Chapter 8
Scenario Derivatives First, Second, and Third Order Scenarios: Generic (Landscape) Variables

As I write, our much vaunted windmills aren't turning because it isn't very windy, and we can't rely on coal-fired power stations because they're all being closed down. And we haven't been able to build any new nuclear reactors because of some newts. Which makes us reliant on gas. And that's a problem because a burly Russian with a beef about something or other is standing on the hose that delivers natural gas from the Urals to Europe. And to make matters worse for our energy needs, the cable that brings electricity from France to Britain was damaged by a fire, and it won't be mended for the best part of a year . . .. . .
Jeremy Clarkson—Motoring Journalist and Farmer—Sunday Times October 2021.

Abstract It is rare for scenarios to be stand-alone and discrete: rather they contain any number of linked downstream sub-scenarios called derivatives. The bigger the initial primary event the more likely that it will have multiple ramifications generating spin-offs of varying degrees of intensity and visibility. Yet, the subsidiary status of derivative scenarios makes them more dangerous as they are often overlooked due to the dominance of the primary event and where the impact of unintended and uncertain consequences of initial actions generated by the first order scenario can play out. A number of MTTs are introduced which help the analyst determine what, when, and where these derivative scenarios can occur. A variety of qualitative and quantitative methods such as horizon scanning, mind maps, PESTLE and dynamic PESTLE, hypothesis generation and analysis, the analytic hierarchy process (AHP), and Bayesian belief networks (BBNs) are highlighted. The chapter thus posits that only constant scanning can mitigate unconsidered surprises hidden within derivative scenarios.

Keywords Scenario derivative · Horizon scanning · Mind maps · PESTLE and dynamic PESTLE · Hypothesis generation and analysis · The analytic hierarchy process (AHP) and Bayesian belief networks

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8.1 Introduction

In Chap. 7 two different scenarios lenses were identified—the reactive and the exploratory. However, whilst initial main scenarios, or first order scenarios, can be classified in this way, it is very rare for such scenarios to be stand-alone and discrete but impact other areas of the contextual environment. Such conditions can generate additional inputs varying in degree of intensity and, indeed, visibility which in turn can feed back and impact the first order scenario—a classic "wicked problem" situation.

With each first order scenario invariably producing second, third, or more levels of scenario type events we can call such additional outcomes "derivative" scenarios. It is within these derivatives that the impact of unintended and uncertain consequences of initial actions as generated by the first order scenario (good and bad) can play out, for the main actors and stakeholders concerned. We have seen such an example of how the responses, or lack of them, to an initial event such as the COVID pandemic are not limited to the prime objective of developing an effective vaccine against the virus. Other areas have been impacted as well—some of which have been aggravated by poorly thought-out responses to the impact of the virus spread—such as the impact on the education of children and students as a result of lockdown, mental health issues from extended social isolation, the impact on specific business sectors especially hit hard by lockdown and travel restrictions such the commercial aviation and the hospitality sector, and so it goes on. Chapter 11 in Part B will specifically look at the reactive response to the COVID-19 pandemic.

When trying to identify derivative scenarios the analyst has to take into account the issues such as the following (non-exclusive):

(a) Are secondary, tertiary, and further scenarios easily identifiable?
(b) At each level what different states present themselves as possible options?
(c) The further removed the derivative scenario is from the first level or core scenario, the weaker the likelihood of such a chain of sequences will occur although they may of course actually occur at some unspecified time in the future.
(d) Derivative scenarios identified at "time t" can change significantly at "time t + 1" and, more importantly, how far away is "t + 1"?
(e) The challenge for the analyst is that traditional planning cycles such as weekly, monthly, quarterly, or annually do little to address the dynamic nature of events so that such scenario option identification has to be performed in real time.
(f) Both reactive and exploratory type scenarios need to incorporate secondary and tertiary impacts as potential downstream outcomes. This requires continuous scanning as in e.) above.

Having identified that most scenarios generate downstream second, tertiary, and more possible outcomes, this chapter introduces the reader to a variety of methods (MTTs) which can be deployed to address such derivative scenarios. Be aware though that such methods are only support tools to bring about awareness of the existence of such derivative outcomes. In themselves they are essentially scanning devices.

Whilst the following section introduces a number of MTTs, it is important to recognise that derivative scenarios cannot be assumed to follow linear or overtly causal paths. Foresight approaches rather than trend extrapolating forecasting methods need to be used (as per Chap. 6). Therefore:

- Do not assume linear causality
- Do not rely on fixed observation cycles (weeks, months, etc.)
- Seek rough preferences or options rather than fixed probabilities. Bayesian approaches have a role here as long as they are used as rough guides to decision-making.
- Apply adaptive planning principles to help define:
  - Regular defined intervals (weekly, monthly, quarterly, or annually)
  - Ad hoc—response mode
  - Continuous monitoring activity

The key take-away from this introductory part of the chapter is not so much the use of particular methods to identify derivative scenarios as the awareness that such derivatives exist. Thus, analysis doesn't end once a core scenario has been identified or selected.

So what MTTs might help us in seeking our derivative type scenarios?

8.2 Methods, Tools, and Techniques (MTTs)

The MTTs introduced in this chapter are:

- Horizon scanning
- Mind maps
- PESTLE and dynamic PESTLE
- Hypothesis generation–analysis of competing hypotheses (ACH, inconsistency finder, quadrant crunching
- Analytic hierarchy process (AHP)
- Bayesian neural networks (BNNs)

8.2.1 Horizon Scanning

At a basic level awareness of derivative scenarios can be described as "horizon scanning", and as such makes management aware of the need to look beyond a single specific scenario itself.

According to "horizonscan.org" the activity is:

> a systematic process focusing on detecting the early signs of any potential developments. It helps researchers confirm or discredit existing phenomena as well as identify emerging trends that are on the margin of current thinking. In today's fast-paced world, things can become obsolete as quickly as they emerge. Horizon scanning aims to detect patterns or signals of coming disruptions that could have a transforming impact on our cities, the way we work, our communities, and our habits. The result of horizon scanning will help decision makers plan on how to exploit or mitigate these changes and secure the most positive outcome for their organization.

In November 2017, the UK's Government Office for Science published "The Futures Toolkit" in which it highlighted horizon scanning defining it as "*the process of looking for early warning signs of change in the policy and strategy environment*".

8.2.1.1 The Process

Horizon scanning combines desk research and some workshop discussion and, whilst it tends to look towards a long termer term horizon, is not focused exclusively on it. Many of the further out, downstream developments are the long-term outcome of a range of factors, some of which may be apparent already.

Horizon scanning is an open-ended process involving participants who are both internal and external to the organisation and with no limit as to the number of participants. The "futures toolkit" suggests that in order to keep the process manageable the early stages of an exercise should involve around 10 people and be expanded at a later date if specific expertise is sought. The participants are in essence authors, and it is suggested they each should produce roughly one scan a week over a 6 week period—although this is only a guideline.

Although this can offer an in-depth view of the horizon in a short period of time it does not address the open-ended nature of changing circumstances which can impact downstream outcomes. The author would suggest a more permanent ongoing process to address this issue and develop an in-house team dedicated to the activity. Another risk is that certain key stakeholders may not be included resulting in missed content and hence lower credibility in the scan. One interesting point made in the "toolkit" is that whilst horizon scanning is relatively straightforward it does rely on intuition and insight:

> which can feel counterintuitive to those who are more practiced in evidence based strategic thinking. The hardest part for many authors is knowing whether something they have read is interesting or different enough to include in the scan. Scanners should always err on the side of being irrelevant. (The Futures Toolkit, 2017)

8.2.2 Mind Maps

Mind maps have been used to "kick off" discussions relating to a complex problem with numerous levels of complexity and interconnectivity. Many readers may have seen such maps already; a typical example is shown in the example below (Farrand et al., 2002) (Fig. 8.1).

As you can see it is a very visual approach and as such encourages participants to engage directly with the map's construction. A mind map is a powerful graphic technique which helps the brain to include a variety of cognitive factors such as word, image, number, logic, rhythm, colour, and spatial awareness—in a single format.

Mind maps provide an effective method of taking notes as they show not only facts but also the overall structure of a subject and the relative importance of individual parts of it. Key to the format is that the map helps individuals to associate ideas and make connections they might not otherwise make. Mind maps hold information in a format that your mind will find easy to remember and quick to review. In fact, they abandon the list format of conventional note taking, doing this in favour of a two-dimensional structure. The maps support representation and creativity because they let participants and the reader have an overall point of view of the topic by a single observation of that topic context or structure. .

Maps can be constructed offline by individual team members who then are brought together to discuss the various versions in order to help develop a map enhanced by group consensus. Whilst often created around a single subject or concept a mind map does allow the user to see how ideas can be connected to the central concept from which other ideas can branch out.

In summary, five main characteristics of mind mapping can be identified:

1. The main idea, subject, or focus is crystallised as a central image.
2. The main themes radiate from the central image as "branches".
3. The branches comprise a key word (or even a key image) attached to its associated line.
4. Topics of lesser importance are represented as "twigs" of the relevant branch.
5. The branches form a connected nodal structure.

The case example presented as part of Chap. 12 uses mind mapping as an initial stage in the process which is then integrated with an additional method for further analysis.

8.2.3 PESTLE and Dynamic PESTLE

Another methodical approach looking at how the analyst and decision-maker can begin to visualise and identify and address linked issues includes the presentation of a simple contextual tool to identify some of the main variables and their different

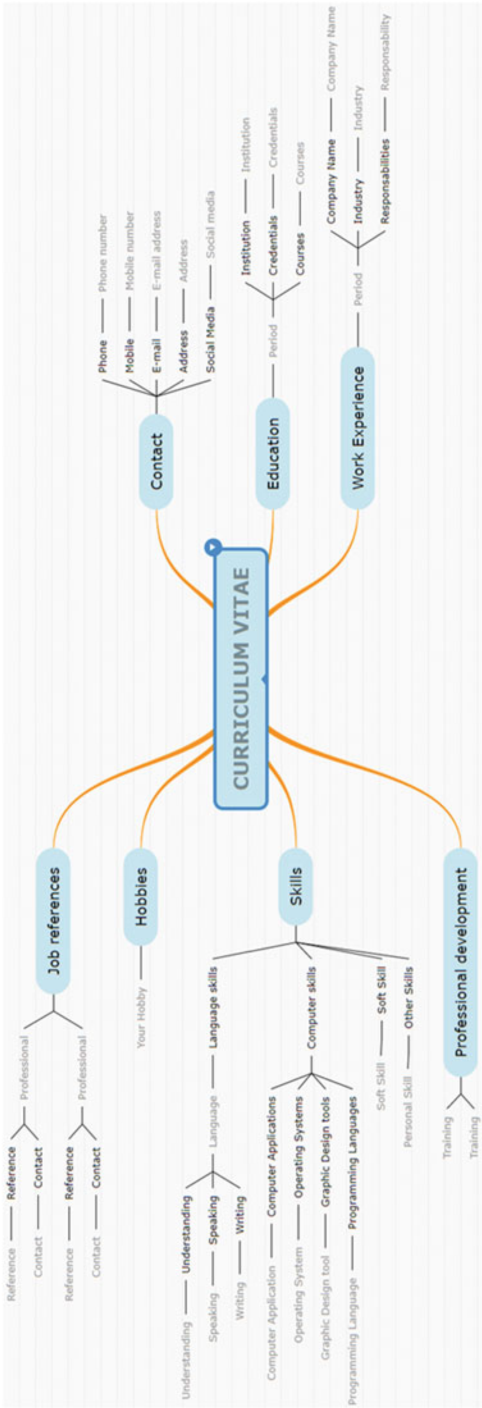


Fig. 8.1 Mind map example. *Ref*: mindomo.com

dimensions which in turn will help visualise derivative scenarios. The term "contextual" implies external rather than internal drivers.

The impact of second/third/nth order derivatives: Because we are now able to "identify" or rather select the various components of a scenario beyond its initial prime modus operandi, such potential outcomes can be elevated from quadrants 3 and 4 (unknown-unknowns or unknown-knowns) in the uncertainty profile template, to quadrant 2—"known-unknowns". Re-defining an uncertainty event in this category will allow the analyst to allocate a rough hierarchy of probable outcomes—but be aware these probability-derived numbers should not be seen as a rigid hierarchical classification but act as a rough guide for decision-makers (see BNNs later in this chapter).

8.2.3.1 A Basic Contextual Framework Using PESTLE

PESTLE is an acronym for **p**olitical, **e**conomic, **s**ocial, **t**echnological, **l**egal, and **e**nvironmental variables or factors. The "E" is often used to reflect "ethical" considerations but such is the prevalence of environmental (including climate change) issues that it probably outweighs ethical standpoints. In any case, ethical and regulatory factors can be nested under the legal heading. It's often used in conjunction with another acronym, SWOT—which mainly relates to internal/micro factors. There are a number of other acronymic variations such as STEEPLE—the main variables just changed or STEMPLES social, technical, economic, military, political, legal, and environmental and security plus demographic, religious, psychological, or other factors) (50 minutes.com, 2015).

A key starting point in the process to identify the main scenario drivers is to begin at the macro level—that is an overall perspective of the key contextual factors which determine strategic decision-making. The PESTLE strategic framework thus helps environmental scanning and enables management to track key external and macro factors impacting their organisation.

In many ways, this is a top-down as opposed to a bottom-up approach and has a number of attributes as it indicates a more holistic/systems outlook when looking at future risks and opportunities.

As identified in Chap. 3, which discussed the role of problem structuring methods (PSMs), scenario planners often struggle with determining what the problem is. There is often pressure to treat the problem as a puzzle and cut off chunks which have to be solved (Pidd, 1996)—leading to the dilemmas of problem-solving discussed in Chap. 3. Most problems challenged by uncertainty, complexity, and interconnectivity are "wicked" or close to being wicked. Stepping back and looking at the contextual drivers which are impacting an organisation, it helps to rapidly identify such drivers as a first stage in the process.

The advantage of using a tool like this is that the main variables are pre-determined by the acronym itself—and, as such, can speed up other idea creation activities such as brainstorming—leaving the analyst to populate the variables with appropriate criteria according to the topic being addressed.

A traditional **disadvantage** of standard PESTLE is that the analysis generated can be superficial, compounded by an unranked sequence of issues so that they appear as just a list of isolated sub-variables. Another weakness of PESTLE, and indeed SWOT, is the method's failure to offer a choice of outcomes that analysts and decision-makers can act upon. Real-world situations reflect complexity due to the various interactions of the different variables used in the model.

What I shall be presenting here is a variant which offers the analyst a much more dynamic tool and which addresses the inherent complexity of multi-variable scenarios.

The challenge for the analyst though is to populate each of the PESTLE headings with scenario-specific conditions or states. Thus, under political, there will be a need to refine and make more explicit the question that the scenario is trying to address. For example, are we talking about local, national, international, or global political issues. Social factors will also likely to be specific to any one of a sub-set of stakeholders.

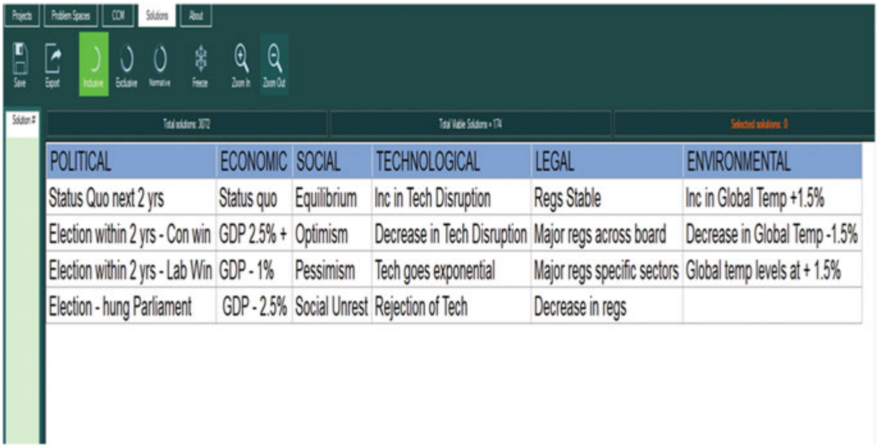
Nonetheless, the PESTLE acronym does provide an initial focus from which to develop more topic-related conditions and invites the analyst to engage with factors beyond just the narrow lens of the problem of the first order scenario itself. For example, one way is to ask where the subject "pandemic" resides in the PESTLE acronym (unless you want to substitute the P—political with P—pandemic)? The answer is that it doesn't but it **does** have an impact on, and more crucially is impacted by, the acronym sectors themselves—the **context** around the pandemic.

It has to be recognised that real-world situations are much more complex due to the interactions of the different variables and their sub-components used in the PESTLE array. Using the acronym letters as just discrete arrays of conditions does not do justice to the power of the model.

Standard PESTLE analysis can be turned into something much more dynamic and meaningful for management as it addresses the inherent complexity of multi-variable scenarios. Rather than leaving the PESTLE format as just a static matrix, the approach demonstrated enables the analyst to identify much reduced sets of second and third order scenarios which are viable and thus worth exploring—filtering out much of the noise present generated by the basic PESTLE matrix.

8.2.3.2 Dynamic PESTLE: A New Approach

The process of constructing a PESTLE-based matrix allows for the creation of a problem space which identifies not only the key variables themselves but the various states (or sub-variables) within each main variable. The product of the problem space is the total number of configurations or combinations generated by the PESTLE matrix. Pair-wise analysis of each of the states within one variable is assessed for consistency with every other state in all the other variables using the MA method introduced in Chap. 7. This process reduces the original set of configurations by eliminating all those configurations in the larger set which contain inconsistent pairs. Software can then automatically compile a reduced set of **viable** solutions with no



POLITICAL	ECONOMIC	SOCIAL	TECHNOLOGICAL	LEGAL	ENVIRONMENTAL
Status Quo next 2 yrs	Status quo	Equilibrium	Inc in Tech Disruption	Regs Stable	Inc in Global Temp +1.5%
Election within 2 yrs - Con win	GDP 2.5% +	Optimism	Decrease in Tech Disruption	Major regs across board	Decrease in Global Temp -1.5%
Election within 2 yrs - Lab Win	GDP - 1%	Pessimism	Tech goes exponential	Major regs specific sectors	Global temp levels at + 1.5%
Election - hung Parliament	GDP - 2.5%	Social Unrest	Rejection of Tech	Decrease in regs	

Fig. 8.2 PESTLE problem space

inconsistent pairs—i.e. they can work. Integral to the ability of identifying viable options produced by the model is the ability also to produce alternative viable configurations which in themselves can contain secondary and tertiary possible outcomes.

In our example, the analyst is looking at *"what outlier options could be considered for the UK over the next two years or so, based on a selection of political scenarios"?*

A small problem space was generated—Fig. 8.2—, totalling some 3072 different configurations (a small size). Following pair-wise analysis to reduce the original set of configurations, software compiled a reduced set of **viable** solutions, from 3072 to 174, or by 94%.

These 174 viable solutions were then triaged according to the distance principles explained in Chap. 7, earlier.

An anchor configuration reflecting current knowledge was selected, scenario 2791 (red cells)—Fig. 8.3. This "known" configuration (in effect a known-known) indicated a visible or likely outcome based on current policy analysis such that a scenario statement or narrative could read as follows:

> There would be a high probability of an election yielding a hung parliament, where GDP could be under 1% causing pessimism within society, compounded by increasing disruption from new technological systems, accompanied by major regulation of specific sectors (such as Social Media), accompanied by weak action in relation to climate change due to the poor state of the economy over the next two years.

Analysis of the viable 174 scenarios identified that some 20 scenarios were distanced the maximum 6 parameter/states from the anchor configuration, representing 11.5% of the solution set. These 20 outlier scenarios, being so far distanced from the anchor, could offer intriguing perspectives not readily identifiable

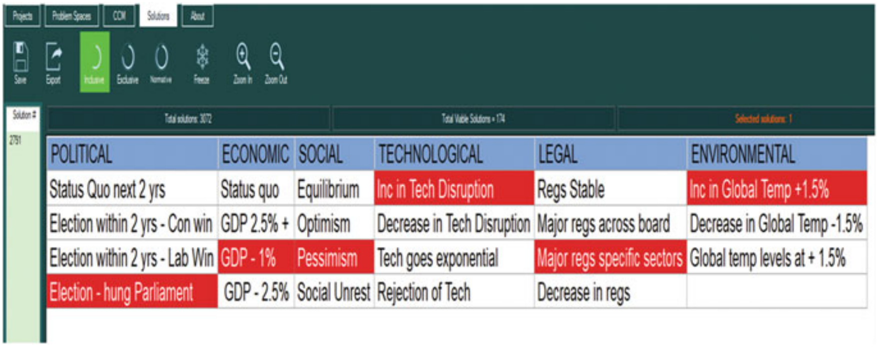


Fig. 8.3 Example of an anchor configuration

had this exercise not been carried out—interpreted here as being a low probability or occurrence/high impact event.

One of these 20 scenarios (782) was selected as being in the outlier (weak signal) zone due to the high level of variance from the anchor (current knowledge) scenario. This example of a viable configuration, substantially different from current knowledge, is shown below:

In Table 8.1, the current knowledge or anchor scenario as per Table 8.1 is "frozen" and is identified as cells with ***bold italic*** text. Outlier (solution) scenario 782 (those cells with **bold** text) is at the maximum distance from the anchor scenario in that all six variables are different from the anchor. As a VIABLE scenario (**bold** text cells), all the cells in the configuration are different from the anchor configuration (purple cells). This scenario having passed muster as a solution is very much an outlier in relation to current knowledge or policy and should be subject to further analysis. More importantly, one can ask whether the analyst would have isolated this scenario as being worthy of further analysis—its high degree of variance from the anchor scenario qualifying it as an outlier or weak signal.

In other words, this outlier indicated that a potential scenario could be characterised by the following narrative: *"There being an election within 2 years resulting in a Conservative win, with the economy remaining static and there being a decline in new disruptive technologies, whilst no additional regulation being introduced and there being a small decrease in the global temperature change due to remedial actions at a global level."*

Perhaps it is not a scenario deemed probable under current perceptions and political positions but, according to this model, possible and thus worthy of consideration.

8.2.3.3 Dynamic PESTLE: A Summary

The very flexibility of this approach thus turns the static PESTLE tool, when supported by software automating pair-wise analysis, into a much more dynamic

Table 8.1 Italicised anchor configuration (frozen)

		Total solutions = 3072	Total viable solutions = 174	Selected solutions 1		
Solution number	Political	Economic	Social	Technological	Legal	Environmental
782	Status Quo next 2 years	**Status quo**	**Equilibrium**	***Inc in Tech Disruption***	**Regs Stable**	***Inc. in Global Temp >1.5C***
	Election within 2 yrs—Con win	GDP 2.5%+	Optimism	**Decrease in Tech Disruption**	Major regs across board	**Decrease in Global Temp < 1.5C**
	Election within 2 yrs—Lab win	***GDP minus 1%***	***Pessimism***	Tech goes exponential	***Major regs in specific sectors***	Global temp levels at + 1.5C
	Election—hung Parliament	GDP minus 2.5%	Social Unrest	Rejection of Tech	Decrease in regs	

Table 8.2 Allocation of different scenarios

	Identifiable/known	Unidentifiable/unknown
Predictable/ known	**Q1. Known-known (I know what I know)** Does not apply	**Q2. Known-unknown (I know what I don't know)** Scenarios 12–14 Possible
Unpredictable/ unknown	**Q3. Unknown-known (I don't know what I know or I think I know but turns out I don't)** Scenarios 29–32 Possible Scenarios 33–34 Plausible Scenarios 43–44 Plausible *Scenarios 53–56 Highly Unlikely*	**Q4. Unknown-unknown (I don't know what I don't know)** *Scenarios 57–58 Highly Unlikely* *Scenarios 66–67 Highly Unlikely*

tool. Decision-makers and analysts are now offered a range of alternative strategic options based on different inputs AND outputs, visually, and which can be reviewed in real time.

Apart from identifying possible downstream scenarios (second, third order, and more) one can now determine where within the uncertainty profile template matrix such scenarios may reside (Table 8.2).

In Chap. 7, some 76 types of uncertainty were identified. Although initially presented as an appendix (Appendix 6) we shall re-introduce the 76 different options available.

How can the scenario profile 782, selected above in our example, be interpreted into terms of its allocation to the uncertainty file template quadrants?

The narrative description of the scenario has been expressed above but for ease of context I shall repeat the narrative again, thus:

> There being an election within 2 years resulting in a Conservative win, with the economy remaining static and there being a decline in new disruptive technologies, whilst no additional regulation being introduced and there being a small decrease in the global temperature change due to remedial actions at a global level.

We know from the model that it is viable. Although there is uncertainty as to such a specific scenario coming about, it has been visualised and thus should be seen as belonging to quadrant 2—a known-unknown. Of the 20 viable scenarios identified in the model as being different across all six configuration variables how can these be allocated within the uncertainty profile matrix? It will of course be up to the analyst and decision-maker to place these 20 viable options into some form of objective hierarchy.

As a first phase this dynamic form of PESTLE allows for the analyst to identify viable scenarios derived at secondary and tertiary levels characterised as being **low probability/high impact** (even catastrophic and existential) events of which 20 have been identified, outliers and wild cards, and even narratives seen currently as perhaps ghost technologies bordering on science fiction.

Once this first level of allocation has been performed, then other methods, such as the analytic hierarchy process (AHP—see below)), can be introduced to refine the hierarchy of viable options for further decision-based analysis.

8.2.4 *Hypothesis Generation*

The world of intelligence analysis has been a valuable and innovative source of methods—unfortunately little of it seems to have been adopted or absorbed by not only commercial organisations but by business school education curricula. Some of the most prolific and insightful work has been developed over the years by two former US intelligence analysts Heuer and Pherson (2010). For the purposes of looking at a method for determining how scenarios might be identified for future analysis, whether at primary secondary or tertiary levels, we shall be looking here at a number of techniques which are particularly useful when looking at exploratory scenarios (as per the previous chapter). These techniques come under the more broader term "hypotheses generation". Three approaches are reviewed in this section.

- Analysis of competing hypotheses (ACH)
- Inconsistency finder™
- Quadrant crunching

8.2.4.1 Analysis of Competing Hypotheses (ACH)

A core technique that forces analysts to challenge mind-sets is analysis of competing hypotheses (ACH), which involves the identification of a complete set of alternative explanations (presented as hypotheses), the systematic evaluation of each, and the selection of the hypothesis or hypotheses that fit best by focusing on evidence that tends to disconfirm rather than to confirm each of the hypotheses. ACH helps analysts overcome three common traps or pitfalls that can lead to intelligence failures: being overly influenced by a first impression based on incomplete date, an existing analytic line, or a single explanation; failing to generate a full set of explanations or hypotheses at the outset of a project; and relying on evidence to support one's favoured hypothesis that also happens to be consistent with alternative hypotheses and, therefore, has no diagnostic value. ACH can help overcome what is called "confirmation bias", the tendency to search for or interpret new information in a way that confirms one's preconceptions and avoids interpretations that contradict prior beliefs. These biases will be explored in more detail in Chaps. 11 and 12.

According to Heuer and Pherson (2010), ACH is appropriate for analysing where alternative explanations are needed for what has happened, is happening, or is likely to happen. It is appropriate when controversial issues require an audit trail showing how they considered and arrived at particular judgements and is well suited for dealing with tech issues such as *"For which weapons system is this part most likely to be imported?"* ACH is also useful in dealing with the potential for denial and deception (and the method was indeed originally developed for this purpose).

The technique can be used by an individual analyst but most effective with a small team that can challenge each other's evaluation of evidence. It can take time (several hours) and the introduction of a facilitator is a useful additional asset.

ACH helps analyst overcome a number of cognitive biases and intuitive traps that can lead to intelligence failures or analytic mistakes:

- Succumbing to tendency to select the first answer that appears “good enough” (satisficing).
- Failing to generate a full set of explanations or hypotheses at the outset of a project.
- Ignoring or discounting information that does not fit the preferred explanation.
- Relying on evidence to support one’s favoured hypothesis that is also consistent with other hypotheses and thus has no diagnostic value in assessing the relative likelihood of the hypotheses.

ACH can help overcome confirmation bias—the tendency to search for and interpret new information in a way that conforms to one’s preconceptions and avoids interpretations that contradict prior beliefs.

ACH ensures all analysts are working from the same evidence, arguments, and assumptions with each member of the team being allowed their say. Review of the ACH matrix provides a systematic basis for identifying and discussing differences between two or more analysts.

8.2.4.2 The Method of Analysis of Competing Hypotheses

ACH consists of the following 8 steps.

- Identify all possible hypotheses
- Make a list of significant evidence for/against
- Prepare a hypothesis versus evidence matrix analysing the diagnosticity of the evidence
- Refine matrix. Delete evidence and arguments that have no diagnosticity
- Draw tentative conclusions about relative likelihoods of each hypothesis. Try to disprove hypotheses
- Analyse sensitivity to critical evidential items
- Report conclusions
- Identify indicators for future observations

8.2.4.3 Other Strengths of the Method

1. *Encourages systematic analysis of multiple competing hypotheses.* As an analytic process it identifies full sets of alternative hypotheses whilst systematically evaluating both consistent and inconsistent data for each hypothesis—discarding those with high levels of inconsistency. This analysis of multiple hypotheses allows for viable, but not readily apparent, hypotheses to be assessed as opposed to the usual suspects.

2. *Creates an explicit record of the use of hypotheses and evidence that can be shared, critiqued, and experimented with by others.* This recording is important in that this part of the process allows the analysts to assess the evidence prior to making a judgement or decision.
3. *Easy to learn.* The eight-stage process as defined above is not onerous to understand.
4. *Focuses attention on disconfirming evidence—counteracting the common bias of focusing on confirming evidence.* This counteracts tendencies to rely on pre-conceived ideas and "gut feelings" as by deploying a more systematic approach to challenging evidence it helps to raise questions not previously thought of. Such a process helps being taken by surprise by an unforeseen outcome. This can occur when the topic is of a controversial nature and where sources of disagreement need to be identified.
5. *Does not require precise estimates of probabilities.* As for a number of problem structuring methods the dictum that it is often better to be approximately right rather than precisely wrong applies to the ACH method.
6. *Does not require complex explicit representations of compound hypotheses, time, space, assumptions, or processes.* ACH takes the analyst though a process of making well-reasoned analytical judgements. As such it is particularly useful for issues requiring weighing up of alternative explanations of what has happened or might happen (as an early warning system).
7. *Process benefits from computerisation of the process.* Whilst benefiting from computerisation the software is available free and can be downloaded at https://www.softpedia.com/get/Science-CAD/ACH.shtml. The only issue readers should be aware of is that the software to date is only available for download on Microsoft and not Mac.

8.2.4.4 Weaknesses

1. *Does not and cannot provide detailed and accurate probabilities.* ACH analysis can assign high weights for credibility and relevance, but may be insufficient to reflect the conclusiveness of such evidence. For example there may be circumstances when a few reports clearly support one hypothesis but are sufficient to refute all other hypotheses regardless of what other less definitive evidence may indicate. If you require mathematical accuracy in calculating probabilities for each hypothesis, other approaches may better of better use. Methods such as Bayesian belief networks (see Sect. 8.2.6 below) may require a methodologist trained in Bayesian statistics to assist in the process. Although the Bayesian probability calculations are mathematically correct, the results are still subject to a variety of subjective judgements about the evidence that go into the Bayesian calculation. ACH's strength comes from its process and takes the analyst through, but not from precise probability calculations for each hypothesis. The final judgement is made by the analyst, not by the computer.

2. *Does not provide a basis for marshalling evidence by time, location, or cause.* Evidence needs to be representative of the problem as a whole. If there is considerable evidence on a related but peripheral issue and comparatively few items of evidence on the core issue, the inconsistency or weighted inconsistency scores can be misleading. Thus, the analyst has to be aware of any unbalanced sets of evidence.
3. *Awareness is still required of behavioural factors—cognitive biases usually reflect entrenched positions.* It is unlikely that ACH will resolve an impasse between analysts with firmly entrenched views about an issue. If an analyst is unable to see alternative perspectives, the evidence will always be interpreted in a way that supports that analyst's preferred view. On the other hand, ACH can still be of value by helping to pin down the exact basis for the disagreement.
4. *Does not provide a basis for accounting for assumptions.* ACH is not appropriate for all types of decisions. It is used to analyse hypotheses about what is true or what is likely to happen. It is then left to the analyst team to identify recommended preferences. If one wants to evaluate alternative courses of action, such as alternative business strategies, or which computer to buy, this method has limited uses. A more hierarchy-based method such as AHP (see Sect. 8.2.5 below) will be of more value. This reflects the argument that decision-making under uncertainty requires the analyst to seek out a range of methods which can be linked or integrated into the decision support process—there is rarely, if ever, one method which fits all. Thus, before one can select a hierarchy of preferred options, one has to first present objectively determined viable options for the analyst to consider. Methods such as ACH (and Morphological analysis) allow for this approach.

8.2.4.5 Summary

The ACH method offers benefits for systematically considering multiple hypotheses and avoiding confirmation bias. It is easy to use and provides a basis for documenting the evidence used and the hypotheses considered. It supports a process for generating and comparing hypotheses under circumstances when accurate probabilistic scoring is not feasible (Heuer & Pherson, 2010).

8.2.4.6 Inconsistency Finder (IF) Tm

This method is a simpler form of ACH and helps focus attention on information which is inconsistent with the main hypothesis being explored. It is used whenever a set of alternative hypotheses exists or has been recently identified so that analysts need to:

- Carefully weigh the credibility of multiple explanations or alternative hypotheses explaining what has happened, is happening, or is likely to happen.
- Evaluate the validity of a large amount of data as it relates to each hypothesis.

- Challenge their current interpretation of the evidence (or interpretation of others).
- Create an audit trail.

For more details on the method I refer you to Pherson's *Handbook of Analytic Tools and Techniques* (2019).

8.2.4.7 Quadrant Crunching (QC)

Quadrant crunching (QC) is an application based on morphological analysis (MA) and was developed by Pherson and Schwartz and first published in 2008. As such it is a systematic process for identifying all potentially feasible combinations between different sets of variables. lt helps analysts avoid surprise by examining multiple possible combinations of selected key variables as well as helping to identify and challenge assumptions as well as helping to discover "unknown-unknowns".

It is mainly useful when dealing with highly ambiguous situations where there is little data and the chances for surprise are great. Analysts are required to rethink an issue from a broad range of perspectives and systematically challenge all the assumptions that underlie their lead hypothesis.

By generating an extensive list of potential scenarios, decision-makers are in a better position to select those that appear most credible or deserve most attention. They can then take the necessary action to avoid or mitigate the impact of bad scenarios and help foster preferred outcomes. It will help decision-makers to identify those scenarios in quadrants 3 and 4 and transfer them to Q2 type scenarios in the uncertainty profile matrix.

8.2.4.8 The Method

The basic process is as follows:

- State your lead hypothesis or key assumptions
- Break down the lead hypothesis or key assumption into its component parts or key dimensions (aka MA)
- Identify contrary assumptions for each dimension
- Array the combinations of these contrary assumptions in a set of 2 x 2 matrices
- Generate scenarios for each quadrant
- Select the scenarios most deserving of attention
- Develop indicators that would suggest whether the selected scenarios are becoming more or less likely

A more detailed run-through based on an example has been provided by Pherson and the essence of the process is shown in Appendix 10.

A number of the methods we have introduced are excellent at identifing viable, internally consistent options. However, such options may still be numerous. Faced with an array of viable possibilities decision analysts need to form some form of prioritisation if such processes are to prove of value to management. In other words, the question needs to be asked "how can these possible options" be placed in some form of hierarchy. A group of methods do exist under the generic category of multi-criteria decision analysis (or MCDA). This guide will not cover all such methods but highlight one established approach—the analytic hierarchy process (AHP). It does have its critics although the author considers these to be of limited concern as AHP is still working close to the uncertainty domain and as such methodological purity can be sacrificed in favour of a broader attempt in mitigating uncertainty.

8.2.5 The Analytic Hierarchy Process (AHP)

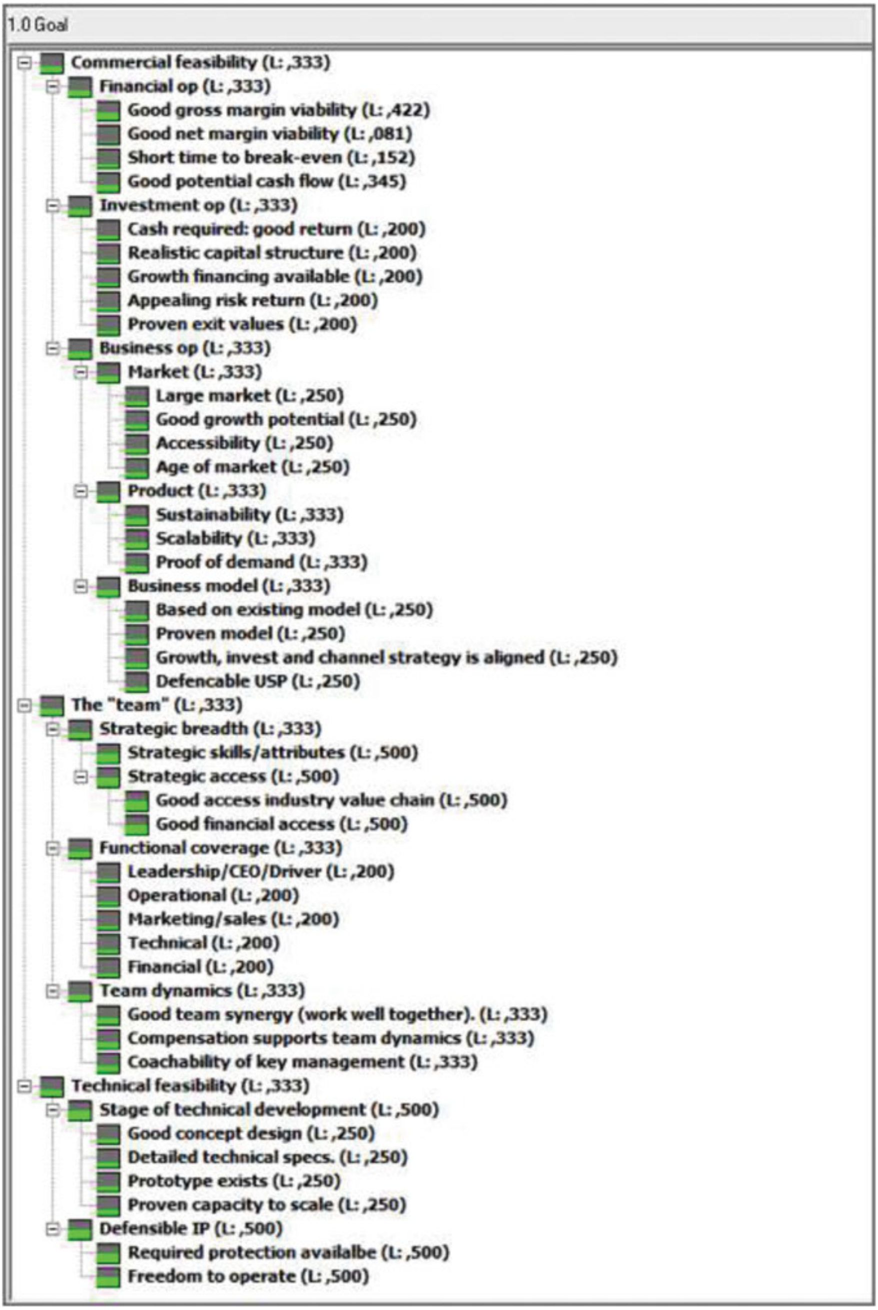
The method was developed in the 1970s by Thomas Saaty (2008). According to Saaty, AHP provides the process which acknowledges subjective and personal preferences of an individual or a group in making a decision. Fundamentally, the AHP works by developing priorities for alternatives and the criteria used to judge the alternatives. Software is available with probably the most well known being "expert choice" (found via expertchoice.com). Other versions are also available and a Google search yields a number of low-cost alternatives.

Wikipedia states that:

> Rather than prescribing a "correct" decision, the AHP helps decision makers find one that best suits their goal and their understanding of the problem. It provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions.

It well suited to handling intangible and fuzzy issues and where *"elements of the hierarchy can relate to any aspect of the decision problem—tangible or intangible, carefully measured or roughly estimated, well or poorly understood—anything at all that applies to the decision at hand"*.

AHP is particularly suited to group decision-making where individual experts' experiences are used to estimate the relative strengths of factors through pair-wise comparisons. Each of the respondents compares the relative importance of each pair of items using a specially designed questionnaire (generated by the software). An example of such a first level of questions addressing the question "Should we invest in this Start-up?" is shown below.



Once the set of items being evaluated is built, the decision analyst systematically considers the various elements by comparing them using pair-wise analysis, each item being compared to another item in the array in respect to their impact on an element above them in the hierarchy and where judgement is made about the elements' relative meaning and importance. Key to the ethos of AHP is that it is human judgement that qualifies the evaluation of each pair.

The AHP software then converts these evaluations to numerical values that can be processed and compared over the entire range of the problem. In the final step of the process, numerical priorities are calculated for each of the decision alternatives.

Fundamentally, the AHP works by developing priorities for alternatives and the criteria used to judge the alternatives. First, priorities are derived for the criteria in terms of their importance to achieve the goal; then priorities are derived for the performance of the alternatives on each criterion. These priorities are derived based on pair-wise assessments using judgement. The process of prioritisation solves the problem of having to deal with different types of scales, by interpreting their significance to the values of the user or users. Finally, a weighting and adding process is used to obtain overall priorities for the alternatives as to how they contribute to the goal. With the AHP a multidimensional scaling problem is thus transformed to a unidimensional scaling problem.

A more detailed description of the process is shown in Appendix 11.

8.2.6 Bayesian Belief Networks (BBNs)

The Bayesian approach uses the degree of a person's belief that an event will occur, rather than the actual probability that the event will occur. These probabilities are known as Bayesian probabilities and are properties of the person, not the event (Kreig, 2001). The causal relationships in Bayesian belief networks allow the correlation between variables to be modelled and predictions to be made, even when direct evidence or observations are unavailable (Kreig, 2001).

Bayesian belief networks aim to provide a decision support framework for problems involving uncertainty, complexity, and probabilistic reasoning. The approach is based on conceptualising an issue of interest as a graph represented by a network of connected nodes and links. In the graph, nodes represent important domain variables, and a link from one node to another represents a dependency relationship between the corresponding variables. To provide quantitative description of the dependency links, Bayesian belief networks (BBNs) use probabilistic relations, rather than deterministic expressions. The main use of BBNs is in situations that require statistical inference—in addition to statements about the probabilities (i.e. likelihood) of events, the user knows some evidence, that is, some events that have actually been observed, and wishes to update his or her belief in the likelihood of other events, which have not as yet been observed. BBNs can use both "forward" and "backward" inference (Wooldridge, 2003).

Although the probability and Bayesian theory that forms the basis of BBNs has been around for a long time, it is only in the last few years that efficient algorithms and software tools to implement them have been developed to enable evidence propagation in networks with a reasonable number of variables. The recent explosion of interest in BBNs is due to these developments, since for the first time they can be used to solve realistic size problems.

A fuller description of BNNs is beyond the scope of the chapter. However, for a more detailed explanation of the method I would recommend that readers seek a comprehensive publication by Norman Fenton and Martin Neil, titled *"Risk Assessment and Decision Analysis with Bayesian Networks",* published by CRC Press 2013.

Methods such as BNNs have been introduced as they are at the border where more qualitative methods addressing uncertainty start to overlap with more quantitative approaches as more data is identified. Again I should warn that although BNNs produce output in a quantitative format, such data is only to be taken as an indicator rather than a specific number—they reflect, as the title of the method indicates, a belief system rather than a precise number.

8.3 Conclusion

This chapter has attempted to make aware that scenarios are not just singular, discrete, events; most if not all main scenarios contain any number of linked downstream sub-scenarios which can be called derivatives. A number of MTTs were introduced which can support the analyst in determining what, when, and where these derivative scenarios can manifest themselves. But be aware there is no single method which can guarantee specific paths emanating from the main scenario. Suffice it to say that the major message herein for management is to be aware that any one scenario can encapsulate or even disguise any other number of scenarios. Only constant scanning for these derivative items can help mitigate unconsidered surprise.

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