing the initial list of technologies to a smaller list representing the critical technologies, as identified by the set of criteria that are being applied. Prioritisation is potentially a controversial activity, creating a pecking order among technologies—and thus some loser. In order to avoid direct lobbying at this stage, the voting process can be split in two parts. At the first stage, experts identify innovative and technology-enabled products and services which are most attractive and feasible for the country. At the second stage, they identify a set of technologies providing most important contribution to the selected products and services.

In surveys such as that described above, a voting procedure is effectively being used to make the selection from the initial list of technologies. It is common for there to be some assessment of attractiveness (impact) and feasibility, though these can be explored at more or less depth. In studies which are mainly Critical Technology exercises (the UK Foresight had a wider remit) this prioritisation process takes centre stage.

Klusacek (2003) describes how this approach was used in the Czech ForSTI exercise. Technologies having a good score for both attractiveness and feasibility are potential candidates for the final list of critical technologies; and these two parameters were calculated from more detailed criteria which respondents applied to technologies from an initial list. The individual criteria included 4 economic benefits (e.g. contribution to GDP, to exports), 5 social benefits (e.g. contribution to health, to security. . .), 7 environmental benefits (e.g. materials and energy effectiveness. . .) and 8 research and technology opportunities (e.g. ability of research to produce technologies, possibility of breakthroughs. . .); feasibility was considered in terms of 5 areas of application potential (e.g. competitiveness of the sector, support in policy and regulations. . .) and 7 areas of research and technology potential (e.g. level of technology infrastructure, financial requirements. . .). The individual criteria were ranked on 5 point scales (ranging from 1 (low), to 5 (extremely high) benefits or potential).

More elaborated prioritisation criteria were formulated and used as a part of the Delphi survey designed for the Turkish Vision 2023 exercise (Box 9.1).[8]

Box 9.1: Prioritisation Criteria for Vision 2023

Each topic statement was assessed considering a set of 'feasibility' and 'importance' criteria (Fig. 9.5).

It should be remembered that the formulation for identifying prioritisation criteria is a part of the ForSTI process. For instance in the case of aforementioned Vision 2023, the criteria were initially identified by the ForSTI Steering Committee. A long list of criteria was generated. Then the list was shortened through first clustering. The final set of criteria illustrated in the figure was determined following a final voting session during a Steering Committee meeting. The process did not end with the final list. Each criterion in the list was given a weight considering that some of them might be more crucial for the selection of critical technologies than the others. These weights were used to generate a feasibility and importance 'index' for each technology area. The weights given for the importance index was as follows:

- Competitive strength: 28 %
- S&T and innovation capacity: 26 %
- Environment and energy efficiency: 16 %
- Creation of national value added: 15 %
- Quality of life: 15 %

(continued)

[8] http://www.tubitak.gov.tr/en/about-us/policies/content-vision-2023 (Accessed on 03.11.2015).

Box 9.1 (continued)

A more complicated algorithm was used for weighting the feasibility criteria to generate feasibility index. Weights were given based on the levels of technological development (including basic research, applied and industrial research, pre-competition industrial development, and industrial development). Below is the matrix produced to illustrate how the feasibility criteria were weighed against the level of development (Fig. 9.6).

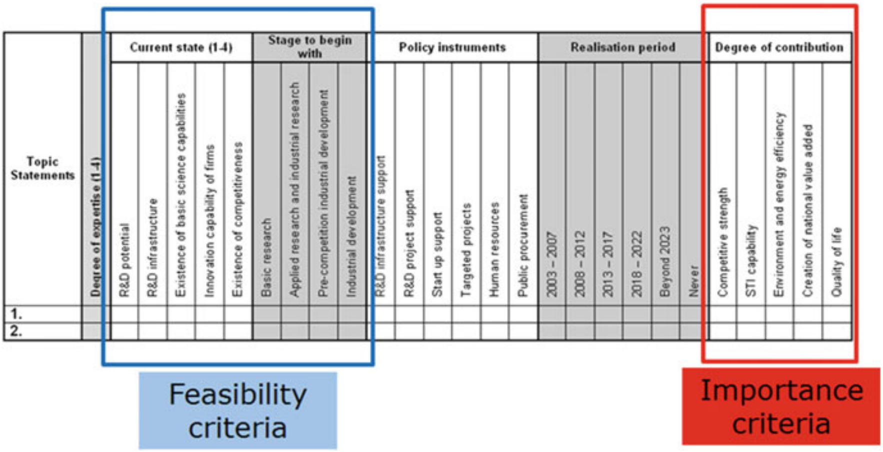


Fig. 9.5 Prioritisation criteria in a Delphi survey: the case of Vision 2023

Weights					
Initial Capability	Researcher potential	R&D infrastructure	Existence of basic science capabilities	Innovation capability of firms	Existence of competitive firms
Basic research	% 25	% 25	% 25	% 15	% 10
Applied research and industrial research	% 25	% 20	% 20	% 20	% 15
Pre-competition industrial development	% 20	% 20	% 15	% 20	% 25
Industrial development	% 20	% 15	% 10	% 30	% 25

Fig. 9.6 Feasibility index used in Vision 2023

Following this example, it should be said that identifying critical technologies through setting priorities can be a complicated, painful and divisive process. Building consensus between the participants of ForSTI through this process plays an important role. We should also underline that likewise in any stage of the process the approaches to the identification of critical technologies and setting priorities should be tailored to match the situation. Once again, one size does not fit all!

The next step would normally be to consider what sorts of policy measure should be recommended to increase the prospects of this opportunity being seized. However, this is most often the task undertaken by the expert panel or core group, and this group may well want to review the results of the survey (or whatever voting approach has been used). For example, it might be that some technologies have been considered only by a few experts, or that there is very substantial difference in viewpoints across different respondents. The expert group, then, will typically generate the final list of technologies as well as elaborate the recommendations of what should be done in respect of these choices. Again, there is a chance that some special interests will be voiced or lobbying take place, so the sponsors and project managers should have a clear explanation of any major changes introduced into the prioritisation at this point (Be aware, too, that the algorithms for combining scores on individual elements could be playing an important role here—for example, economic benefits might be ranked above environmental ones, scientific feasibility above commercial exploitation). Sometimes an additional validation by external (for example international) experts can provide more credibility to the results of the critical technology study.

Box 9.2 outlines highlights of a recent Russian Critical Technologies study.

Box 9.2: Russian Critical Technologies 2020

Among the key instruments of Russian STI policy is *National S&T Priorities and List of Critical Technologies*, a high-level document signed by the President. This is used as a background for selecting projects to be funded in the framework of the National S&T Programme, and in a number of other government STI related programmes. The first list of national critical technologies in Russia was developed in 1996; it has subsequently been revised in 2002 and 2006. The 2006 lists comprised 8 S&T priorities, and 34 critical technologies. Government regulations specify that these documents will be revised regularly, (every 4 years) and work on the revision of critical technologies started in 2010.

The aim was to consider the most important technologies in terms of their potential for bringing practical results within a 10-year horizon; there was a particular focus on technologies that are close to practical implementation. The study was to a large extent based on the results of an earlier performed *national S&T Delphi: 2025* that enabled the assessment of future demand for technology-intensive goods and services.

(continued)

Box 9.2 (continued)

Two main criteria were used for selection of critical technologies:

1. promoting economic growth and enhancing competitiveness of Russia's national economy in both traditional and emerging markets;
2. providing Russia's national security, including its technological security.

The number of critical technologies to be selected for the civil sector was restricted, in order to concentrate resources and provide sufficient budget funding for each of the critical technologies (funds coming from the national S&T programme and other instruments). Each critical technology was to be accompanied with a set of measures for achieving research results and their further implementation.

The methodology involved the following actions:

- developing criteria for creating expert panels for priority areas;
- detailed analysis of critical technologies from the previous list, assessment of their use for developing innovation products, competitiveness in domestic and foreign markets;
- identification of research areas with the greatest potential for developing innovative products and contributing substantially to the economic growth and competitiveness;
- creating revised lists of priorities and critical technologies, together with recommendations on their use,
- evaluating the innovation potential of critical technologies,
- developing proposals concerning practical implementation of the selected S&T priorities.

To achieve this, quantitative and qualitative methods were used, including desk research on promising S&T areas and two expert surveys (involving more than 200 leading Russian scholars). One was aimed at the evaluation of existing S&T priority areas, one asked about the most important prospective innovation products and services, as well as about the technologies that might play a critical role for those innovations. The survey results for each priority area were discussed by leading researchers and industrialists in thematic expert panels.

Each expert was asked to nominate 10–12 important innovation products (or services) in their sphere of interest and work, that would meet the two criteria mentioned above, and that could be produced in Russia, with the help of domestic S&T developments in the forthcoming decade.

The choice of key products was accomplished, initially by. The experts described the main features of each of these products, and identified technologies that need to be developed for their creation. The information on the products thus

(continued)

Box 9.2 (continued)
obtained was systematized, and offered to expert panels for further discussions. During these discussions, the original set of products was revised; major innovation product groups were identified according to the main priorities mentioned above. Sets of the most important innovation products and services that can be produced in Russia in the next 10 years, typically encompassing around 20–30 product groups, were thus generated for each priority area.

In addition, experts in the thematic groups analysed the national system of social and economic goals, as formulated in the *Concept of National Socio-economic Development 2020*, as well as in a number of other major strategic documents of the Russian Federation. Major government bodies, state academies of sciences and the largest state-owned corporations were asked to submit their proposals for revising the national S&T priorities and critical technologies and these proposals were analysed in relevant thematic expert groups.

Having examined the survey results and these discussions, expert panels drew up a list of prospective innovative goods and services involving new technologies. Those technology areas promising most innovative potential were identified, and compiled into revised lists of S&T priorities and critical technologies. These revised lists were approved by the Russian president in July 2011.

Altogether six S&T priorities in the civil sector were formulated, as in the left-hand column of the table below: Nanoindustry; Information and communication technologies; Life sciences; Rational use of nature (efficient use of materials, etc.); Transport and aerospace; and Energy.

The revised list of critical technologies consisted of 26 items, as in the right-hand column. For each of these, a detailed "passport" was prepared. This contained:

- a brief description of the particular technology,
- the subject area,
- the areas of practical application,
- how its level of development in Russia compared to that of the world leaders in the field,
- production capacities, and, finally,
- an assessment of the global and national markets for innovative products and services related to the technology in question.

Priority areas	Critical technologies
Nanoindustry	1. Computer modelling of nanomaterials, nanodevices, nanotechnologies
	2. Nano-, bio-, information, cognitive technologies
	3. Nanomaterials and nanodevices diagnostics
	4. Nanodevices and microsystems
	5. Technologies for manufacturing and processing construction nanomaterials
	6. Technologies for manufacturing and processing functional nanomaterials

(continued)

Box 9.2 (continued)

Priority areas	Critical technologies
Information and communication	7. Technologies providing broadband access to multimedia services
	8. Information, management and navigation systems
	9. Technologies and software for distributed and high-performance computer systems
	10. Technologies for creating component base & energy-efficient lighting devices
Life sciences	11. Bio-catalytic, bio-synthetic and bio-sensor technologies
	12. Biomedical and veterinary technologies
	13. Genome, proteome and post-genome technologies
	14. Cellular technologies
	15. Bioengineering technologies
	16. Technologies to reduce damage from socially significant illnesses
Rational use of nature	17. Technologies for monitoring and forecasting the state of environment, prevention and liquidation of environment pollution
	18. Technologies for exploring, developing and mining natural resource sites
	19. Technologies for prevention and managing consequences of natural and technological emergences
Transport and aerospace	20. High-speed transportation vehicles and intelligent systems for operating and managing new types of vehicles
	21. New-generation rocket and space systems and transportation vehicles
Energy efficiency, energy saving, nuclear power engineering	22. Basic power electrical engineering technologies
	23. Nuclear power engineering, nuclear fuel cycle, safe handling of nuclear waste and depleted nuclear fuel
	24. New and renewable energy sources including hydrogen power engineering
	25. Energy saving systems for energy transfer, distribution and use
	26. Energy-efficient power generation and transformation technologies based on biofuel

9.3.3 Limitations and Potential Weaknesses of the Critical Technologies Approach

The focus on technologies may lead to an overlooking of nontechnology issues (including issues involving "upstream" science and "downstream" innovation processes). This focus on technologies may risk neglecting broader social options—it might be possible, for example, to examine critical areas for social innovation instead or alongside critical technologies. In principle, the approach could be tailored to address issues where technology is not the main focus.

In common with other approaches based on expertise, there is a danger of relying on a relatively narrow group of experts, whereupon there are possibilities of simply reproducing the received wisdom of "the great and the good" (in the English formulation—one which implies a rather restricted elite view), and of being "captured" by a particular industry lobby pressing for its own interests.

9.4 Moving on to Interpretation: Roadmapping

The various methods so far outlined in this chapter are very much oriented towards establishing the options which are able to accomplish most by way of moving toward a desirable future, or to identifying priorities where there are many options to consider.

These methods can be seen as extending the process of Integration that is codified by modelling techniques, moving it on to beginning to create appraisals of more normative futures, often with targets and some basic indicators attached. The ForSTI process at the Intelligence stage develops an understanding of the past and present state-of-the-art of systems. The Imagination phase then develops a set of alternative futures and the Integration phase makes those options explicit and comparable for appraisals. Once the process shifts from the exploratory to a normative stage, the next task is to develop strategies to plan the journey into the desirable future. This is the key function of the Interpretation phase, which moves on yet further from Integration. Probably the most salient method here is the technique of Roadmapping, to which we now turn.

A roadmap is a layout of paths or routes that exist (or could exist) in some particular geographical space. It is used by travellers to decide among alternative routes towards a physical destination. Roadmaps provide essential understanding of proximity, direction and some degree of certainty in travel planning. As a frequently used method within industry, roadmapping has proved to be a useful tool for technology management, strategic and operational decision making and action planning. It is a normative and goal oriented method, where attempts are made to achieve a desired future state of development. The method was originally suggested by Motorola in the beginning of the 1980s, since when it has been used in a wide variety of contexts—particularly in high-tech industries at corporate and sectoral levels.

Galvin (1998) defines roadmap as "*an extended look at the future of a chosen field of inquiry composed from the collective knowledge and imagination of the brightest drivers of the change*". Roadmaps communicate visions, attract resources from business and government, stimulate investigations and monitor progress. They became the inventory of possibility for a particular field. Although roadmaps are deceptively simple tools in terms of format, their development poses significant challenges. This is because their scope is broad, and generally covers a number of complex conceptual and human interactions (Phaal et al. 2004).

As decision aids, roadmaps are used for (1) portraying structural relationships among science, technology and applications, thus (2) improving coordination of activities and resources in increasingly complex and uncertain environments, (3) identifying, evaluating, and selecting strategic alternatives that can be used to achieve desired S&T objectives, (4) communicating visions to attract resources, (5) stimulating investigations, and (6) monitoring progress.

The major benefits of Roadmaps include:

- Providing a mechanism for translating desirable futures, societal demands or grand challenges to be addressed into future markets, products, services, STI, and eventual research and development activities to be pursued from the present day
- Helping to identify opportunities and gaps in STI programmes
- Allowing a plan for the allocation of resources including time, financial resources and skills
- Enhancing communications among stakeholders such as researchers, STI developers, product manufacturers, service providers, suppliers and users among all the other interested groups
- Providing information to make better STI investment decisions by developing consensus among decision makers
- Creating a multi-disciplinary and cross-functional working environment with the better alignment of decision making in research, industry and policy making

Roadmaps have been used in a number of application areas for a wide variety of purposes, such as product planning, service/capability planning, strategic planning, long-range planning, knowledge and asset planning, programme planning, process planning and integration planning. In recent years roadmapping has become also a very popular tool for ForSTI exercises.

9.4.1 Format and Architecture of Roadmaps

Due to the wide range of application areas, types of roadmaps have varied. Some examples include:

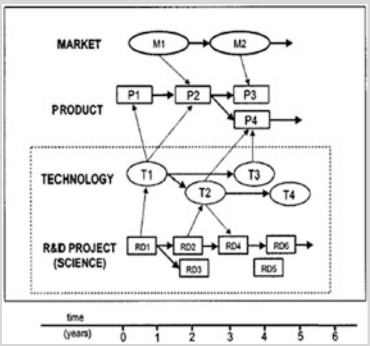
- science/research roadmaps
- cross-industry roadmaps

- industry roadmaps
- technology roadmaps
- product roadmaps
- product-technology roadmaps, and
- project/issue roadmaps

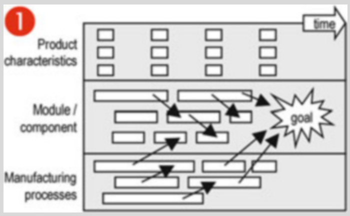
As a result of these diverse application areas roadmaps have been presented in different formats. However, the main elements of roadmaps, which are nodes and links, are always maintained. Box 9.3 presents key elements of roadmaps and various ways of organising roadmaps in different formats, which can be determined according to the purpose and focus of the roadmap.

Box 9.3 Elements and formats of Roadmaps

Elements of a roadmap
A roadmap consists of **nodes (a)** and **links (b)**.
These elements can have quantitative and qualitative attributes.
Construction of a roadmap requires identification of the nodes and their attributes, connection of the nodes with links, and specification of the link attributes.



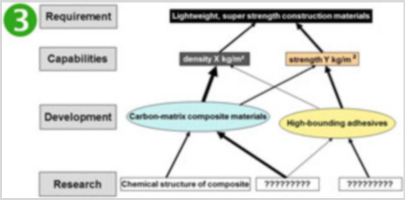
Formats of roadmaps
Roadmaps can be represented in various formats based on the objectives, use and roadmapping tools.
Typical roadmap formats include:
1. **Multiple layers,**
2. **Bars,**
3. **Network diagrams**
4. **Flow charts**[9]
Besides these formats, roadmaps can be organised as tables, graphs, pictorial representations, a single layer, and texts.

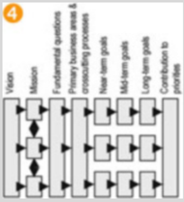


(continued)

[9]Figures 1, 2 and 4 are based on (Phaal et al. 2001).

Box 9.3 (continued)





Whatever format is used, a generalised architecture can be mentioned for all roadmaps. This architecture typically involves four or five layers, though there are examples of roadmaps with three or more than five layers. All layers may have different attributions based on the objectives, contents and orientations of the roadmaps. For example, the roadmap structure suggested by Phaal (2015) is a market oriented one, which considers a new market or exploiting an existing one by developing businesses, products and services, systems, and science and technology (Fig. 9.7).

Another roadmap presented by Zurcher and Kostoff (1997) involved four layers, labelled as requirements, capabilities, development and research (Fig. 9.3). Different combinations of layers can be used for different roadmaps. Some options are given below, which can be selected and combined in line with the purpose of the roadmap (Table 9.1).

In ForSTI, the process of roadmapping helps to facilitate a structured dialogue. It aids communication, both at the operational, technical and strategic levels, while providing a practical means for ensuring better alignment in the prioritisation and resourcing of STI programmes. The emphasis on the visual and graphical aspects of roadmaps offers several benefits, compressing extensive and complex information into a relatively small space while enabling comprehension of relations over time and across the layers that have been chosen. Thus roadmaps help to check the consistency of ideas from concepts to products and services and STI activities. For instance, they effectively integrate **technology push** with **market pull**.

From an STI planning and assessment perspective, roadmaps are fundamentally visual display aids that crystallise the linkages among the existing or proposed research programmes, development programmes, capability targets, and requirements. As an example, Fig. 9.8 presents a roadmap for "environmentally friendly, non-polluting car".

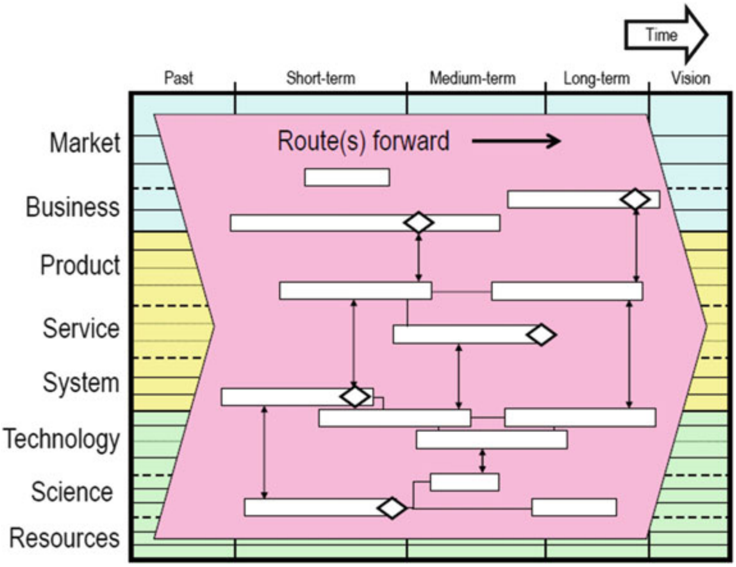


Fig. 9.7 An example roadmap framework (An earlier version of this architecture presented by Phaal (2003) included five layers: Market, Product, Technology, R&D Programmes, as well as Resources at the bottom of the roadmap to indicate capital investment/finance, supply chain and staff/skills requirements across time. This 2015 version of the architecture adds Business, Services, and Systems layers into the roadmap architecture as these have become more and more crucial across time for successful market generation and exploitation.)

Table 9.1 Possible layers for a roadmap architecture

Layers	Labels
Layer 1	Markets, Customers, Competitors, Environment, Industry, Business, Trends, Drivers, Opportunities, Objectives, Visions, Strategy, . . .
Level 2	Products, Services, Applications, Capabilities, Performance, Features, Components, Families, Processes, Systems, Platforms, Requirements, Risks, . . .
Level 3	Technologies, Competencies, Knowledge, . . .
Level 4	Science, Research, Development, . . .
Level 5	Resources, Skills, Partnerships, Infrastructure, Supplier Facilities, Organisation, Standards, Finance, . . .

The top layer of the roadmap illustrates the key requirements for achieving the overall aim: An environmentally friendly non-polluting car should have improved fuel efficiency with reduced CO_2 emissions. These requirements are made explicit with capability levels identified at the second layer. For instance, an improved fuel efficiency requirement will be met if the car reaches the fuel consumption levels of 100 miles-per-gallon. One of the ways of achieving this level of consumption is to develop Fuel Cells, which is indicated in the third layer of the roadmap. Finally, the fourth layer explains that research on electro-chemistry should be conducted to develop fuel cells. The whole

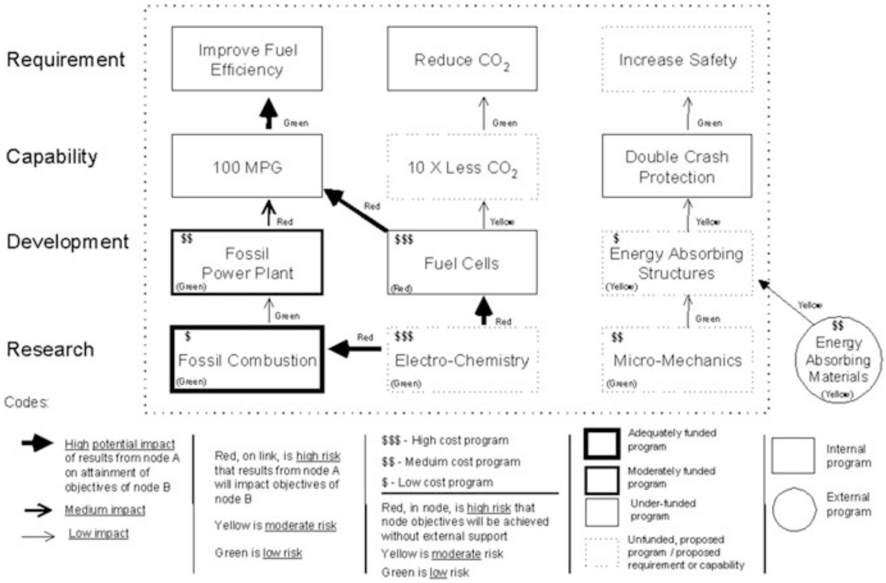


Fig. 9.8 A roadmap for "environmentally friendly, non-polluting car". *Source:* Zurcher and Kostoff (1997)

roadmap can be read and interpreted in this way. The roadmap also illustrates further attributions for its nodes and links. For instance, the thickness of the arrows indicates the impacts of the notes, which may be high, medium or low. This shows the impact of one node on attainment of the objectives of the other one. Similarly, other attributions to indicate the risks, costs and funding increases the power of the roadmaps for communicating as much information as possible on the STI programmes.

It is also important to remember that the context and requirements for STI are liable to changes continually due to some uncertainties being resolved and some new ones emerging, not least in technology applications and STI policy. This may necessitate rethinking or recalibration of timescales, required capabilities, and other targets in STI programmes. Therefore, roadmap processes should ideally have a sufficiently flexible structure to incorporate these dynamic changes.

Roadmaps are produced through a systematic process, typically engaging the participation of knowledgeable stakeholders through workshops. The process can be organised as a stand-alone activity, as well as being a part of a larger overall ForSTI process. We describe the key steps of the roadmapping process in the next section.

9.4.2 The Process of Roadmapping

Roadmapping asks a set of critical questions:

- Where are we now?
- Where do we want to go?

- What are the ways of getting there?
- What should we do from now on?

The answers for the first two questions are given in the earlier phases of the ForSTI activity. The initial scoping and scanning in the Initiation and Intelligence phases helps us to establish where we currently are. The process of Imagination and Integration helps us to explore futures and undertake appraisals, which result in some specification of a desirable future to be aimed at. Then the process of roadmapping explores the ways of achieving the desirable future, the strategies and actions liable to be required.

A fully-fledged roadmapping process consists of two key components. The first one is a workshop with the participation of experts and stakeholders. The second component is data generation and analysis. The two processes go in parallel and support each other. A roadmapping activity may be undertaken in a single workshop in a day up to several months. The amount of resources (time, skills, funding, expertise etc.) devoted for the roadmapping activity will affect the quality and the quantity of the output. However, regardless of the duration and intensity of the activity, a systematic roadmapping process roughly consists of three phases (Fig. 9.9). Although the process is described for Technology Roadmaps, the steps can be considered as generic and can be applied to other types of roadmaps (e.g. policy, strategy, market/product roadmaps).

The planning and preparation phase includes collection of the information for the roadmapping process, ensuring the participation of experts and stakeholders, organising necessary infrastructure such as hardware and software, which may be used to facilitate the roadmapping process. Then, scope and boundaries of the roadmap are defined. The discussions in this preliminary phase of the roadmap are organised around the overall goals, needs and problems identified. As mentioned above, this phase can be informed by other methods. For instance, scenario planning might precede roadmapping for the creation and specification of future

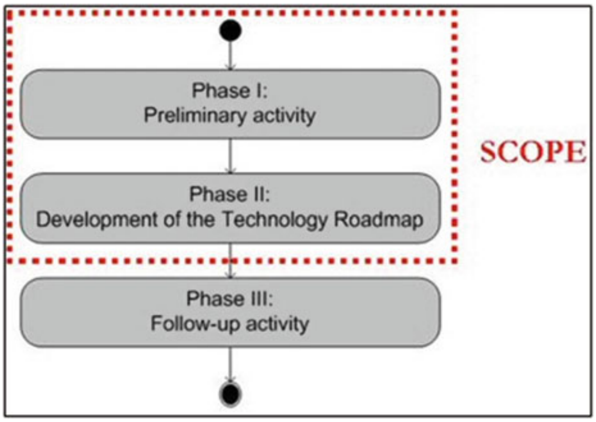


Fig. 9.9 Three phases of the roadmapping process. *Source:* Bray and Garcia (1997)

markets, products and technologies. Saritas and Aylen (2010) discuss ways of integrating scenarios and roadmaps before, during, and after the roadmapping exercise. Saritas and Oner (2004) present ways of integrating the Delphi surveys with roadmaps in the ForSTI process. During the second phase, the focus of the roadmap is defined; this is where what to include in and exclude from the roadmap is discussed. At this stage it is useful to identify measurable capability levels, which will then be used to assess whether the target levels have been achieved. Subsequently, important gaps in market, product and technology intelligence are identified. Alternative products and technologies (for example) are discussed along with their timelines. The type of R&D or similar "upstream" effort liable to be required for obtaining those technologies and products can then be identified. A roadmapping report is produced which should inform—and indeed specify much of—the development of strategic and operational level strategies for securing funding, planning human and other resources and equipments and organising supply chains.

Phaal et al. (2001) suggests four consecutive workshops for the roadmapping process. Following the preliminary phase, the first workshop considers the future markets. First, performance dimensions, and market and business drivers are defined and grouped. Following the prioritisation, Strengths, Weaknesses, Opportunities and Threats (SWOT) are discussed. Then, product, technology and knowledge gaps are identified. The second workshop is more product-oriented. Creation of product feature concepts, grouping, impact ranking and analysing gaps are the main activities of this phase. In the third workshop, technology solutions are produced and grouped. Following an impact ranking, gaps are identified. The final workshop covers the setting of milestones, product and technology charting, resource identification, analysis of gaps and lastly plans on the way forward.

Following the construction of the roadmap, various follow-up steps are taken to critique and validate the roadmap. A roadmap is usually presented with a report, which explains its logic. This report also covers strategies and actions to be taken along with an implementation plan. It needs to be disseminated to relevant parties.

The process does not end with the roadmap itself. A follow-up stage for the implementation, monitoring and revision processes should also be considered as a part of the overall process. This phase begins with the launch of the roadmap and may recur sometime after during the implementation process. Review and evaluation procedures are useful, not only to monitor the progress, but also to update the roadmap and derive lessons for the future roadmapping activities. A recent publication by the International Energy Agency (IEA 2014) provides an example of roadmapping process and guidance on development and implementation of it in the energy technology domain. Box 9.2 presents a case study of a Technology Roadmapping Exercise in the area of Information and Communication Technologies and Systems.

In ForSTI applications, roadmaps ***represent the information obtained throughout the ForSTI process***, and ***present it to a wide range of participants*** to elicit their responses, and obtain their participation for consensus generation on actions. The roadmapping process enables sometimes conflicting and perhaps qualitatively different views, priorities and concerns of the participants to be ***compared***, ***merged*** and ***synthesised*** into a coherent set of outcomes. Roadmaps are then used to (1) provide a mechanism to forecast developments in targeted areas; (2) present a framework to help plan and coordinate (S&T) developments at any level such as within an organisation or company; throughout an entire discipline, industry or cross industry; even at national or international levels; and (3) provide information to help make better informed and targeted decisions.

Because roadmapping is a participative process, it generates not only products like visualisations and reports, but also important process outcomes. During the process, roadmapping ***facilitates a structured dialogue*** and aids ***communication***, which are essential to the ForSTI process. Roadmapping helps to develop consensus among decision makers. Thus, it brings better alignment of organisational decision making. Roadmapping involves multidisciplinary cross-functional working—and this may well be essential for the roadmap to meet its objective of providing common guidance for the whole organisation.

Several critical factors require attention when embarking upon a roadmapping exercise:

1. The pathways between S&T and eventual applications are many; are not necessarily linear or unidirectional; and require significant amounts and types of data
2. Substantial time and efforts are required to portray these links as accurately as possible, and substantial thought is necessary to articulate and portray this massive amount of data
3. Because of the inherent uncertainties in research and development, as well as the continually evolving requirements and capability targets in large programmes, a roadmap should have a sufficiently flexible structure to incorporate these dynamic changes
4. Committed leadership is important because considerable time and effort is involved in the creation of the roadmap. Leaders and sponsors must ensure that the process is completed successfully and produced expected outcomes.
5. Role of the roadmap manager or facilitator and the competence of roadmap participants/team effects the success of the roadmapping process

It should be remembered that incomplete roadmaps only portray a fragmented and isolated picture. To be most effective, roadmapping and other management decision aids need to be fully integrated into strategic planning and operations of the organisation. Starting any major STI initiative requires clear messages for all interested parties, whose activities need to be aligned to a greater or lesser extent.

Box 9.4 presents a case study on Technology Roadmap.

Box 9.4: TECHNOLOGY ROADMAP – Case Study

A roadmapping study for the sector of light emitting diodes (LEDs) commissioned by the Russian Nanotechnology Corporation (RUSNANO) was produced in 2008–2011. It was a part of a wider ForSTI study of the nanotechnology sector development until 2030 which had considered long-term trends, problems and challenges, and identified major factors affecting the sector's development in Russia and in the leading developed countries. RUSNANO, being a corporation established by the government with a mission to support nano-based industries in Russia, planned to use the roadmap for identification of prospective areas in nano-enabled manufacturing industries, assessment of potential domestic and global markets, and building a set of optional "roads" that could connect existing R&D capacities with emerging markets.

The roadmap for the LED innovation-based development was oriented toward identifying key LED market niches where RUSNANO (via investing in proper start-ups and promising companies) could get substantial results in the next 5–10 years.

The study engaged 113 key Russian experts representing research community, LED-producing companies (including multinationals located in Russia), users of LED-based equipment, certification bodies, and regulatory agencies. The experts had to meet rather strict requirements like high citation index, regular participation in top-level scientific and/or professional events, professional status, etc.

The study included the following major stages: (1) analysis and integration of the results of relevant Russian and international studies (foresight reports, analytical materials, research papers, market overviews, etc.); (2) expert survey and interviews; (3) discussions in the roadmapping workshops with engagement of expert panels; (4) integration of expert knowledge and development of the roadmap (analytical report and visual presentation); (5) series of discussions at round tables.

Analysis

At this stage, major types of sources of light, potential application areas and relevant market niches were analysed. LEDs and alternative sources of light were examined with respect to their consumer properties and economic efficiency. Among major market segments there were considered lighting, mobile devices and appliances, large-size displays, signal devices and information signs, transport vehicles, consumer electronics and industrial equipment architectural and aesthetic illumination. For each of this niches key products were analysed vis-à-vis their market prospects.

Expert survey

The survey and interviews covered key Russian experts in relevant areas. The questionnaire included issues that had to be clarified before discussing them at the panels meetings, namely: prospects of particular LED technologies;

(continued)

Box 9.4 (continued)
factors enabling and hampering LED production; research and production capacities available in Russia, et al. More than 20 in-depth interviews with key experts allowed identifying the futures uncertainties ("forks" or bifurcations) to be shown on the roadmap.

Roadmapping workshops

In the series of workshops experts discussed technological and market-related prospects of LEDs. Discussions were based on the information obtained from desk research, survey and interviews. They integrated technology push and market pull approaches and focused on finding consensus between researchers and practitioners (producers and user of LEDs) with respect to future prospects of LED industry in Russia.

Development of the roadmap

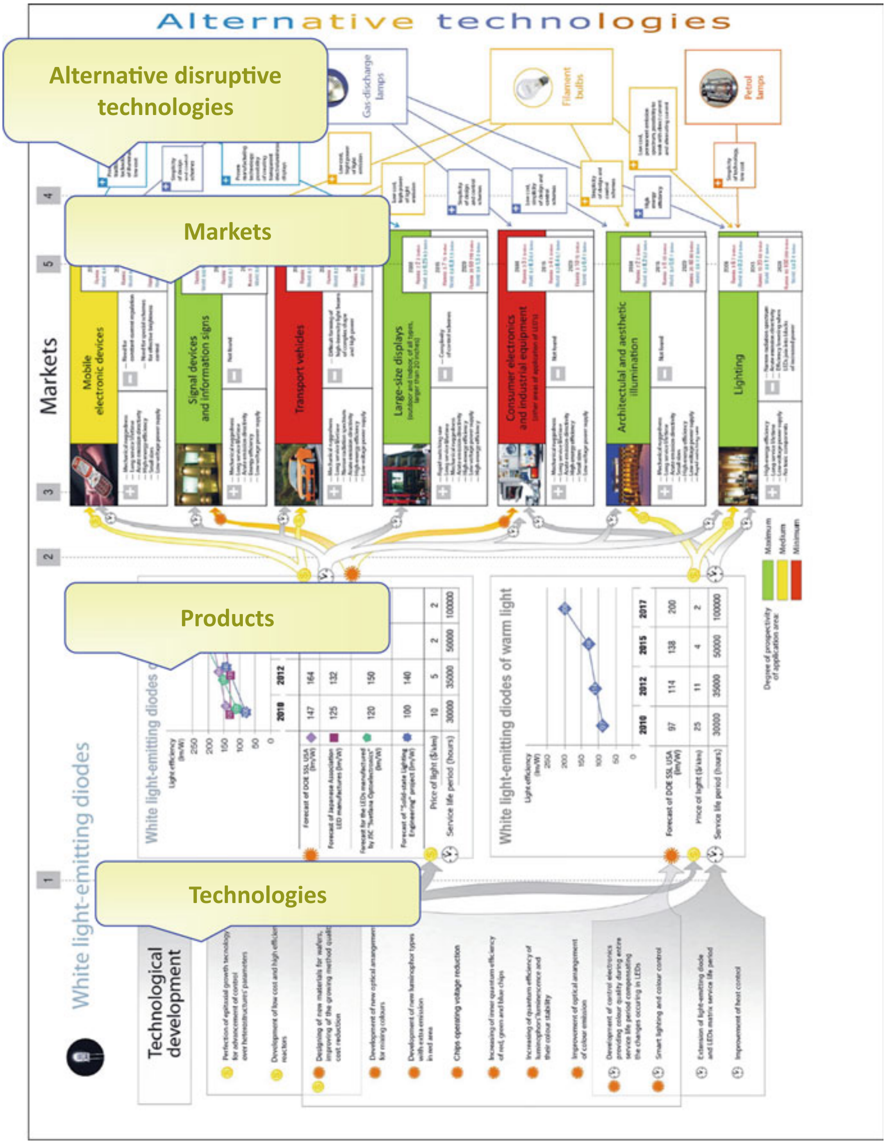
The roadmap was a result of intense discussion in expert panels. It had three parts related to colour LEDs, white LEDs and organic LEDs. Each of them had four layers: (1) technological development describing key technologies and their potential contribution to key characteristics of LED-based products (light efficiency, lm/W; price of light, US$/klm; and service life period, hours); (2) forecasted characteristics of products providing their market competitiveness; (3) market prospects (scenarios and quantitative estimates of national and global markets); and (4) description of alternative technologies which can play a disruptive role in the LED markets.

Roundtables

Two large-scale round tables, with participation of more than 100 experts, industrialists and policy-makers each, were organised to discuss (and validate) the project results. After presentation of the roadmap, the major discussions were devoted to policy measures necessary to support the development of the national LED industry and potential strategies in this sector. A number of proposals have been formulated. A part of them was later implemented. At the second round table, after intense discussions, participants decided to establish a national LED association.

Implementation

The roadmap was used as a background for selection of companies applying to RUSNANO for funding of their activities. Several of them were selected by RUSNANO for investment (they bought up to 49 % of shares for each of them, and later, after the company became profitable, sold the shares). The roadmap was considered as a document both describing the "corridor" of opportunities for RUSNANO investment and providing control figures to monitor the competitive characteristics of companies' products.



9.5 Conclusions

Following the previous chapter's examination of models, this chapter moved first into the tools for appraisal. Determining what may be a desired future state of the system is often not a straightforward process, since various values and interests are called into play, and numerous uncertainties may be confronted. This may require intensive negotiation between the different stakeholders involved in the process. Future expectations of different stakeholders like research institutions, for- and non-profit organisations, policy makers, and wider society may be fundamentally different from each other. The ForSTI process cannot achieve complete consensus across all these stakeholders. However, the creative and inclusive exchange of ideas and information sharing among participants can help to achieve some measure of agreement as to values, goals, and even targets for the future. Major persisting disagreements can be delineated and debated, although eventually commitments will need to be made towards one or other combination of activities.

Various methods can be used in this process to aid decision making have been described earlier in this book. Multi-Criteria Analysis and Cost/Benefit Analysis (CBA) are among the ones mentioned in this chapter. SWOT analysis can also be mentioned as a useful technique for the purpose of assessment.[10] These methods generally aim at employing a broad range of criteria for prioritisation and selection among alternatives. CBA may attempt to monetise all of these elements, but normative judgements may involve not only economic considerations, but also wide range of social, technological, environmental, political, value/cultural aspects (i.e. STEEPV). Techniques such as ranking, weighing, and scoring of different options can support comparisons across them, and can help clarifying the basis on which priorities can be determined. These ways of prioritising across actions are inherent to Critical/Key Technology approaches, which dominate ForSTI in some settings.

Following the identification of the future priorities, the normative stake of ForSTI begins. Roadmapping is one of the most frequently used tools to portray the route towards the desirable or preferable futures. It has been used extensively in several industries and policy settings, to take into account the fact that actions will need to vary over time as the future unfolds. In recent years, it has become a popular method in national and regional ForSTI exercises, particularly for science and technology policy and planning. Roadmaps produce clear messages the stakeholders and also guides for the synchronisation of different activities. They can be used to monitor progress across time, and can be revised in the cases of faster or slower progress, or when visions or the ways of achieving them have changed.

[10] See Miles and Keenan (2002) for uses of SWOT in the ForSTI process.

Intervention and Impact: Outcomes, Action and Evaluation 10

10.1 Introduction

The overall purpose of ForSTI is to provide input into policy and strategy planning and to mobilise collective strategic actions. In the Intervention phase we move on from the issue of formulating recommendations, to experience in following these through in the form of concrete action to implement structural and behavioural transformations. Actions suggested at this phase aim to give messages on the first and most immediate interventions to the existing systems. Operational level questions are asked for actions such as: 'what and how', 'where and how' and 'who and how'. The actions for change are determined by considering the following capabilities of the system under investigation: (1) Adapting; (2) Influencing and shaping its context; (3) Finding a new milieu or modelling itself virtuously in its context; and (4) Adding value to the viability and development of wider wholes in which it is embedded. Action plans, Operational plans, Priority lists can be among the outputs produced at this phase, in addition to the outcomes achieved through ForSTI, such as networking, mutual learning and collective visioning, which are key enablers for follow up actions upon the completion of the exercise.

During this chapter, we will also consider the evaluation activities. ForSTI process requires substantive investments, often through public funding, and implies considerable costs in terms of time and expertise invested. If impacts of ForSTI cannot be made clear, the commitment for investing resources will decrease, and as a result the activity will be discontinued. Therefore, an Impact phase is added to the process, which is concerned with the review, evaluation and renewal of the ForSTI exercise. This phase will examine the impacts during the process (e.g. production of baseline reports, articulation of appraisals of future prospects and alternatives ("visions"), and building new linkages), immediately after (e.g. new integrated projects and programmes) and sometime later (e.g. innovation impacts and new working communities).

I. Miles et al., *Foresight for Science, Technology and Innovation*, Science, Technology and Innovation Studies, DOI 10.1007/978-3-319-32574-3_10

10.2 Outputs and Outcomes of ForSTI

In the first place, it is useful to differentiate between the "outputs" and the "outcomes" of ForSTI. The first refers to what the exercise produces at the end of the process, and the second to what happens as a result of carrying out the exercise and especially of carrying out actions or implementing policies that are adopted.

In general, the outputs of ForSTI may be addressed to one or more specific target groups, which typically involves the sponsor of ForSTI, whereas the outcomes are likely to address different audiences. Therefore, when starting ForSTI, the target groups should be defined (i.e. the "users", who should receive and benefited from outputs). This is a key reason for ensuring that these prospective users have an appropriate level of involvement in the ForSTI process from the outset. Moreover, they can help to define the targeted outcomes that should be achieved for the relevant target group as well as for broader society. Table 10.1 outlines some of the types of outputs and outcomes that can be expected through ForSTI activities.

Different outcomes are produced at the different phases of the exercise, both immediately after and sometime later (see Table 10.2).

ForSTI exercises produce 'action plans' and 'demonstrators'. The action plans indicate what needs to be done, by whom and when. They should also indicate verifiable measures and indicators for monitoring progress to assess the degree of success attained. Demonstrators incorporate a series of action points and identify sets of actions that can be pressed simultaneously on the same agency. The main danger regarding demonstrators is that they may give an impression that the ForSTI activity emphasises too much focus on a certain project.

Table 10.1 Some types of outputs and outcomes from ForSTI

Type of outputs	Formal outputs	Outcomes
Material for long-term reference and dissemination activities beyond those organisations directly involved in ForSTI	Reports, books, electronic records (videos, web resources)	Networking with ForSTI activities and actors in other settings etc.
Dissemination with those organisations directly involved	Workshops, newsletters, press articles, web sites	Visions developed in workshops, results and evaluation circulating within networks
Networking	Institutionalisation of networks e.g. through formation of permanent organisations and meeting places	Development of new networks or new links established within existing ones
Strategic process	Formal incorporation of results within strategic processes, e.g. through use of lists of key priorities as a framework for assessing projects and plans	Informal incorporation of results and knowledge of networks and key sources of knowledge, within strategic processes

Source: Miles et al. (2003)

Table 10.2 Various outcomes from ForSTI at different times

Timing	Outcomes and outputs
During the exercise	Production of baseline and benchmarking reports, codified information to aid future-thinking Building of new linkages Changing perceptions/new understanding/enlightenment Articulation of widely-shared/divergent visions Priorities and recommendations
Immediately after	New (interdisciplinary) R&D programmes and projects Further use and development of ForSTI results
Sometime later	R&D and innovation impacts New working communities

Source: Keenan (2006)

It is important to have a clear notion of the types of outputs and outcomes to be expected from ForSTI. This should be done right from the beginning at the Initiation stage, and should be communicated with the sponsors, clients and stakeholders of ForSTI. Some changes may happen in the type and quantity of outputs and outcomes, however, ForSTI should strive for delivering actionable recommendations and creating impact beyond formal reports to bring different actors of the system to work together as the agents of change.

10.3 Reporting on and Disseminating the ForSTI Process and Findings

Typically, a ForSTI exercise will be obliged to present a report to its sponsor, and most often there will be a number of publications, of different forms, aimed at wider audiences, and quite possibly different outputs for specific types of stakeholder. In this, ForSTI is not so different from many other types of project that involve working with considerable volumes of information and drawing on high levels of expertise, to inform debate and decisions. Much experience has been developed around science communication[1]—and especially in biomedical fields, where there has been much attention paid to provide resources that can enable patients and carers to make informed consent to medical treatment or clinical trials.[2] Plans for dissemination and interaction around the ForSTI outcomes should be made early on in the exercise, rather than be made only after results have been fully articulated.

While the project report may well need to include much detail of the management and the methodological decisions (and difficulties) of the exercise, the important messages from the exercise can be spelled out in more succinct ways, and illustrated by means of such communication devices as cartoons and other images.

[1]There is a journal entitled Science Communication that covers developments in this field; and handbooks including Bucchi and Trench (2008) and Wilson (1998).

[2]There is also much literature on this topic, for example Manson and O'Neill (2007).

It is important to allow users access to information that will enable them to understand just how the results may be influenced by the methods and other choices made in the course of the exercise,[3] but this needs to be balanced against the need to present critical results in a clear and informative way. The Executive Summary of a report can play a significant role here.

Various types of conventional and online publication can be employed, and tools such as press releases and online tweets used to alert media and other users to their existence. As well as a broad overview document, various summaries of critical issues, and of implications for specific stakeholder groups, can be prepared. It is often very helpful to enlist professional journalists or other skilled communicators into these tasks. Material can be dramatised with storytelling, graphics, and even short videos—again drawing on skilled professionals for assistance in ensuring quality products. Video and audio interviews with ForSTI participants and practitioners can also be helpful ways of communicating key messages. Material may be disseminated through both public and more specialised news media, for example magazines and journals aimed at specific stakeholder groups. (Efforts at building bridges to relevant journalists are liable to be well-rewarded). This can mean creating informed intermediaries who will be able to grasp the significance of developments in an ongoing exercise and to separate key messages from those that may be superficially more newsworthy. It may also help offset the danger that media interest will only be parked by controversy and criticism (for example, running stories only when someone feels slighted for not having their specific views or lines of work endorsed by the ForSTI priorities).

In addition to traditional publication, there are various ways in which further debate can be facilitated. Comments can be allowed on webpages (these will typically need moderation, to exclude spam and trolls). Blogs can be setup to post updates and news items of relevance. Consultation processes can be used, with stakeholders encouraged to generate extensive reactions to the exercise. In some cases, modelling tools may be made available for users to generate their own scenarios or assessments, guidelines may be presented for conducting scenario and other workshops, material may be produced for schools and other bodies to use to seed their discussions or even to use as a basis for generating plays and poems. Online communities can be fostered to take the exercise further. We anticipate increasing accumulation of practice in these fields.

It is often the case that the biggest impacts of an exercise are achieved through direct contact between ForSTI and individual stakeholders, in the course of dissemination and consultation as well as when active engagement in the project is involved. In addition to straightforward presentations of key issues, it is possible to use the ForSTI process and its results as a starting point for workshops in which, for example, residents of a town or members of an innovative cluster can explore the implications of various scenarios for their own practices and future options. Such an

[3]In the third cycle of the UK's TFP, it was common for a series of "state of the science" reviews to be published for expert reference, alongside the less technical documentation.

approach had been employed in various EU ForSTI activities over recent decades.[4] Both conventional seminars/lectures and more interactive workshops can be employed at various regional and sectoral levels, and aimed at various stakeholder groups, not least young people, effecting much deeper understanding and engagement than might otherwise be the case.

It is important not to let such "formal" outputs displace more informal means of communication. The capturing of results in publications is sensible but more informal outputs in the form of improved networks and the embodiment of new knowledge in people's practices and organisations' approaches to issues are critical. These may be harder to identify and quantify than documentation, but represent achievements that may have more long-lasting and substantial effects.

10.4 Influencing Outcomes: Strategies, Actions and Stakeholders

ForSTI is not an ivory tower exercise. It is intended to achieve impacts upon the behaviour of sponsoring and/or other stakeholders—for example leading to changes in public STI policy or that in other fields. In effecting this, ForSTI may work in various ways, which may take four basic forms:

1. ForSTI typically produces texts and other symbols bearing narratives that can frame how people approach issues. This production of symbols is an important part of any exercise: it can result directly in policy advice
2. ForSTI can highlight the need to develop and coordinate policies and strategies in fields connected with its focal object, not least by assessments of priorities for resource allocation
3. ForSTI can play a role in coalition building with its narratives and insights facilitating actor alignment and mobilisation around a new or transformed agenda
4. ForSTI as a social 'technology' can broaden the participation of stakeholders in discussing the long-term issues, and helping to establish new networks and communities around these (Keenan 2005).

A more extensive list of possible impacts of ForSTI is provided by the EFMN project—see Table 10.3.

We discuss the evaluation of ForSTI efforts below, but as this discussion of different functions and modes of influence suggests, the complexities of the process can make simple evaluation difficult. It is widely recognised that it is difficult to attribute decisions and directions uniquely to ForSTI. Often other policy

[4] See for example projects described at http://www.cipast.org/cipast.php?section=1012 (CIPAST); http://cordis.europa.eu/interfaces/src/urban.htm (VALUE—see also http://pubs.iied.org/pdfs/G01293.pdf); and http://www.ecologyandsociety.org/vol12/iss1/art8/ (All accessed 17/10/2015).

Table 10.3 Reported impacts from the practice of Foresight

• Better informed strategies in general
• Making the case for increased investments in R&D
• Using foresight results to evaluate and future-proof strategies
• More informed STI priorities
• Development of new ways of thinking
• Creating a language and practice for thinking about the future
• Highlighting the need for a systemic approach to both policymaking and innovation
• Development of reference material for policymakers and other innovation actors
• Better evidence-based policy
• A source of inspiration for non-governmental actors
• Creation of new networks and clusters
• Establishment of communication structures between innovation actors
• Collective learning through an open exchange of experiences
• Enhanced reputational position and positive image of those regions running a foresight exercise
• Better visibilities of a region's strengths and competencies
• Interest from the general public
• Achievement of long-term reform of the productive system through a raised emphasis on high technology
• Accumulation of experience in using foresight tools and thinking actively about the future
• Stimulation of others to conduct their own foresight exercises after being inspired

Source: EFMN (2009)

interventions are being tried out, and the thinking and experience of decision makers are evolving under various influences, so a shift in behaviour may or may not be largely attributed to a ForSTI effort. The impact of ForSTI is liable to involve interaction of ForSTI processes and their outputs with the broader strategic behaviour of policy and economic actors (and with the other influences on this behaviour). One practical implication of this is the need for ForSTI exercises to be designed with interfaces with existing strategic processes in mind. This may mean ensuring that ForSTI results are available before, rather than after, the formulation and publication of major STI policy measures, for example (In any case, aligning the ForSTI phases with the policy cycle is rather important).

Keenan (2005) made this point about the policy cycle, also stressing that information needs to be presented in such a way that policy/strategy mechanisms can receive and absorb it. In addition to the issue of timing, it may be vital to consider how far recommendations should take into account available funding, and even the capacity for reform of existing procedures. There may well be a need to introduce highly disruptive thinking, but this may require some accommodation with the pragmatics of policy (in the event that sufficiently powerful coalitions cannot be established to achieve transformative change).[5]

[5]See Kahane (2012) for heartening accounts of the use of scenario analysis to facilitate disruptive change.

One of the main long-term outcomes of ForSTI exercises goes beyond informing action around the focal object of the exercises—it involves influencing attitudes to ForSTI itself, so that hopefully each exercise can contribute to the fostering of a "**ForSTI culture**". Given the importance of STI issues, it is important that a wide range of economic organisations and social actors should recognise the relevance of longer-term perspectives, and can themselves initiate relevant ForSTI processes when needed to guide action.

Panel members can play significant roles in embedding Foresight in their own organisations. They can also contribute to the development of ForSTI capabilities by liaising with other organisations to see how far they are adopting the messages of the ForSTI exercise. For example, panel members could share out responsibilities for monitoring the implementation of action plans, etc., by relevant parts of national or local government; they can provide briefings and inputs of other kinds. It can be very demanding of Panel members, especially unpaid ones, to maintain such a level of activity, of course, and they may benefit from the support of more "centralised" activities of one sort or another. This is one reason why a Foresight Unit of some sort can be a valuable instrument—this may be situated within national government, an executive agency, or even be based in Universities or public laboratories.

The following section will address the issue of ForSTI evaluation, which involves assessing the impact of ForSTI and determining what lessons are to be drawn from the conduct and management of the exercise.

10.5 From Intervention to Impact: Evaluation of Impacts

The impacts of ForSTI should be kept in mind from the beginning of the process, and the methodology should be designed to achieve those impacts. An effective communication strategy is essential during and after the ForSTI process for assisting the participants and target audience in making sense of the results. Impacts of ForSTI are measured through an evaluation exercise, which is commonly conducted based on three criteria including (1) appropriateness of objectives and methodology; (2) efficiency of implementation with a focus on management and organisational processes, and appropriate use of funds; and (3) impact and effectiveness through the recognition of the results, creation of a ForSTI culture and new combinations of stakeholders and networks.

Evaluation helps to discover whether, or to what extent, the exercise has achieved its desired outcomes—where it may have fallen behind expectations, and where it may have exceeded them. Information on the achievements of the activity can be used for other purposes (such as dissemination of results and decisions about renewal of the activity). This information is useful for those participating in the activity as well as for those managing the exercise. Evaluation provides a good opportunity for participants to express their views about what worked and what did not, and to learn about:

- the appropriateness of the original objectives, and the degree to which these were adequately formulated and communicated to those involved
- the management of the exercises, such as whether the activities might have been performed more efficiently and effectively with a different organisational structure and methodology
- whether or not the ForSTI methods selected were appropriate to the objectives and tasks
- what were the barriers to ForSTI and in which ways should these be tackled

Although the Impact phase can be considered as the final phase of the process, there is a strong learning element involved in this process, which determines how to design and implement and better ForSTI exercise next time round. Thus, it can also be considered as a beginning of the next cycle of ForSTI.

10.5.1 Tools for ForSTI Evaluation

ForSTI is a very resource-intensive activity itself and produce recommendations for the allocation of even bigger resources, for instance by identifying key STI priority areas to be invested. Therefore, it is reasonable to expect that the process itself and its outputs should be subject to evaluation in a systematic way. Georghiou and Keenan (2006) propose three basic tests to consider when evaluating ForSTI:

- Accountability—with questions such as whether the activity was efficiently conducted and proper use made of the funds
- Justification—with questions such as whether the effects of ForSTI justify its continuation and extension
- Learning—asking how can ForSTI be performed better, and tailored to particular circumstances

The evaluation activity may aim to consider either one or a combination of these aspects. However, it must be noted that the evaluation of ForSTI is not a straightforward process. It has its own challenges. Some challenges are associated to the nature of the evaluation activity in general, and some others are more specific to the evaluation of the Foresight activity. It is certainly a good idea to be aware of them before embarking upon a ForSTI evaluation.

Regarding the evaluation activities, OECD (2006) lists four generic challenges:

1. Timing: Have expected effects come about already?
2. Attribution: Can we confidently assign outcomes to the intervention being evaluated? Related challenge of so-called ‘project fallacy’ effect.
3. Appropriability: Where should we look for effects?
4. Inequality: Where effects tend to be skewed to a few ‘blockbuster’ projects.

In addition, there are the following challenges associated more specifically with the ForSTI activities (Barre and Keenan 2008):

- Non-standard approaches to ForSTI in most places
- Wide-ranging and often vague objectives
- Difficulty of assessing intangible objectives associated with ForSTI
- The complexity of cause-effect relationships
- The systemic and distributed nature of ForSTI
- ForSTI's embeddedness
- ForSTI's dynamism and flexibility
- Experimental nature of ForSTI

Following the understanding of challenges, we now look at the criteria used for the evaluation of ForSTI. Typically, a set of criteria is identified for the purpose of evaluation. Georghiou and Keenan (2004) list three criteria:

1. Appropriateness
   (a) Appropriateness of objectives
   (b) Appropriateness of approach in view of the objectives
   (c) Role of benchmarking
2. Efficiency and implementation
   (a) Focus on management and organisational processes
3. Impact and effectiveness
   (a) To 'measure' impacts, indicators will be need to be developed, based upon the Programme's 'theories of action' and their representation in 'logic charts'

Logic charts have been used in order to assess all these criteria in an integrated way. In ForSTI, they are used as diagrammatic representations that display the hierarchical relationships between higher and lower levels of objectives, activities and expected outputs and effects with logical links and assumptions. Figure 10.1 illustrates the logic chart, which was used as a design framework for the evaluation of the third cycle of the UK ForSTI programme.

Three different layers are seen in the example logic chart above. The first two layers are concerned with the objectives. The **overall objectives** are the ones that sponsors hope to contribute to by funding research in this area. Information on overall objectives can be found in policy statements. At the national level, this can be the improvement of the performance and use of science and engineering as in the case of the UK. **Programme objectives** are more specific and are related with the ForSTI activity itself. These can be classified into different groups, for instance, strategic (e.g. wealth creation), structural (e.g. changes in the relations between industry and academic actors), and technological (e.g. future technological opportunities to address societal challenges).

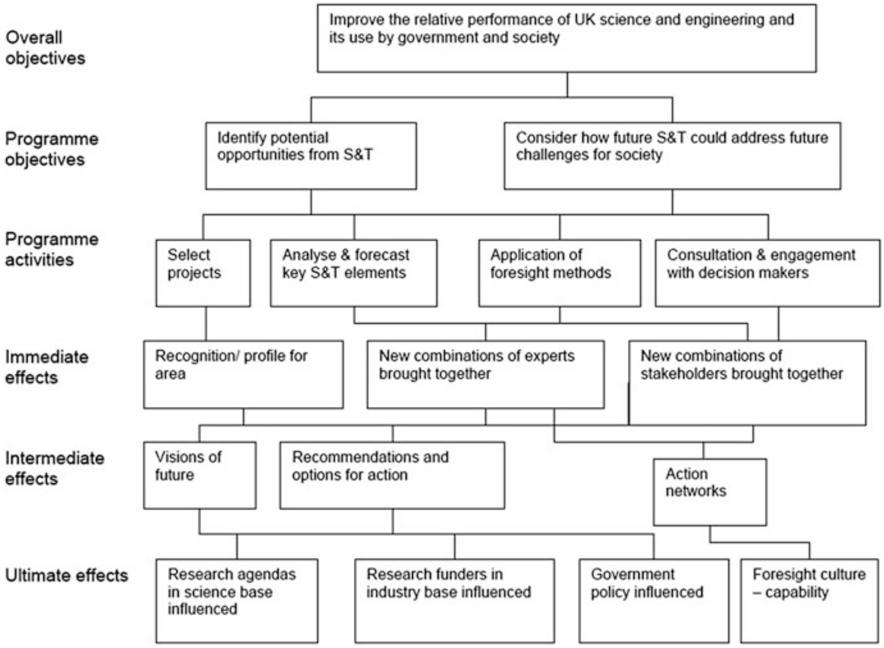


Fig. 10.1 Logic chart for the evaluation of the third cycle of the UK ForSTI programme. *Source:* Georghiou et al. (2006)

The next layer in the logic chart is concerned with the **programme activities. These** represent actions that are implemented to achieve the aforementioned objectives, e.g. projects/themes to be focused upon, application of the ForSTI methods and engagement with policy makers and stakeholders.

The third group of layers is concerned with the effects of ForSTI. These may be observed in different time frames. Some of them are **immediate effects**, which are observed during the course of the ForSTI activity. These may be in the form of collaborative programmes, which may bring together previously separate groups like experts and stakeholder groups and enable mutual learning and collective visioning. **Intermediate effects** are observed during or shortly after the completion of the programme. The aforementioned 'outputs' from the ForSTI programmes usually fall into this category. Examples may include future visions, recommendations for actions, and on the 'outcome' side, it can be the establishment of action networks. Finally, the **ultimate effects** refer to the effects that may be expected sometime after the completion of the programme. The effects on research agendas, funders, government policies, and generation of a ForSTI culture can be considered as examples of ultimate effects. The timescale for these will vary considerably according to the type of programme.

Thus, the logic charts portray relationships between expected outputs and effects of ForSTI as well as the links between ForSTI and broader policy objectives. They allow for the consistency of a programme with higher goals to be assessed and enable their contribution to these to be evaluated. Logic charts also help to identify expected outputs and effects, thereby allowing (1) the configuration of appropriate indicators to measure success-relevant for data collection during the evaluation and (2) the analysis of success of the programme vis-à-vis expectations.

Production of a logic chart itself is a process. Necessary information such as policy statements and programme documentation related to ForSTI should be at hand. Discussions should be undertaken with the programme managers. Production of an agreed logic chart may require a few iterations. Below we will take a closer look at the evaluation process.

10.5.2 The Evaluation Process

An evaluation process begins with the definition of the scope and purpose of the activity. The scope of the evaluation usually covers the begging of the ForSTI activity from the initiation, i.e. with a decision to commit resources, establish a Project Team, and set up a Steering Committee. The programme typically ends with the publication of a final report, or list of priorities, which may mark an end for the programme—though further dissemination and implementation activities may follow. Three types of evaluation activities may be undertaken before, during and after this process, which are:

1. Ex-ante evaluation
2. Real-time evaluation
3. Ex-post evaluation

Ex-ante evaluation takes place before the launch of a ForSTI activity. This type of evaluation helps to make decisions whether ForSTI should be undertaken or not, and if yes, to make decisions about the programme by simulating it. **Real-time evaluation** is undertaken during the course of the ForSTI activity. Progress and problems related to the execution of the activity are considered at this stage, and necessary revisions are made to improve the process and outcomes. Finally, **Ex-post evaluation** is conducted following the completion of the programme. Ex-post evaluation can also be undertaken in a few years upon the completion of ForSTI to consider the impacts of the implementation of the outputs and outcomes. The timing issue is also linked to the type of question being asked. If a linear or sequential view of ForSTI is taken, issues related to process are best investigated while the activity is still under way. However, many outputs and outcomes will not be clearly visible at this time and will need to be considered during the ex-post evaluation stage.

Evaluation of ForSTI may be concerned with the process and/or outputs and outcomes (Georghiou and Keenan 2008). Process evaluation covers the organisation and management of ForSTI. The following are examples of questions, which may be asked at this stage:

- Were the 'right' people involved?
- Did expert panels receive adequate support?
- Was the exercise adequately linked to decision-making centres?

Questions related to the appropriateness and efficiency of methods used can also be asked at this stage, such as:

- Should a Delphi have been used?
- Were scenario workshops properly facilitated?

These questions may be asked in the real-time evaluation or immediately after the completion of the activity.

The evaluation of outputs may involve the numbers of participants, reports disseminated, meetings held, website hits etc., and thus measures the activity itself, not its effects. Effects should not be shadowed by the numbers. For instance, the new networks established may vary, for instance, in their novelty, size and significance.

However, in order to prove real impact, ForSTI needs to demonstrate **behavioural additionality**, meaning that the activity and its outputs and outcomes should be embedded in the behavioural routines of the organisations concerned (OECD 2006). Evaluating the impact of ForSTI output on the strategic behaviour of policy and economic actors is one of the challenging, but a crucial task. The interaction between ForSTI outputs and the strategic behaviour of policy and economic actors should be investigated as a part of ForSTI evaluation. The aim is to understand whether ForSTI activity is accountable for the resources allocated to support it. Following sorts of questions can be asked in order to evaluate the additionality:

- Would ForSTI have happened without the policy intervention?
- Is ForSTI done differently/better because of the policy intervention?
- Are the resulting actions better because of ForSTI?
- Have persistent changes been achieved (e.g. establishing a ForSTI culture)?

As the implementation of ForSTI outputs is stretched over time, the answer lies in a longer timescale and is affected by the creativity or commitment, which may be coming from other sources. When making assessments about what effects can be attributed to the ForSTI activity, there is a need for an understanding that it is only one of several influences upon public policy, or the strategy of firms. Figure 10.2 illustrates this non-linear relationship between ForSTI and its implementation context.

It may take a longer term to observe the accuracy of the future appraisals in ForSTI. This may not be a problem with short time horizon, say in a 5-year critical technology exercise. However, if ForSTI is looking into a longer term futures, say into next 15–20 years, it may be more difficult to see the expected developments come into place. In long running ForSTI programmes, like the Japanese one with a

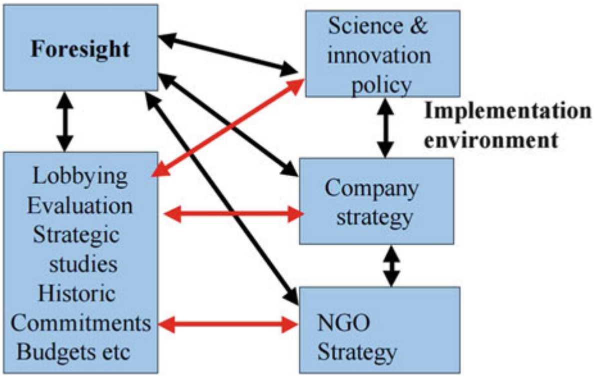


Fig. 10.2 ForSTI in a non-linear relationship with its implementation context. *Source:* Georghiou (1996)

continuation from the early 1970s, it is possible to make assessments of earlier rounds. In order to test the accuracy of the appraisals in more recent exercises, various indicators can be formulated, which may indicate the progress towards the foreseen developments. For instance, scientific evidence can be used by analysing publications and patents, which may lead to an eventual technology, product or market foreseen through the ForSTI activity. Other evidence from policy/strategy documents, media or other material can be considered as a source of evidence to track transformations and what sorts of signals they may give about future developments.

Some normative issues should also be mentioned regarding evaluation. ForSTI information should be presented in a way that it can be received, interpreted and absorbed by policy mechanisms. Therefore, factors associated to the successful adoption of ForSTI, including timing, availability of funding, and capacity and commitment to change and reform should be considered when evaluating the success of ForSTI.

10.5.3 Some Evaluation Experiences

Table 10.4 shows some experiences of ForSTI evaluation, and serves mainly to emphasise that diverse range of approaches exist for evaluation and there is currently not a consistent and comparable approach emerged. Two of the countries mentioned are discussed further as case studies.

Case l: UK ForSTI Evaluation Experiences

The UK ForSTI programme has been accompanied by a fairly large number of evaluation activities, many of which were examining just one or other feature of the programme. (Table 16.2 in Georghiou et al. 2008, lists many of thee.) While most of these were not confidential (indeed several were very widely circulated), most were never published in any formal sense. One which is publicly available, though not all that easily accessible, is a PhD thesis (Keenan 2000), which examined the

Table 10.4 Recent ForSTI evaluation activities

Country	Type of effort
Europe	
Austria	Internal assessment of impacts by Science Ministry
France	Self-evaluation, by a senior member of the sponsoring organisation
Germany	Delphi 98 evaluation questionnaire; FUTUR evaluated in 2002 and again in 2004 [see Georghiou (2003) and Cuhls and Georghiou (2004)]
Hungary	Panel evaluation 2003/04, addressing process and impact
Malta, Cyprus and Estonia	"Light" expert evaluation of the eForesee project, examining the achievements of an EU-funded project that linked the ForSTI activities of three countries
Netherlands	Self-evaluation, PhD study, Masters thesis, evaluation by Advisory Council for Science & Technology (AWT)
Sweden	Process (and not the impacts) evaluated continuously by an Evaluation Committee. New evaluation in 2005
United Kingdom	For the first cycle: sub-critical ad hoc studies; some limited external (and independent) scrutiny, e.g. by Parliament, a PhD study, etc. For the second cycle: OSI conducted a self-evaluation in order to redirect the programme. For the third cycle: External evaluation conducted (Georghiou et al. 2006)
Asia	
Japan	Assessment of realisation of results some 15–20 years after identification in STA forecasts. Also Foresight evaluated as a part of broader evaluations of its host institute NISTEP
Latin America	
Colombia	For the first cycle (2004): Early Assessment process with interviews, documentary analysis and workshop For the second cycle (2008): External evaluation addressing process and impact with face-to-face and telephone interviews, documentary analysis, online surveys, benchmarking and an international panel (Popper et al. 2010)

Source: Adapts and expands Georghiou and Keenan (2008)

whole of the first cycle of the programme, but focused in detail on the network-building activities of just a couple of panels. Georghiou et al. (2006) undertook the first formal evaluation of UK ForSTI, examining the various projects that had been undertaken in the first few years of the third cycle of the UK TFP; this evaluation was until recent cuts downloadable from the UK Foresight website. (One-year progress and impact reports on past projects are available in the online archive, however.[6]) The Parliamentary Office of Science and Technology (POST 1997) had earlier published a less systematic but nevertheless insightful and impactful review

[6]https://www.gov.uk/government/publications?keywords=1+year+review&publication_filter_option=research-and-analysis&topics%5B%5D=all&departments%5B%5D=government-office-for-science&official_document_status=all&world_locations%5B%5D=all&from_date=01%2F01%2F2000&to_date (accessed 13/02/2016).

of the first cycle of UK ForSTI. There had been numerous studies conducted for internal use by the ForSTI team, including, in the first cycle a survey of panel members, and later an effort to establish performance indicators on the basis on panel opinions. Several other efforts to develop indicator and evaluation frameworks had been undertaken, but more lasting impact was achieved by an urgent review of the second cycle of the programme, based mainly on interviews with stakeholders and experts in 2002. This confirmed (and perhaps was designed to confirm) views from senior policymakers that ForSTI had failed to build on the success of the first cycle; it led to the complete restructuring of the programme, though it is not clear just how the rather successful new model put in place for the third cycle was determined.

The UK case is one in which there was little thought about evaluation of ForSTI at the outset, and the result was a number of small evaluation efforts—many of which were, according to Georghiou et al. (2008, p. 389) "at a sub-critical level, or else relied very heavily on anecdotal and potentially prejudiced evidence". Around the turn of the century, there was growing government enthusiasm for applying performance indicators to monitor and evaluate public sector activity (part of the "New Public Management" drive.). This is particularly problematic for ForSTI activities, which are aimed at long-term impacts and where short-term output indicators may fail to capture important process outcomes. Several efforts were made to establish ways of assessing ForSTI in terms of key indicators, but these confront a further difficulty. This is that ForSTI, as we have seen repeatedly throughout the present book, involves much unpaid involvement by engaged stakeholders (especially, but not only, panel members), rather than public servants; asking these "volunteers" to do further work that effectively represents a monitoring of their own performance is, as they say, "a big ask". Georghiou et al. (2008) report an effort to develop a "softer" evaluation approach was adopted that separated process from impact. Process information could be compiled by civil servants and the ForSTI team; much impact information could be sourced from participants who would have a clear interest in how effective their efforts were proving. Five main stakeholder groups were identified (the research community; those involved in education, training and public understanding of science; industry and commerce; the voluntary sector; and government itself), and A set of key indicators developed, as displayed in Fig. 10.3.

Georghiou et al. (2006), as noted, undertook a fairly wide-ranging evaluation of the third cycle of the UK ForSTI Programme, launched in 2002. The second cycle had been terminated abruptly, following discontent with its achievements; there was much interest in seeing how far the new model was faring. The new model mainly involved a succession of projects investigating specific areas of STI in some detail, as compared to an effort to overview developments across all sectors and technologies. Since the projects were typically designed to take 2 years to complete, by 2006 a number of them had already been completed. The evaluation study considered the impact of the programme and of its constituent projects (several of them had been completed by that time), and to examine its cost-effectiveness (was it value for money? Did it provide additionality in the context of STI policy

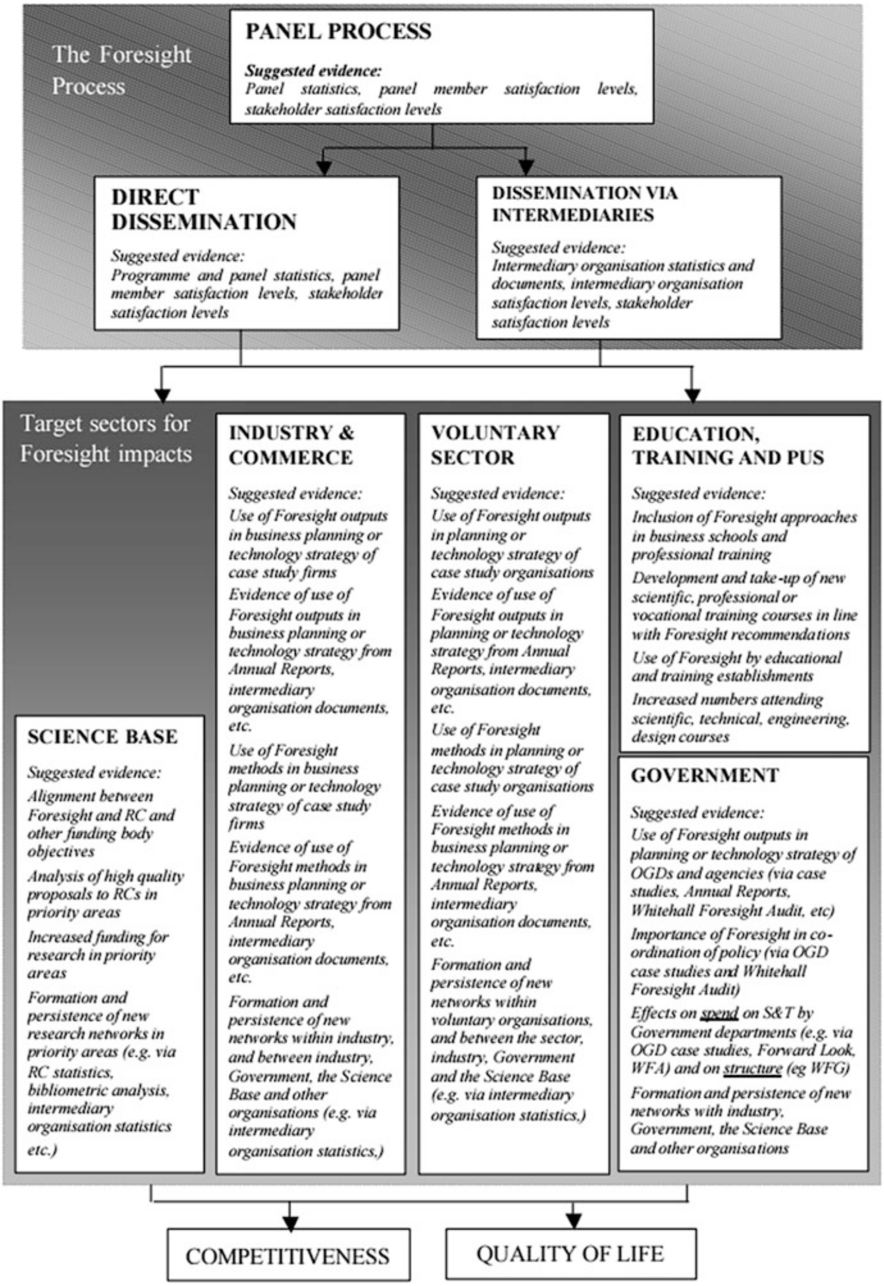


Fig. 10.3 UK second cycle evaluation framework. *Source:* Georghiou (2003)

initiatives?) and its management (was the organisations of ForSTI adequate and running well?).

In this evaluation, semi-structured interviews were the key instrument for collecting information during on the ForSTI exercise, allowing for in-depth exploration of the issues arising. (It was not believed that this could be effectively achieved via survey methods, not least because of the diversity of the projects being examined.[7]). 8 members of the ForSTI team and 28 stakeholders (e.g. the policymakers that the project was meant to influence) were interviewed.

The evaluation study was broadly favourable as to the value of the TFP. The Stakeholders who were interviewed were overwhelmingly positive about the achievements of and need for the Programme. Outputs like reports and meetings were of high quality, and new valuable combinations of knowledge were presented in accessible ways. Further, the evaluation concluded that the objectives of identifying both ways in which STI could address future challenges for society, and potential opportunities for application of STI. National policies and programmes had been influenced, in some cases very substantially, and in the one case where influence was limited the reasons were largely beyond the control of the ForSTI team, and more to do with changes in policymaking personnel and reluctance to grasp some difficult nettles. (In retrospect, it could be argued that the project, on drugs, was extremely accurate in terms of pinpointing emerging problems, but that this is a focal object that policymakers are loath to confront.) There was evidence for behavioural additionality, in that beyond the impact of the new knowledge that the project had injected into the policymaking process, some interviewees reported that the policymaking process itself had been changed: more attention was given to longer-term issues and ForSTI-type inputs A further achievement was that the projects constituted interdisciplinary platforms bringing together and establishing dialogue among a range of stakeholders who were not being mobilised through conventional departmental or basic research funding efforts.

Case 2: Evaluation of German FUTUR Initiative

The second case concerns a recent evaluation, that of the German FUTUR initiative. This was commissioned by the responsible ministry, BMBF, and was largely a process evaluation, focusing upon:

- The objectives of FUTUR, which were assumed to summarize the central assumptions upon which the exercise is based
- The different instruments and methods with regard to their effectiveness, efficiency and interplay
- The process in general

[7]However, interviewees were all supplied with interview guides, derived from the logic chart (presented earlier in Fig. 10.1) in an effort to achieve more consistency and comparability across their responses, as well as helping ensure that the whole rage of topics was covered.

The evaluation approach was developed by ISI-Fraunhofer and involved formulating the underlying assumptions and hypotheses that underpinned the ideals and conduct of FUTUR. These hypotheses were then "tested" through their operationalisation into questions that could be detailed in surveys and interview protocols.

Following a survey of participants a document was constructed to support an International Panel of Foresight Evaluation Experts. This panel held a one-day hearing with interviews and the Chair consulted with the Ministry as a user at the most senior level before producing the evaluation report. The limitations of this exercise were: too little time and resources available, and the fact that the exercise was conducted too early to pick up outcomes. However, several process-related recommendations were made and an impetus was gained for the continuation and improvement of the activity. A key finding was that the participants felt disconnected from the implementation process and, to a lesser extent, the programme managers responsible for implementation lacked a sense of ownership of FUTUR.

10.6 Conclusions

This chapter has discussed the output and outcomes of the ForSTI activity. It has considered what these might be, and how the desired outcomes are liable to be very much influenced by the outputs that are designed into the process. One major outcome is the extent to which the exercise has contributed to building a ForSTI culture that persists beyond the original activity.

We have stressed that outputs as understood in terms of formal publications and presentations are not, however, the only influence upon outcomes. In addition to changes in the context within which ForSTI is operating, the outcomes may be very dependent on the processes of the exercise, the ways in which it has been implemented. In particular, the range of stakeholders involved, and the depth of their engagement in various activities, can have a huge bearing on the reception of results, and the extent to which the proposed actions are adequately understood and put into practice.

Evaluation is important for assessing the actual and envisaged outcomes of ForSTI, and for learning lessons concerning the success and limitations of an exercise. Because ForSTI is context-dependent, and an exercise will ideally be closely tailored to its context, it is important that evaluation takes into account the period in which ForSTI emerged and its interaction with other elements of the system.

11 Conclusions

There have been many publications dealing with ForSTI, especially since the turn of the twenty first century. Much of this literature (including many web resources) presents the results of particular projects; and unfortunately it is quite often rather unclear about just what data and which methods have led to what conclusions. Despite the apparent prevalence of airport bookshop paperbacks—ones where some expert conjures their vision of the future out of a magic hat—there is a great deal more material available that attempts to be systematic and transparent as to methods than was the case a few years ago.

This book has sought to make a distinctive contribution by simultaneously:

- outlining the philosophy and the origins of this approach, as well as the rationale for adopting ForSTI in specific circumstances; and
- explicating many of the most common techniques in use and the methodological decisions to be made.

The preceding chapters have shown that ForSTI is a versatile approach, and is one that will often be need to brought to bear when we are considering STI developments. ForSTI is also highly relevant to the grand challenges confronted by our civilisation, where our responses will often require the application of new STI. This is not to say that ForSTI is a panacea. Many other approaches need to be employed if we are to tackle grand challenges and seize great opportunities. But without ForSTI, we suggest, there are substantial risks of failing to adequately address major long-term issues.

This depends upon ForSTI itself being "fully-fledged"—using multiple methods, and drawing upon the contributions and engagement of wide community of stakeholders as well as a narrow group of experts (or worse, narrow interest groups). Such ForSTI may not always be feasible—there may be social or political obstacles, or some unanticipated emergencies may be so acute that we have to act without much time for reflection. But while ForSTI is not always appropriate or even feasible, and while it will never be the only approach needed to face long-term

I. Miles et al., *Foresight for Science, Technology and Innovation*, Science, Technology and Innovation Studies, DOI 10.1007/978-3-319-32574-3_11

issues, this does not undermine the case for ForSTI being undertaken more systematically and more widely than it has been to date. Likewise, the accumulation of experience on ForSTI practice does not mean that one model of ForSTI needs to be imposed on practitioners. In reality, there is much room for further experimentation and development of new approaches. It will also be important to document and share lessons learned from the exercises that are undertaken in the evolving contexts of our ever-changing world.

This book has examined major phases of ForSTI activities—beginning with the need to be clear about our objectives, as well as open-minded as to what our conclusions might be. While particular activities and tools will tend to predominate at specific phases of the exercise, we have stressed that there is a great deal of flexibility in how this can be organised. We may often want to refresh our horizon-scanning, or provoke a fresh round of creativity, at various points in the process, for example. While it is a good idea to plan for this from the start, it is also a good idea to leave "wriggle room"—to allow for experiment and innovation in the course of the exercise. Often some modifications of familiar procedures are forced upon us—for example, because we are running out of time in a workshop! But often changes are inspired by the activity itself—we may need to bring new criteria to bear in making recommendations or selecting among options, for example, perhaps because key stakeholders have demonstrated their importance or because the exercise has thrown up considerations that has not been anticipated at the design stage.

Previous chapters have stressed that there is no single recipe for a successful ForSTI exercise—such an exercise needs to be tuned to objectives and resources. Now we must reiterate the point that it is unwise to be tied down in too rigid a structure. This is especially true when we have not undertaken sufficient pilot testing of the tools. Pilot testing is important—trying out a questionnaire on a few friendly and critical respondents, "talking through" how a workshop is to operate with facilitators and others who have had experience of such activities. But even after such testing, we may well find it valuable to modify our plans in response to the early feedback on implementation. In a study that one of the authors conducted, it was only during implementation of a multilingual Delphi that it was found that respondents in one language found the translation of questions to be very poor (new translations needed to be commissioned) and that another language, since it used non-Latin characters, could not be processed by the software (new software was required)!

ForSTI can be used for many purposes, as has been made clear at numerous points in this book. Most exercises will indeed address several goals, even though it is typical for one or two to dominate. Just as the implementation process may need to evolve, the intended objectives of the exercise may evolve. Sometimes this will be forced upon the activity by outside influences—there may be a major political change that requires a new approach to policy and thus to the factors to take into account in the exercise; or there may be disruptions concerning our focal object, such that a technological breakthrough or disaster overturns some of the assumptions on which the exercise was based. The objectives may need to be shifted to accommodate a new external agenda (though if the ForSTI team consider that what is going on is more a matter of fashion or ideology than of substance, they may resist this). Internal developments can also play a role. The exercise may give rise to new perceptions. While these will most often be framed in terms of the original objectives of the activity, on occasion they may warrant some rethinking of these objectives. For example, it might be that serious risks are identified in relation to a line of activity originally earmarked as promising for commercial development or for application to meeting a social need (whether or not policies are actively promoting it). Devising strategies for mitigating these risks could then be positioned as one of the objectives of the study. (Such risks are not necessarily technological hazards or security threats—they might concern, for instance, social inequalities or economic challenges—for example, massive life extension may imply all sorts of ongoing medical costs, as well as possible social disruptions.) Conversely, opportunities could also be identified which were not part of the original brief. Such opportunities might not even involve the focal object, but may be spotted in analysis of the wider system in which this object is located—for example, applications of a new technology may be seen in areas other than those which the exercise is focused on.

ForSTI can be used for many purposes, then, and many methods are available to bring to bear on the focal topic. The choice of methods, as discussed earlier, will in large part reflect resources (not least time!) and capabilities (social and political as well as technical), as well as the nature of the topics of concern and the objectives of the work. But in general, a fully-fledged exercise will make use of multiple methods. In particular, benefits may be drawn from the combination of both systematic formal tools (such as statistical analysis or modelling) with creative thinking (such as brainstorming in the context of wild cards scenarios and vignettes), and of both expertise (in panels, Delphis, etc.) and broader participation (stakeholder engagement and consultation in workshops, conferences, surveys, etc.). The combination of approaches should both enhance chances of spotting unexpected but plausible developments, and the mobilisation of state-of-the-art scientific understanding of the focal object. It can help to affect both political and scientific legitimacy and thus achieve a measure of ownership and buy-in from key stakeholders. (Some stakeholders may remain opposed to the ForSTI process or its results, usually because they feel their immediate interests to be threatened. The answer to this is to mobilise other stakeholders in support of the exercise (or some contentious component of it), on cognitive more than on emotional grounds.)

Another aspect of ForSTI where we would argue that there is no universal solution concerns just how different methods are combined together. There is some tendency for particular methods to be more or less appropriate at different phases of the ForSTI process, as noted in Chap. 3 and demonstrated in subsequent chapters, but, as also noted, this is in practice quite flexible. In accumulating further experience and evidence concerning ForSTI studies, it would be valuable to examine how, and under what rationale, different tools have been brought together, and with what result. For instance, Pombo-Juarez et al. (2016, forthcoming) suggest a particular combination of methods—and implementation of these methods in particular ways—to help ForSTI interventions into complex areas of STI development, where the applications of the new technologies are liable to cut across multiple layers of governance and multiple disciplinary and professional fields. Discussion of the combination of (specific implementations of) methods has been relatively underdeveloped in the ForSTI literature, despite the proliferation of methodological guides in the last decade. This is an important theme for practitioners to focus upon, and a promising line for research on ForSTI practice.

There have been several discussions of the future of ForSTI itself (though we are not aware of much articulation of this issue of methods mix in these discussions—often indeed they simply represent advocacy of one or other set of tools). More prominent has been stress on the potential of ICT applications to ForSTI and foresight more generally. Ideas include crowdsourcing of ideas for wild cards, large-scale online surveys and consultations, online access to models and modelling tools, use of virtual reality and visualisation approaches to explore scenarios and trends, virtual meeting rooms together with face-to-face meetings enhanced by telepresence of remote participants, and much more. By now, many of these ideas have been tried out; often the degree of success is less than originally anticipated, but it is common for those involved to see great potential in future development of the tools. As ICT becomes more embedded into everyday life, it can be expected that there will be much more experimentation with these approaches, and opportunities to involve all sorts of stakeholders in their development. The major challenge, it can be suggested, will be that of retaining the fruitful and insightful elements of human dialogue, even when there is less emphasis on face to face contact and synchronous discourse.

Furthermore, it is important not to neglect the continuing opportunities to use approaches that are less reliant on ICT. One example which has proved successful in a number of exercises, for example, is graphic facilitation, where a cartoonist provides ongoing illustrations of the group process and/or of the future appraisals it creates. These cartoons can both provoke dialogue in the workshop, and helpful illustration of the ForSTI themes in eventual publications. Examples of visual thinking and graphical facilitation applied in urban systems by Ravetz can be seen at the Urban 3.0: Creative Synergy & Social Intelligence website.[1] It may well be that other sorts of social facilitation technique—for example, commentary from anthropologists or cognitive psychologists—could play useful roles in facilitating social interaction in the course of ForSTI. In this context, we would suggest that ways of establishing and improving dialogue between expert and lay participants need particular attention.

As well as application of new approaches like this, the boundaries between ForSTI and other fields of long-term analysis need to be confronted. The focal objects of ForSTI are frequently similar to those addressed in by such other fields as emergency preparedness (Dehmer et al. 2015), risk analysis (Palomino et al. 2013), environmental modelling (The Royal Society 2015), climate change analysis (IEA

[1]Available at: http://urban3.net/visual-thinking/, accessed on: 20.01.2016.

2015), and the like. The social dimensions of STI are often poorly addressed—by social scientists no less than by scientists and engineers: ForSTI may be an arena whereby disciplinary barriers can be broken down to help resolve this problem. More work is required on this, and the ways in which social dimensions of STI have been confronted in ForSTI to date can be more explicitly documented and analysed.

There is no likelihood that the world will become a simpler, less turbulent context for STI, nor that STI itself will cease to evolve rapidly. ForSTI will, then, remain important for the anticipatory governance of STI-related topics—of which there are a vast number. Recent experience suggests that even countries with well-established ForSTI institutions may see a scaling back of activities—this has been the case in the UK since the economic crisis of the least few years, where the ideology of a new government and its commitment to reducing many public sector activities (under the guise of tackling austerity) resulted in a much weakened Foresight Programme. The term “foresight” may also fall out of fashion, as rising politicians and bureaucrats seek new slogans to provide a narrative underpinning for their careers. The need for ForSTI is likely to remain, but the activity may take place under new labels and guises. It is important to ensure that the core principles survive, and that, whatever the label, we can continue to learn from the decades of experience with ForSTI that have been accumulated. This is not guaranteed, because new labels may provide opportunities for the activity to be “highjacked” by interested parties—academics whose reputation depends upon their appearing to be doing something new, consultants who seek to capture a lucrative market, and policymakers who wish to be identified with something that looks like a quick fix to addressing intractable problems, for example.

ForSTI is too important to be left to narrow elites. Everyone is affected by the outcomes of STI. Few people can claim to have a reasonable grasp of more than a few of the disciplines and practices involved in contemporary STI, of course. But ForSTI can help to alert many more people to the critical issues that these raise, and enhance the level of debate they occasion, and assist in building capabilities to act constructively given this. Development of capabilities for fully-fledged ForSTI is thus an urgent social necessity. Hopefully this book, by setting out experience, philosophy, and methods in some detail, has supported this process.

References

Abt, C. (1971). *Serious games*. New York: Viking Press.

Ackerman, F. (2008). *Critique of cost-benefit analysis, and alternative approaches to decision-making*. A report to Friends of the Earth England, Wales and Northern Ireland. Retrieved December 10, 2014, from http://www.foe.co.uk/sites/default/files/downloads/policy_appraisal.pdf; http://www.ase.tufts.edu/gdae/Pubs/rp/Ack_UK_CBAcritique.pdf

Ajzen, I. (1988). *Attitudes, personality, and behavior*. Chicago: Dorsey Press.

Aldiss, B., & Wingrove, D. (1986). *Trillion year spree: The history of science fiction*. London: Atheneum.

Allen, J., James, A. D., & Gamlen, P. (2007). Formal versus informal knowledge networks in R&D: A case study using social network analysis. *R&D Management, 37*(3), 179–196.

Barré, R. (2008). Foresight in France. In Georghiou, L., Cassingena Harper, J., Keenan, M., Miles, I., & Popper, R. (Eds.), *The handbook of technology foresight*. Cheltenham: Edward Elgar.

Barre, R., & Keenan, M. (2008). Revisiting foresight rationales: What lessons from the social science and humanities? In C. Cagnin, M. Keenan, R. Johnston, F. Scapolo, & R. Barre (Eds.), *Future-oriented technology analysis: Strategic intelligence for an innovative economy*. Berlin & Heidelberg: Springer.

Beck, M. B. (2002). *Environmental foresight and models developments in environmental modelling*. Amsterdam: Elsevier.

Berkhout, F., & Hentin, J. (2002). *Foresight futures scenarios: Developing and applying a participative strategic planning tool*. GMI newsletter. Retrieved January 1, 2016, from http://greenleaf-publishing.com/productdetail.kmod?productid=416

Bezold, C. (2009). Jim Dator's alternative futures and the path to IAF's aspirational futures. *Journal of Futures Studies, 14*(2), 123–134.

Bimber, B., & Popper, S. (1994). *What is a critical technology?* RAND paper DRU-605-CTI, Santa Monica.

BMBF. (2003). *Eine Erste Bilanz. Futur: Der deutsche Forschungsdialog*. Bonn: BMBF.

Bray, O. H., & Garcia, M. L. (1997). *Technology roadmapping: The integration of strategic and technology planning for competitiveness*. Innovation in Technology Management—The Key to Global Leadership, PICMET '97: Portland International Conference on Management and Technology, IEEE, 25–28.

Bucchi, M., & Trench, B. (Eds.). (2008). *Handbook of public communication on science and technology*. London: Routledge.

Buzan, T. (1974). *Use your head*. London: BBC Books.

Buzan, T., & Buzan, B. (1993). *The mindmap book*. London: BBC Books.

Cameron, H., Loveridge, D., Cabrera, J., Castanier, L., Presmanes, B., Vazquez, L., et al. (1996). *Technology foresight: Perspectives for European and international co-operation*. Manchester: PREST. Final Report to European Commission DG XII.

Carrington, P. J., Scott, J., & Wasserman, S. (Eds.). (2005). *Models and methods in social network analysis*. Cambridge: Cambridge University Press.

I. Miles et al., *Foresight for Science, Technology and Innovation*, Science, Technology and Innovation Studies, DOI 10.1007/978-3-319-32574-3

Chappin, E. J. L., & Dijkema, G. P. J. (2010). Agent-based modelling of energy infrastructure transitions. *International Journal of Critical Infrastructures, 6*(2), 106–130.

Ciarli, T., Coad, A., & Rafols, I. (2013a). *Quantitative analysis of technology futures. Part 1: Techniques, contexts and organizations*. London: Nesta. Retrieved February 25, 2016, from http://www.nesta.org.uk/sites/default/files/quantitative_analysis_of_technology_futures_part_1_techniques_contexts_and_organizations.pdf

Ciarli, T., Coad, A., & Rafols, I. (2013b). *Quantitative analysis of technology futures Part 2: Conceptual framework for positioning FTA techniques in policy appraisal*. London: Nesta. Retrieved February 25, 2016, from https://www.nesta.org.uk/sites/default/files/quantitative_analysis_of_technology_futures_part_2_conceptual_framework_for_positioning_fta_techniques_in_policy_appraisal.pdf

Coates, J. F., Mahaffie, J. B., & Hines, A. (1998). *2025: Scenarios of US and global society reshaped by science and technology*. Greensboro: Oakhill Press.

Codagnone, C. (2009). *Reconstructing the whole: Present and future of personal health systems*. Report to European Commission from Framework Programme 7 project PHS2020. Available from http://www.ehealthnews.eu/images/stories/pdf/phs2020-book-rev16082009.pdf

Cole, S. (2008). Global issues and futures: A theory and pedagogy for heuristic modelling. *Futures, 40*(9), 777–787.

Cole, H. S. D., Freeman, C., Jahoda, M., & Pavitt, K. L. R. (Eds.). (1973). *Thinking about the future: A critique of the limits to growth*. London: Chatto and Windus for Sussex University Press.

Coulthard, G. J. (2009). *A review of the educational use and learning effectiveness of simulations and games* (In partial fulfilment of the requirements for a Doctor of Philosophy at Purdue University). Retrieved September 9, 2014, from http://www.coulthard.com/library/paper%20-%20simulation.html

Cowan, R., & Jonard, N. (2001). *The workings of scientific communities*. Research Memoranda 030. Maastricht: MERIT, Maastricht Economic Research Institute on Innovation and Technology.

Crooks, A. T., & Heppenstall, A. J. (2012). Introduction to agent-based modelling. In L. Georghiou, J. Cassingena Harper, M. Keenan, I. Miles, & R. Popper (Eds.), *Agent-based models of geographical systems*. Berlin: Springer Science+Business Media.

Cuhls, K., & Georghiou, L. (2004). Evaluating a participative foresight process: Futur—The German research dialogue. *Research Evaluation, 13*(3), 143–153.

Currie-Alder, B. (2003). *Why participation? Enhancing our understanding of participatory approaches to natural resource management* (Living document for Minga Program Initiative). Ottawa, ON, Canada: International Development Research Centre.

Dehmer, M., Meyer-Nieberg, S., Mihelcic, G., Pickl, S., & Zsifkovits, M. (2015). Collaborative risk management for national security and strategic foresight: Combining qualitative and quantitative operations research approaches. *EURO Journal on Decision Processes, 3*(3), 305–337.

Delrea, S. A., Jagera, W., Bijmolta, T. H. A., & Janssen, M. A. (2007). Targeting and timing promotional activities: An agent-based model for the takeoff of new products. *Journal of Business Research, 60*(8), 826–835.

Department for Communities and Local Government. (2009). *Multi-criteria analysis: A manual*. Wetherby, West Yorkshire: Communities and Local Government Publications. Retrieved December 10, 2014, from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/7612/1132618.pdf

Drechsler, W., Kattel, R., & Reinert, E. S. (Eds.). (2011). *Techno-economic paradigms*. London: Athena Press.

DTI. (2002). *Foresight futures 2020: Revised scenarios and guidance*. London: DTI (Department of Trade and Industry).

EFMN. (2009). *Mapping foresight: Revealing how Europe and other world regions navigate into the future*. Brussels: European Foresight Monitoring Network (EFMN), European Commission.

Finegood, D., Merth, T., & Rutter, H. (2010). Implications of the foresight obesity system map for solutions to childhood obesity. *Obesity, 18*(Suppl. 1), S13–S16. Retrieved January 15, 2016, from http://www.healthandenvironment.org/docs/Schettlerforesight_commentary.pdf

Fluegelman, A. (Ed.). (1976). *The new games book*. Garden City, NJ: Doubleday.

Fluegelman, A. (Ed.). (1981). *More new games*. Garden City, NJ: Doubleday.

Forbus, K. D. (2008). *Qualitative modelling*. In F. van Harmele, V. Lifschitz, & B. Porter (Eds.), *Handbook of knowledge representation*. Amsterdam: Elsevier.

Forrester, J. W. (1961). *Industrial dynamics*. Cambridge, MA: MIT Press.

Forrester, J. W. (1968). *Principles of systems*. Cambridge, MA: MIT Press.

Freeman, C. (1987). *Technology policy and economic performance: Lessons from Japan*. London, New York: Frances Printer Publishers.

Freeman, C., & Jahoda, M. (Eds.). (1978). *World futures: The great debate*. London: Martin Robertson.

Galvin, R. (1998). Science roadmap. *Science, 280*(5365), 5803.

Georghiou, L. (1996). The UK technology foresight programme. *Futures, 28*(4), 359–337.

Georghiou, L. (2002). Impact and additionality of innovation policy. In P. Boekholt (Ed.), *Innovation policy and sustainable development: Can innovation incentives make a difference* (pp. 7–22). Brussels: IWT-Observatory.

Georghiou, L. (2003). *Evaluating foresight and lessons for its future impact*. A paper presented at The Second International Conference on Technology Foresight, NISTEP, Tokyo, February 27–28. Accessed July 27, 2016, from http://www.nistep.go.jp/IC/ic030227/pdf/p6-1.pdf

Georghiou, L., Cassingena Harper, J., Keenan, M., Miles, I., & Popper, R. (Eds.). (2008). *The handbook of technology foresight*. Cheltenham: Edward Elgar.

Georghiou, L., & Keenan, M. (2004). *Towards a typology for evaluating foresight exercises*. Paper presented at EU-US Seminar: New Technology Foresight, Forecasting and Assessment Methods, Seville, May 13–14.

Georghiou, L., & Keenan, M. (2006). Evaluation of national foresight activities: Assessing rationale, process and impact. *Technological Forecasting and Social Change, 73*, 761–777.

Georghiou, L., & Keenan, M. (2008). Evaluation and impact of foresight. In L. Georghiou, J. Cassingena Harper, M. Keenan, I. Miles, & R. Popper (Eds.), *The handbook of technology foresight*. Cheltenham: Edward Elgar.

Georghiou, L., Keenan, M., Miles, I., Cameron, H., & Saritas, O. (2006). *An evaluation of the UK Foresight Programme: Final report*. UK Office of Science and Technology, Department of Trade and Industry, 92.

Gordon, T. (1998). *The real-time Delphi method* (excerpt from the Millennium Project Futures Research Methodology v3.0). Retrieved December 19, 2014, from http://www.millennium-project.org/millennium/RTD-method.pdf

Gordon, T. J. (2008). *"The Real-Time Delphi Method", excerpt from futures research methodology—v3.0, the millennium project*. Accessed July 25, 2016, from http://www.millennium-project.org/millennium/RTD-method.pdf

Gough, C., & Shackley, S. (2006). Towards a multi-criteria methodology for assessment of geological carbon storage options. *Climatic Change, 74*(1–3), 141–174.

Government Chief Scientific Adviser. (2014). *Innovation: Managing risk, not avoiding it. Evidence and case studies* (Annual report). London: The Government Office for Science. Retrieved December 12, 2014, from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/381906/14-1190b-innovation-managing-risk-evidence.pdf

Government Office for Science. (2004). *Future flooding* (A series of publications and reports). Retrieved September 9, 2014, from https://www.gov.uk/government/publications/future-flooding

Government Office for Science. (2011). *Sharing experience: Improving engagement across SAC Secretariats*. Retrieved August 12, 2012, from www.bis.gov.uk/assets/goscience/docs/s/10-1012-sharing-experienceacross-sac-secretariats.pdf

Green, L., Popper, R., & Miles, I. (2005). From Seville to success: IST success scenario and policy priorities. In L. Georghiou, J. Cassingena Harper, M. Keenan, I. Miles, & R. Popper (Eds.), *Challenges and opportunities for IST research and applications* (pp. 154–187). Bucharest: Academia Romana, Publishing House of Romanian Academy of Sciences. ISBN 973-27-1289-9.

Greenland, C. (1983). *The entropy exhibition: Michael Moorcock and the British 'New Wave' in science fiction*. London: Routledge & Keegan Paul.

Groves, C. (2013). Four scenarios for nanotechnologies in the UK, 2011–2020. *Technology Analysis & Strategic Management, 25*(5), 507–526.

Groves, D. G., & Lempert, R. J. (2007). A new analytic method for finding policy-relevant scenarios. *Global Environmental Change, 17*, 73–85.

Haegeman, K., Spiesberger, M., Veselitskaya, N., Sokolov, A., & Weiss, G. (2015). FTA supporting effective priority setting in multi-lateral research programme cooperation: The case of EU-Russia S&T cooperation. *Technological Forecasting and Social Change, 101*, 200–215.

Harvey, D., Gregory, J., Hoffert, M., Jain, A., Lal, M., Leemans, R., et al. (1997). An introduction to simple climate models used in the IPCC second assessment report, in "An Introduction to Simple Climate Models Used in the IPCC Second Assessment Report", IPCC Technical Paper II. In J. T. Houghton, L. G. M. Filho, D. J. Griggs, & K. Maskell (Eds.), *Intergovernmental panel on climate change*. Geneva: UNEP. Accessed July 27, 2016, from http://www.ipcc.ch/pdf/technical-papers/paper-II-en.pdf

Harzing, A. W. (2016). *Publish or perish*, version 4.25.1 (17 January 2016). Retrieved February 4, 2016, from http://www.harzing.com/pop.htm

Herrera, A. O., Scolnik, H. D., Chichilnisky, G., Gallopin G. C., Hardoy, J. E., Mosovich, D., et al. (1976). *Catastrophe or new society? A Latin American World Model*. Ottawa, Canada: International Development Research Centre. Accessed July 27, 2016, from http://cms.unige.ch/isdd/IMG/pdf/21147.pdf

Hussler, C., & Ronde, P. (2007). The impact of cognitive communities on the diffusion of academic knowledge: Evidence from the networks of inventors of a French university. *Research Policy, 36*(1), 288–302.

IEA. (2014). *Energy technology roadmaps: A guide to development and implementation*. Paris: International Energy Agency. Retrieved October 10, 2015, from http://www.iea.org/publications/freepublications/publication/TechnologyRoadmapAguidetodevelopmentandimplementation.pdf

IEA. (2015). *Energy and climate change*. World Energy Outlook Special Report. Paris: International Energy Agency. Retrieved January 20, 2016, from https://www.iea.org/publications/freepublications/publication/WEO2015SpecialReportonEnergyandClimateChange.pdf

Institute of Innovation Research. (2003). *Prospecting bioscience for the future of non-food uses of crops*. Manchester Business School, Report to The Government Industry Forum on Non Food Uses of Crops. Retrieved September 9, 2014, from http://les1.man.ac.uk/cric/Andrew_McMeekin/biosciencenfc.htm

IPCC. (2007). *Climate change 2007: Synthesis report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva: IPCC. Retrieved September 9, 2014, from http://www.ipcc.ch/publications_and_data/ar4/syr/en/contents.html

IPCC. (2013). *What is a GCM?* Last modified on 18 June 2013. Retrieved May 18, 2014, from http://www.ipcc-data.org/guidelines/pages/gcm_guide.html

IPCC. (2014). *Climate change 2013: The physical science basis, Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press. Retrieved September 9, 2014, from http://www.ipcc.ch/report/ar5/wg1/

IPCC SAR WG1. (1996). In J. T. Houghton, L. G. Meira Filho, B. A. Callander, N. Harris, A. Kattenberg, & K. Maskell (Eds.), *Climate change 1995: The science of climate change,* *Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change*. London: Cambridge University Press.

Irvine, J., & Martin, B. (1984). *Foresight in science: Picking the winners*. London: Pinter.

James, A., & Miles, I. (2010). Using scenarios to characterise complex policy interrelationships: The SANDERA Project. In B. Auffermann & J. Kaskinen (Eds.), *Security in futures—Security in change* (pp. 154–168). Turku: FFRC. FFRC eBOOK 5/(2011); ISBN 978-952-249-063-6; ISSN 1797-132. Retrieved from http://ffrc.utu.fi/julkaisut/e-julkaisuja/eTutu_(2011)_5.pdf#page=144

Kahan, D. M., Slovic, P., Braman, D., Gastil, J., & Cohen, G. (2007). *Nanotechnology risk perceptions—The influence of affect and values*. Woodrow Wilson's Nanotechnology Project, Cultural Cognition Project at Yale Law School. Retrieved December 12, 2014, from http://www.nanotechproject.org/process/assets/files/2710/164_nanotechriskperceptions_dankahan.pdf

Kahane, A. (2012). *Transformative scenario planning: Working together to change the future*. San Francisco: Berrett-Koehler.

Kahn, H. (1960). *On thermonuclear war*. Princetown, NJ: Princeton University Press.

Kahneman, D. (2003). Maps of bounded rationality: Psychology for behavioral economics. *American Economic Review, 93*(5), 1449–1475.

Keenan, M. (2000). *An evaluation of the implementation of the UK Technology Foresight Programme* (Doctoral Thesis). The University of Manchester, Manchester.

Keenan, M. (2005). *Designing for impacts of foresight*. A presentation given at the For-Learn Mutual Learning, Workshop, Brussels. Retrieved November 3, 2015, from http://www.powershow.com/view/1184a1-NjkxN/Designing_for_impacts_of_Foresight_Dr_Michael_Keenan_PREST_University_of_Manchester_UK_FORLEARN_M_powerpoint_ppt_presentation

Keenan, M. (2006). *An introduction to foresight*. Presentation given at the UNIDO Technology Foresight Programme—Module 1: Technology Foresight for Organisers, Gebze. Retrieved November 3, 2015, from http://ictt.by/En/Docs/UNIDOTechForesight/201106/1-Introduction%20to%20Foresight%20Gebze%202006_keenan.ppt

Keenan, M., & Miles, I. (2008). Scoping and planning foresight. In L. Georghiou, J. Cassingena Harper, M. Keenan, I. Miles, & R. Popper (Eds.), *The handbook of technology foresight*. Cheltenham: Edward Elgar.

Keenan, M., Miles, I., & Koi-Ova, J. (2003). *Handbook of knowledge society foresight*. Dublin: European foundation. Available from http://www.eurofound.europa.eu/publications/htmlfiles/ef0350.htm and http://mbs.ac.uk/PREST/euforia/documents/ EFL_Handbook_April_2003.pdf

Kelman, S. (1981). Cost-benefit analysis: An ethical critique. *AEI Journal on Government and Society Regulation, 5*(1), 33–40. Retrieved December 10, 2014, from http://www2.bren.ucsb.edu/~kolstad/secure/KelmanCostBeneCritiqu.pdf

Kilduff, M., & Tsai, W. (2003). *Social networks and organizations*. London: SAGE.

Klusacek, K. (2003). *Selection of research priorities—Method of critical technologies*. Prague: Technology Centre ASCR. Retrieved October 16, 2015, from https://www.tc.cz/en/publications/publications/publications-list/selection-of-research-priorities-method-of-critical-technologies

Kuhn, T. S. (1962). *The structure of scientific revolutions*. Chicago: University of Chicago Press.

Lee, H., Lee, C., Seol, H., & Park, Y. (2008). On the R&D priority setting in technology foresight: A DEA and ANP approach. *International Journal of Innovation Technology Management, 5* (2), 201–219.

Lee, Y.-G., & Song, Y.-I. (2007). Selecting the key research areas in nano-technology field using technology cluster analysis: A case study based on National R&D Programs in South Korea. *Technovation, 27*(1/2), 57–64.

Lempert, R. J., Popper, S. W., & Bankes, S. C. (2003). *Shaping the next one hundred years: New methods for quantitative, long-term policy analysis*. Santa Monica, CA: RAND Corporation. Retrieved January 15, 2016, from http://www.rand.org/pubs/monograph_reports/MR1626.html

Levy, R., & Muller, P. (2007). Do academic laboratories correspond to scientific communities? Evidence from a large European university. *International Journal Technology and Globalisation, 3*(1), 56–72.

Leydesdorff, L., & Milojevic, S. (2015). Scientometrics. In L. Georghiou, J. Cassingena Harper, M. Keenan, I. Miles, & R. Popper (Eds.), *The international encyclopedia of social and behavioral sciences* (Section 8.5: Science and Technology Studies, Subsection 85030; 2nd ed.). Oxford: Elsevier.

Linstone, H. (1973). On discounting the future. *Technological Forecasting and Social Change, 4*(2), 335–338.

Linstone, H. A., & Turoff, M. (Eds.). (1975). *The Delphi method, techniques and applications*. Reading, MA: Addison-Wesley (2002 version). Retrieved January 15, 2016, from http://www.is.njit.edu/pubs/delphibook/

Louvet, J. P. (2000). *Les principaux résultats de l' étude "Technologies clés 2005*. Paris: Ministère de l'Économie, des Finances et de l'Industrie.

Loveridge, D. (1996). *Technology foresight and models of the future*. Ideas in Progress, Paper no. 4. Retrieved January 12, 2016, from https://php.portals.mbs.ac.uk/Portals/49/docs/dloveridge/futmodpdf_wp4.PDF

Loveridge, D. (2002). *The STEEPV acronym and process—A clarification*. Ideas in Progress, Paper no. 29. Retrieved January 14, 2016, from https://php.portals.mbs.ac.uk/Portals/49/docs/dloveridge/steepv_wp29.PDF

Loveridge, D. (2009). *Foresight: The art and science of anticipating the future*. New York and London: Routledge.

Loveridge, D., Miles, I., with Keenan, M., Popper, R., & Thomas, D. (2004). *European knowledge society foresight: The EUFORIA Project Synthesis Report*. Dublin: European Foundation. Retrieved January 12, 2016, from http://www.eurofound.europa.eu/sites/default/files/ef_files/pubdocs/2004/04/en/1/ef0404en.pdf

Loveridge, D., & Street, P. (2003). Inclusive foresight. *Foresight, 7*(3), 31–47.

Manson, N. C., & O'Neill, O. (2007). *Rethinking informed consent in bioethics*. Cambridge: Cambridge University Press.

Martin, B. (2010). The origins of the concept of "*foresight*" in science and technology: An insider's perspective. *Technological Forecasting and Social Change, 77*, 1438–1447.

Martin, H., & Daim, T. U. (2012). Technology roadmap development process (TRDP) for the service sector: A conceptual framework. *Technology in Society, 34*(1), 94–102.

Martin, B., & Irvine, J. (1989). *Research foresight: Priority-setting in science*. London: Pinter.

Meadows, D. H., Meadows, D. L., Randers, J., & Bahrens, W. W., III. (1972). *The limits to growth: A report for the club of Rome's project on the predicament of mankind*. New York: Universe Books.

Meier, P. S. (2007). Mind-mapping: A tool for eliciting and representing knowledge held by diverse informants. *Social Research Update, 52*, 1–4.

Mesarovic, M., & Pestel, E. (1974). *Mankind at the turning point*. New York: Dutton.

Miles, I. (2005). Scenario planning. In *UNIDO technology foresight manual, Volume 1: Organization and methods* (pp. 168–193). Vienna: UNIDO. Retrieved January 18, 2016, from http://www.research.ro/img/files_up/1226911327TechFor_1_unido.pdf

Miles, I. (2008). From futures to foresight. In L. Georghiou, J. Cassingena Harper, M. Keenan, I. Miles, & R. Popper (Eds.), *The handbook of technology foresight* (pp. 24–43). Cheltenham: Edward Elgar.

Miles, I. (2010). The development of technology foresight: A review. *Technological Forecasting and Social Change, 77*(9), 1448–1456.

Miles, I. (2012). Dynamic foresight evaluation. *Foresight, 14*(1), 69–81.

Miles, I. (2013). Interactive impacts—Foresight as a product, service and coproduction process. In D. Meissner, L. Gokhberg, & A. Sokolov (Eds.), *Science, technology and innovation policy for the future: Potentials and limits of foresight studies* (pp. 60–82). Berlin: Springer.

Miles, I., & Cunningham, P. (2006). *Smart innovation: A practical guide to evaluating innovation programmes*. Luxembourg: European Commission. ISBN 92079-01697-0. Retrieved January 15, 2016, from ftp://ftp.cordis.lu/pub/innovation/docs/sar1_smartinnovation_master2.pdf

Miles, I., & Keenan, M. (Eds.). (2002). *Practical guide to regional foresight in the United Kingdom*. Luxembourg: European Commission. EUR 20478. ISBN 92 894 4682 (versions of this report were prepared for every EU15 country except Luxembourg). Retrieved January 14, 2016, from http://cordis.europa.eu/foresight/cgrf.htm

Miles, I., Keenan, M., & Kaivo-Oja, J. (2003). *Handbook of knowledge society foresight*. Dublin: European Foundation for the Improvement of Living and Working Conditions. Retrieved November 3, 2015, from http://www.eurofound.europa.eu/sites/default/files/ef_files/pubdocs/2003/50/en/1/ef0350en.pdf

Miller, E. S. (2007). *Bankrupting the enemy: The U.S. financial siege of Japan before Pearl Harbor*. Annapolis, MD: United States Naval Institute.

Ministere de l'Economie, de Finance et de l'Industrie. (2015). *Remise de l'étude TECHNOLOGIES CLES*, Paris, p. 12.

Moll, P. (1991). *From scarcity to sustainability*. Frankfurt am Main: Peter Lang.

NISTEP. (1997). *The sixth technology foresight survey: Future technology in Japan toward the year 2025*. Tokyo: NISTEP.

NISTEP. (2010). *The 9th Delphi survey: The 9th Science and Technology Foresight: Contribution of Science and Technology to Future Society (summary)*. A report on study supported by Special Coordination Funds for Promoting Science and Technology, FY2009, NISTEP report no. 140, Science and Technology Foresight Center, NISTEP, Tokyo. Accessed July 25, 2016 from http://data.nistep.go.jp/dspace/bitstream/11035/693/3/NISTEP-NR140-SummaryE.pdf

Nugroho, Y., & Saritas, O. (2009). Incorporating network perspectives in foresight: A methodological proposal. *Foresight, 11*(6), 21–41.

OECD. (2006). *Government RTD funding and company behaviour: Measuring behavioural additionality*. Paris: OECD.

Office of Science and Technology. (2004). *Future flooding: Executive summary*. London: Office of Science and Technology. Retrieved January 18, 2016, from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/300332/04-947-flooding-summary.pdf

Okuwada, K. (2010a). *The latest Japanese Delphi*. Presentation given at the UNIDO Technology Foresight Training Programme, Module 1: Technology Foresight for Organizers. Retrieved February 9, 2016, from http://ictt.by/En/Docs/UNIDOTechForesight/231106/4-The%20Latest%20Japanese%20Delphi.pdf

Okuwada, K. (2010b). *Toward a new type of science and technology foresight*. Presentation given at the AUGUR workshop on lessons from comparative approaches of recent foresight exercises on June 2. Retrieved February 2, 2016, from http://www.augurproject.eu/IMG/pdf/AUGUR_okuwada1.pdf

Palomino, M. A., Vincenti, A., & Owen, R. (2013). Optimising web-based information retrieval methods for horizon scanning. *Foresight, 15*(3), 159–176.

Pascu, C., Compano, R., & Weber, M. (Eds.). (2005). *Challenges and opportunities for IST research and applications*. Bucharest: Publishing House of Romanian Academy of Sciences Academia Romana. Available from http://fistera.jrc.es/pages/books/content%20Challenges%20book/challenges%20book.htm

Petersen, J. (2000). *Out of the blue—How to anticipate big future surprises*. New York: Madison Books.

PGP. (n.d.). New games foundation, entry on the *Play and Playground Encyclopedia* website. Retrieved June 9, 2014, from http://www.pgpedia.com/n/new-games-foundation. Citations suggest publication after May 2013.

Phaal, R. (2003). *Fast-start technology roadmapping: A presentation given at the UNIDO Technology foresight course for practitioners*. October 9, 2003, Prague. Accessed July 25, 2016, from http://ictt.by/Library/07.TechnologyRoadmaps.ppt

Phaal, R. (2015). *Roadmapping for industrial emergence*. A keynote presentation at the kick-off workshop on System Innovation for Transformation, OECD TIP Steering Group meeting on System Innovation (01.05.2015). London: UK Department for Business Innovation & Skills.

Phaal, R., Farrukh, C., & Probert, D. (2001). *Technology roadmapping: Linking technology resources to business objectives*. Cambridge: University of Cambridge. Accessed July 25, 2016, from https://www.sopheon.com/wp-content/uploads/Article-TechnologyRoadmapping.pdf

Phaal, R., Farrukh, C. J. P., & Probert, D. R. (2004). Technology roadmapping—A planning framework for evolution and revolution. *Technological Forecasting and Social Change, 46*(7–8), 1071–1080.

Polhill, J. G., Gimona, A., & Aspinall, R. J. (2011). Editors introduction, Special issue: Agent-based modelling of land use effects on ecosystem processes and services. *Journal of Land Use Science, 6*(2–3), 75–81.

Pombo-Juarez, L., Konnola, T., Miles, I., Saritas, O., Schartinger, D., Amanatidou, E., & Giesecke, S. (2016). Wiring up multi-layered innovation systems: Contemplations from Personal Health Systems Foresight. *Technological Forecasting and Social Change*, forthcoming.

Popper, R. (2008). Foresight methodology. In L. Georghiou, J.C. Harper, M. Keenan, I. Miles, R. Popper (Eds.), *The handbook of technology foresight*. Cheltenham: Edward Elgar.

Popper, R., & Miles, I. (2005). *The FISTERA Delphi future challenges, applications and priorities for socially beneficial information society technologies*. Report prepared for FISTERA project. Retrieved January 14, 2016, from http://les.man.ac.uk/prest/FISTERA/delphi_results.htm

Popper, R., Georghiou, L., Keenan, M., & Miles, I. (2010). *Evaluating foresight: Fully fledged evaluation of Colombian technology foresight programme*. Colombia: Universidad del Valle, Santiago de Cali. Available from http://community.iknowfutures.eu/action/file/download?file_guid=2204

Porter, A. L., & Cunningham, S. W. (2004). *Tech mining*. New York: Wiley.

POST. (1997). *Science shaping the future: Technology foresight and its impacts*. London: POST (United Kingdom Parliamentary Office of Science and Technology).

Pyka, A., & Fagiolo, G. (2007). Agent-based modelling: A methodology for neo-Schumpeterian economics. In H. Hanusch & A. Pyka (Eds.), *Elgar companion to neo-Schumpeterian economics*. Cheltenham: Elgar.

Rhydderch, A. (2009). *Scenario planning: Guidance note*. London: Foresight Horizon Scanning Centre, Government Office for Science. Retrieved January 15, 2016, from http://www.dti.gov.uk/assets/foresight/docs/horizon-scanning-centre/foresight_scenario_planning.pdf

Richardson, J. (1984). A primer of model systems. In J. Richardson (Ed.), *Models of reality shaping thought and action* (pp. 3–18). Mt Airy, MD: Lomond Press.

Ringland, G. (1998). *Scenario planning: Managing for the future*. Chichester: Wiley.

Ritchey, T. (2009). *Futures studies using morphological analysis*. Article adapted from the Millennium Project: Futures Research Methodology Series, Version 3.0, Swedish Morphological Society. Retrieved January 18, 2016, from http://www.swemorph.com/pdf/futures.pdf

Rosenhead, J., & Thunhurst, C. (1979). Operations research and cost-benefit analysis: Whose science? In J. Evans, J. Irvine, & I. Miles (Eds.), *Demystifying social statistics*. London: Pluto Press.

Roth, C., Obiedkov, S., & Kourie, D. (2008). Towards concise representation for taxonomies of epistemic communities. In S. B. Yahia, A. Napoli, E. M. Nguifo, R. Belohlavek, T. Hamrouni, V. Vychodil, & T. B. Kaiser (Eds.), *Concept lattices and their applications* (pp. 240–255). Berlin: Springer.

Rush, H., & Miles, I. (1989). Surveying the social implications of information technology. *Futures, 21*(3), 249–262.

Saito, N. (2014). *Towards evidence-based STI policy planning in socio-economic context: Snapshots from research outputs of NISTEP*. Presentation given at the OECD International

Symposium on STI Policy for the Future. Retrieved February 9, 2016, from http://gist.grips.ac.jp/en/events/other/document/20141119/3Saito.pdf
Saritas, O. (2006). *Systems thinking for foresight* (Doctoral Thesis). The University of Manchester, Manchester.
Saritas, O. (2013). Systemic foresight methodology. In D. Meissner, L. Gokhberg, & A. Sokolov (Eds.), *Science, technology and innovation policy for the future: Potentials and limits of foresight studies* (pp. 83–117). Berlin: Springer.
Saritas, O., & Aylen, J. (2010). Using scenarios for roadmapping: The case of clean production. *Technological Forecasting & Social Change, 77*(7), 1061–1075.
Saritas, O., & Burmaoglu, S. (2015). The evolution of the use of foresight methods—A scientometric analysis of global research output for cutting-edge FTA approaches. *Scientometrics, 105*(1), 497–508.
Saritas, O., & Burmaoglu, S. (2016). Future of sustainable military operations under emerging and security considerations. *Technological Forecasting and Social Change, 102*, 331–343.
Saritas, O., & Nugroho, Y. (2012). Mapping issues and envisaging futures: An evolutionary scenario approach. *Technological Forecasting & Social Change, 79*(3), 509–529.
Saritas, O., & Oner, M. A. (2004). Systemic analysis of UK foresight results: Joint application of integrated management model and roadmapping. *Technological Forecasting & Social Change, 71*(1–2), 27–65.
Saritas, O., Pace, L. M., & Stalpers, S. (2013). Stakeholder participation and dialogue in foresight. In K. Borch, S. M. Dingli, & M. S. Jorgensen (Eds.), *Participation and interaction in foresight: Dialogue, dissemination and visions* (pp. 35–69). Cheltenham: Edward Elgar.
Saritas, O., & Smith, J. (2011). The big picture—Trends, drivers, wild cards, discontinuities and weak signals. *Futures, 43*(3), 292–312.
Scapolo, F., & Miles, I. (2006). Eliciting experts' knowledge: A comparison of two methods. *Technological Forecasting and Social Change, 73*(6), 679–704.
Scase, R. (1999). *Britain towards 2010: The changing business environment*. London: Economic and Social Research Council (This was originally digitally available at: http://www.esrc.ac.uk/2010/docs/britain.html, but is no longer archived there; hard copies are retailed from usual sources.).
Schwartz, P. (1991). *The art of the long view*. New York: Doubleday.
Seidl da Fonseca, R., & Saritas, O. (2005). *Instruments for strategy and policy: Modeling the structure of the policy-making on science and technology* (UNIDO, Technology Paper Series, TPS 3/05). 14th International Conference on Management of Technology, Vienna, Austria, May 22–25, 2005.
Shackley, S., & Gough, C. (Eds.). (2006). *Carbon capture and its storage*. Aldershot: Ashgate.
Shrikawa, N. (2011). *Foresight-related activities at NISTEP*. Presentation given at the UNIDO Mutual Learning Workshop, Bucharest, August 29–31. Retrieved February 10, 2016, from http://ictt.by/Library/FORESIGHT_20110905_slides/6_MLW%20EVC%20-%20Nobuyuki%20Shirakawa.pdf
Slocum, N. (2003). *Participatory Methods Toolkit: A practitioner's manual*. Bruges, Belgium: King Baudouin Foundation and the Flemish Institute for Science and Technology Assessment (viWTA) in collaboration with the United Nations University—Comparative Regional Integration Studies (UNU/CRIS). Retrieved January 14, 2016, from http://archive.unu.edu/hq/library/Collection/PDF_files/CRIS/PMT.pdf
Sokolov, A., Haegeman, K., Spiesberger, M., & Boden M. (2014). Facilitating EU-Russian scientific and societal engagement: Joint efforts to tackle grand challenges. *Science & Diplomacy, 3*(4), 1–9. Retrieved January 18, 2016, from http://www.sciencediplomacy.org/files/facilitating_eu-russian_scientific_and_societal_engagement_science__diplomacy.pdf
Steering Group of the Technology Foresight Programme. (1995). *Progress through partnership*. London: HMSO.
Taleb, N. N. (2007). *The black swan: The impact of the highly improbable*. New York: Random House.

Tapio, P. (2003). Disaggregative policy Delphi: Using cluster analysis as a tool for systematic scenario formation. *Technological Forecasting and Social Change, 70*(1), 83–101.

The Royal Society. (2015). *Observing the earth: Expert views on environmental observation for the UK*. London: The Royal Society Science Policy Centre. Retrieved January 20, 2016, from https://royalsociety.org/~/media/policy/projects/environmental-observation/environmental-observations-report.pdf

Thuraisingham, B. (1999). *Data mining: Technologies, techniques, tools, and trends*. Boca Raton, FL: CRC Press.

Tuire, P., & Erno, L. (2001). Exploring invisible scientific communities: Studying networking relations within an educational research community. A Finnish case. *Higher Education, 42*, 493–513.

Turner, G. (2014). *Is global collapse imminent?* MSSI Research Paper No. 4. Melbourne Sustainable Society Institute, The University of Melbourne.

UNIDO. (2005). *Dephi method*. Retrieved January 14, 2016, from http://www.unido.org/fileadmin/import/16959_DelphiMethod.pdf

Urashima, K. (2015). Overview of 40 years foresight experiences in Japan. Presentation given at the 1st Asian Innovation Forum. Retrieved February 9, 2016, from www.asianinnovation.org/!Board/down.php?wd=1&bf_code=64

Vaidya, O. S., & Kumar, S. (2006). Analytic hierarchy process: An overview of applications. *European Journal of Operational Research, 169*(1), 1–29.

van der Heijden, K. (2005). *Scenarios, the art of strategic conversation* (2nd ed.). Chichester: Wiley.

Vandenbroeck, P., Goossens, J., & Clemens, M. (2007). *Tackling obesities: Future choices—Building the obesity system map*. London: HMSO. Retrieved April 24, 2014, from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/295154/07-1179-obesity-building-system-map.pdf

Wagar, W. W. (1991). *The next three futures*. London: Adamantine.

Waverley Management Consultants. (2007). *Scenario planning toolkit*. London: Department for Transport. Retrieved January 15, 2016, from http://webarchive.nationalarchives.gov.uk/20140108140803/http:/www.bis.gov.uk/assets/foresight/docs/horizon-scanning-centre/foresight_scenario_planning.pdf

Williamson, J., & Weyman, A. (2005). *Review of the public perception of risk, and stakeholder engagement*. Buxton: Health and Safety Laboratory. Retrieved December 12, 2014, from http://www.hse.gov.uk/research/hsl_pdf/2005/hsl0516.pdf

Wilson, A. (1970). *War gaming*. Harmondsworth: Pelican.

Wilson, A. (1998). *Handbook of science communication*. Bristol: Institute of Physics Publishing.

Yehuda, B. (2008). *The history of the new games foundation*. Blog entry, 14.02.2008. Retrieved June 9, 2014, from http://jergames.blogspot.com/2008/02/history-of-new-games-foundation.html

Zurcher, R., & Kostoff, R. N. (1997). Modelling technology roadmaps. *Journal of Technology Transfer, 22*(3), 73–80.