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Borrowing from Keynes' *A Treatise on Probability*: A non-probabilistic measure of uncertainty for scenario planning

James Derbyshire[1] | Alberto Feduzi[2] | Jochen Runde[2]

[1]Middlesex University, London, UK
[2]Judge Business School, Cambridge University, Cambridge, UK

Correspondence
James Derbyshire, Middlesex University, Hendon, London, NW4 4BT, UK.
Email: jrderby@hotmail.com

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Abstract
Scenario planning is a tool used to formulate contingent but potentially impactful futures to aid strategic decision-making. A crucial element of many versions of scenario planning is an assessment of levels of uncertainty about the broad drivers of change within the system under consideration. Despite the importance of this element, the scenario planning literature is largely silent on the appropriate conception of uncertainty to use, exactly what it attaches to and how it might be measured. This paper seeks to fill this gap by advancing a non-probabilistic measure of uncertainty based on the concept of evidential weight drawn from the economist John Maynard Keynes' 1921 *A Treatise on Probability*.

KEYWORDS
Keynes, openness, organisational myopia, scenario planning, uncertainty

INTRODUCTION: A PRACTICAL TOOL IN SEARCH OF THEORETICAL FOUNDATIONS

Scenario planning is a tool for exploring contingent but potentially impactful futures to guide strategic decision-making. Originating as an aid to military planning shortly after WWII, it was subsequently applied in the public policy domain by Herman Kahn and his colleagues at RAND Corporation (Bradfield et al., 2005). Its popularity in the business domain goes all the way back to its use by Royal Dutch Shell to anticipate the oil crises of the 1970s, captured in two case studies still widely cited as evidence of its efficacy (Wack, 1985a, 1985b). But it continues to be widely used in business (Augier et al., 2018), including by well-known organisations such as British Airways (Moyer, 1996). Scenario planning is also used in other domains, not least—with rising concern about potential threats resistant to traditional forecasting methods such as climate change and the COVID-19 pandemic (Scoblic & Tetlock, 2020)—in public policy.

There is now an established academic literature on scenario planning in which at least 23 distinct approaches have been identified (Bishop, Hines, & Collins, 2007; Phadnis et al., 2014). This proliferation can be seen in positive terms as a reflection of the versatility and rate of development of scenario planning. But it is also a sign of an absence of common theoretical foundations (Phadnis et al., 2014; Bowman, 2015). Although perhaps an understandable consequence of its practice-based origins and associated prioritisation of applicability over theoretical development (Bradfield, 2008), this absence is more than a 'mere academic inconvenience' (Phadnis et al., 2014, p. 122). For practitioners, the absence of sound theoretical foundations makes it difficult to assess the relative merits of competing approaches and to assess which approach is best suited to any particular situation. For those seeking its academic development, there is the catch-22 of weak theoretical foundations being seen as confirming the lack of academic credibility of the subject, at the same time as hindering its prospects of being formulated in ways more suited to rigorous academic discussion and dissemination (Derbyshire, 2017).

The lack of common theoretical foundations also reflects important divisions in the subject, notably between opponents and proponents of the use of probability measures. Shell avoided probability measures in its scenario planning in the 1970s and 1980s on the grounds that they assume an exhaustive list of mutually exclusive outcomes (Jefferson, 2012; Derbyshire, 2017). This assumption was considered anathema in exercises exploring futures with long time horizons that are *open* in the sense of being pregnant with unimagined and therefore unlistable possibilities.[1] Yet other approaches to scenario planning, such as cross-impact analysis, explicitly require the assignment of probabilities (Bradfield et al., 2005). Indeed, Wilkinson (2009) distinguished between two communities in scenario planning, the deductivists and constructivists, who differ inter alia on whether probability measures should have a place (Millett, 2009; Ramirez & Selin, 2014).

Our own view is that the usefulness of scenario planning generally is closely tied to it being able to confront the openness of the future that more traditional probability-based decision tools are ill-suited to. But being critical of probability-based tools is one thing. Coming up with an alternative is another, the more so because the work of clearly articulating alternative measures is only now being undertaken in earnest (Urueña, 2019).

Our aim in this paper is to contribute to this work by arguing for a specific non-probabilistic measure of uncertainty for scenario planning. The measure we propose is a version of 'evidential weight' (EW), an old but until recently often overlooked concept in the history of probabilistic reasoning discussed in the economist John Maynard Keynes' 1921 *A Treatise on Probability* (Keynes, 1921/1973). Using the popular intuitive logics (IL) approach to scenario planning as our illustrative model, we attempt to show how this concept might be deployed in a way that both strengthens the theoretical foundations and enhances the practical usefulness of scenario planning. Specifically, we will argue that EW provides a conceptually coherent and practical measure for ranking causal drivers in terms of uncertainty as required by axes-based approaches to scenario planning.

We begin in the next section with an overview of the IL approach, taking care to isolate where uncertainty enters the analysis. The overview is followed by two sections that attempt to unpack the intuition underlying the role and measurement of uncertainty in IL. We then introduce the concept of EW in Keynes (1921/1973) and explain how this differs from standard probability measures. We close by showing how EW might be used to rank higher level factors and the rationale and benefits of selecting the two broadest and most critical higher level factors with the lowest EW in scenario planning.

[1]We have characterised openness in epistemic terms here, but our own view is that the world itself is open in the sense of being emergent and non-deterministic, that is, that there may be points at which the direction things go is not fully determined by antecedent conditions and is emergent in the sense that it is productive of novelty. This is not least because, as emphasised by Shackle (1955, 1961), human beings have freedom to choose, and thus to change behaviour and innovate in response to evidence that is revealed over time, or simply on a whim.

THE IL APPROACH TO SCENARIO PLANNING

The IL approach to scenario planning was initially developed by Global Business Network, a company founded by former Royal Dutch Shell employees Schwarz, Collyns and van der Heijden (Sharpe, 2008) in response to the increasing time pressures faced by managers and the reduced budgets for strategy departments in the 1980s. The simplicity and modest resource requirements of IL, also sometimes referred to as the 'scenario-axes technique' (Phadnis et al., 2015) or 'GBN matrix' (Bishop, Hines, & Collins, 2007), have led to it becoming something of a standard approach (Ramirez & Wilkinson, 2014) even outside scenario planning's traditional large-corporation stronghold (Phadnis et al., 2015; Derbyshire, 2020). Indeed, Bishop, Hines, & Collins (2007) referred to IL as 'the default scenario technique', even though it is probably more accurate to think of it as a group of similar techniques that share the same 'axes-based' approach (van't Klooster & van Asselt, 2006).

We use Cairns & Wright's (2018) version of IL as our example in this paper. We will illustrate this approach at the same time as presenting it, using an artificial example of a scenario planning exercise conducted by a recently listed mining company that supplies rare-earth metals to manufacturers of batteries for electric vehicles (EVs). The assumed 'focal issue' in this example is the company's valuation 5 years hence. Before we begin, it will be useful to define some terms:

- A *driving force* is anything in the world that has, or has the potential to have, a causal impact on the focal issue. By something having a causal impact, we mean that it has the capacity to make a difference to the focal issue in one or more of its aspects. Driving forces correspond to what are also sometimes called 'causal factors' or 'influences'.
- A *cluster* is an ensemble of driving forces identified by the scenario planning group, arranged in an 'influence diagram' to reveal the cause-and-effect relationships between them. These driving forces, acting in conjunction, are seen to lead to an ultimate 'resolved outcome' for that cluster, which is in turn regarded as a driving force impacting on the focal issue.
- A *higher level causal factor* is a subset of clusters regarded as 'broadest and most critical' in their bearing on the focal issue.

Cairns and Wright's version of IL follows the eight-stage procedure outlined in Table 1.

In Stage 1, the focal issue and scenario timescale are identified. Structured interviews with decision-makers and other stakeholders may be conducted to understand the focal issue and its perception within the organisation. Stage 2 is devoted to drawing up a list of 'driving forces' expected to have a causal impact on the focal issue.

TABLE 1 The simple intuitive logics approach to scenario planning approach

Stage	Description
1 Setting the scenario agenda	Defining the focal issue and setting the scenario timescale
2 Determining the driving forces	Eliciting a multiplicity of driving forces
3 Clustering the driving forces	Clustering driving forces, testing and naming the clusters and selecting a subset of these clusters as 'higher level factors' on the basis of their being regarded as 'broadest and most critical' in their bearing on the focal issue
4 Defining the cluster outcomes	Defining two extreme yet plausible outcomes for each higher level factor over the scenario timescale
5 Impact/ uncertainty matrix	Ranking the higher level factors in terms of uncertainty. The two higher level factors regarded as the most uncertain are selected and labelled.
6 Framing the scenarios	Creating a scenario matrix using the two higher level factors identified in the previous step. The four pairs of extreme outcomes of these higher level factors are used to frame the scenarios.
7 Scoping the scenarios	Building a broad set of descriptors for each of the four scenarios.
8 Developing the scenarios	Developing scenario storylines, including key events, their chronological structures and the 'who and why' of what happens

Driving forces may be identified using the PESTEL dimensions: political, economic, social, technological, environmental and legal (Cairns, Goodwin, & Wright, 2016; Cairns & Wright, 2018). In our example, driving forces might include future electricity prices, the development of a charging infrastructure, alternative forms of transport and so on.

In Stage 3, individual driving forces regarded as causally related are 'clustered' and depicted in 'influence diagrams'. Influence diagrams represent cause-and-effect relationships between individual driving forces that ultimately lead to a specific 'resolved outcome'. The resolved outcome is seen as one that in turn impacts causally on the focal issue. Suppose that for the future valuation of our mining company, one of the clusters concerns the number of EV car sales 5 years hence as shown in Figure 1.

There may be many clusters/influence diagrams. After discussion by the scenario planning team, a subset of clusters regarded as 'broadest and most critical' in their bearing on the focal issue are selected. Then, in Stage 4, two values are assigned to each higher level factor, representing the most extreme yet still plausible resolved outcomes associated with them.[2] For example, the two such values associated with the above cluster might be 20 and 100 m. These assignments are based on assessments of the combined impact of the driving forces in the cluster, including possible interactions, ampliative or otherwise (Derbyshire & Morgan, 2022), between individual or groups of driving forces.

In Stage 5, the higher level factors are ranked in terms of the uncertainty associated with them and the two highest ranked selected. Suppose that these two factors in our example are the one concerning the number of EV car sales already mentioned (labelled Factor A), and another concerning the interest rate 5 years hence (labelled Factor B, which will have its own cluster diagram). Suppose that the proxy used for the resolved outcome in this case is the Bank of England base rate, with the extreme yet still plausible values judged to be −2% and 15%.

The remaining stages are as follows. In Stage 6, the extreme values associated with Factors A and B are used to form the axes of a 2×2 matrix shown in Figure 2, each quadrant representing one of the four combinations of the two resolved outcome values assigned to each higher level factor in Stage 4 (A1/B1, A1/B2, A2/B1 and A2/B2).

In Stage 7, drawing on discussions that occurred throughout the exercise and thus encompassing all driving forces, descriptors are added to each quadrant to aid scenario writing. In Stage 8, four narrative scenarios are then written, one per quadrant. The descriptors are elaborated in long form, as coherent and detailed narratives describing the distinctive world represented by each quadrant and how it comes about.

With minor variations, this basic format is broadly representative of axes-based approaches to scenario planning. What follows focuses on Stage 5 of this format, where the two higher level factors used to frame the scenario writing process are selected on the basis of the level of uncertainty associated with them.

UNCERTAINTY

The problem we seek to address in the remainder of this paper is that the scenario planning literature says little about what the object of uncertainty is in Stage 5 and what the appropriate measure of uncertainty might be. Our aim is to answer these questions and provide an explicit conception of uncertainty suited to scenario thinking.

Let us return to our earlier example of the mining company and the higher level Factor A of EV car sales with the extreme yet still plausible resolved values of 20 and 100 m. With respect to what the object of uncertainty could be here, there are three candidates that immediately stand out:

1. the overall causal impact of the resolved outcome of the higher level causal factor on the focal issue, that

[2]Depending on the nature of the higher level factor, the scale used might be numerical (absolute numbers, percentages, etc.) or qualitative (specific qualities, types of events or states of affairs, etc.).

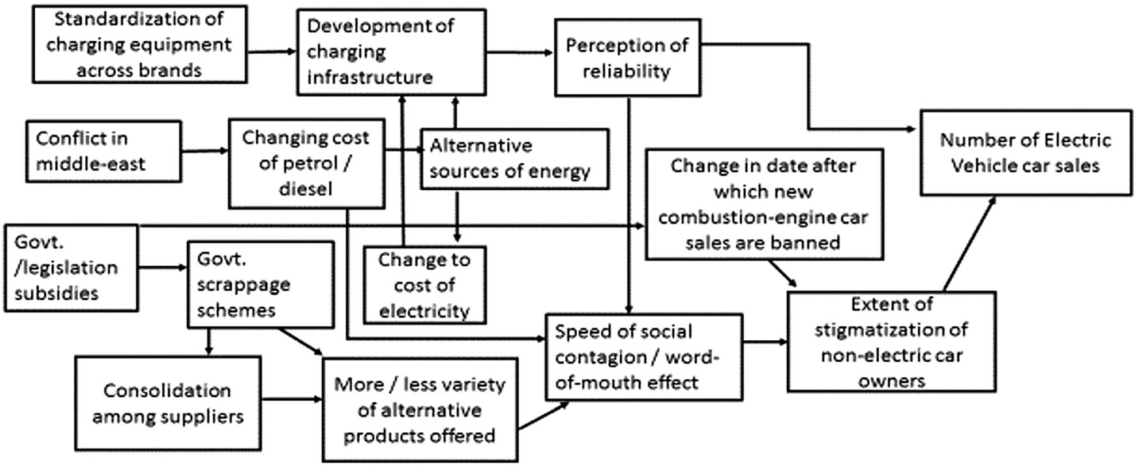

FIGURE 1 Influence diagram for cluster with resolved outcome 'Number of EV car sales'

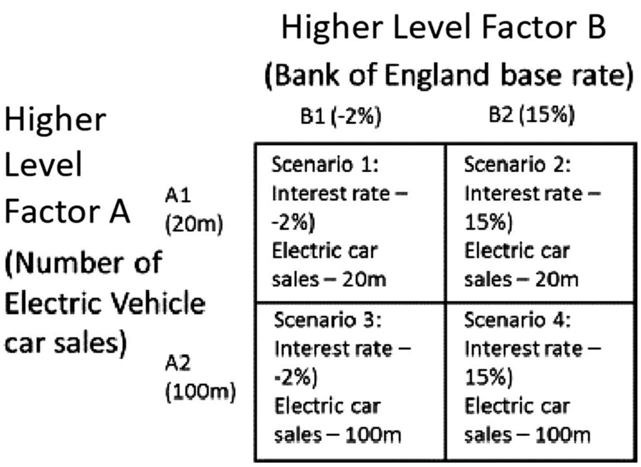

FIGURE 2 2 × 2 matrix for framing scenarios

is, the impact of the number of EV car sales 5 years hence on the valuation of the firm (the designated focal issue);

2. the two extreme values of 20 or 100 m setting the outer limits of the band in which the resolved outcome of that causal factor is expected to fall;
3. whether the resolved outcome of the causal factor will be closer to the lower or higher of the extreme yet still plausible values of 20 and 100 m.

We argue that 3) is the appropriate object of uncertainty by which the higher level factors should be ranked. With respect to 1), the higher level causal factor has already been selected for being amongst the 'broadest and most critical' in their impact on the focal issue. There will indeed be uncertainty about the precise nature and extent of this impact, but that is something that will depend inter alia on the other causal factors it is combined with at the next stage of the procedure, that is, when coming up with the narrative scenarios related to each cell of the final 2 × 2 matrix. An assessment of the uncertainty about the impact of any single higher level factor would therefore be putting the cart before the horse and should be put on hold until the narrative creation stage is reached.

With respect to 2), the extreme values chosen will in most cases be the product of qualitative judgements that are only approximate in nature, so that precise-sounding numbers such as 20- or 100-m EV sales should really be interpreted as proxies for 'low' and 'high' resolved outcomes of the relevant higher level factors. We doubt that there is any mileage in attempting to rank higher level factors in terms of uncertainty about whether the extreme values posited for them will be exceeded. This is because the values chosen, and accordingly the width of the band between them, will affect how likely it will be that the resolved outcome goes on to fall outside that band. The consequence is that a scenario planning group that responds to being highly uncertain about the extreme values by setting a wider band in Stage 4 of the process would then have offset such uncertainty before the higher level factors are compared in terms of uncertainty in Stage 5 of the process.

We are then left with 3). What we have in mind here, using the present example of the number of EV passenger car sales, is that we know that it is causally relevant to the focal issue, that it could plausibly be as low as 20 m and as high as 100 m, but that we have little or no idea and are therefore highly uncertain about, whether it will be closer to the low extreme or the high extreme.

How should such uncertainty be measured? Statistically based probabilities are ruled out since EV car sales are a relatively recent phenomenon, and there will not be a long history of repeated trials to exploit. The major alternative is some version of subjective probability (Ramsey, 1931; de Finetti, 1937; Savage, 1954), proponents of which sometimes argue that the maximum level of uncertainty might be represented by a uniform probability distribution defined over the outcomes between

20 and 100 m. However, the use of probabilities is not particularly useful in scenario planning exercises for two reasons. First, as pointed out by Keynes (1937), it is difficult, if not impossible, to use numerically definite probabilities to capture the uncertainty associated with factors in the distant future:

> By 'uncertain knowledge', let me explain, I do not mean merely to distinguish what is known for certain from what is merely probable. The game of roulette is not subject, in this sense, to uncertainty; nor is the prospect of a Victory bond being drawn. Or, again, the expectation of life is only moderately uncertain. Even the weather is only moderately uncertain. The sense in which I am using the term is that in which the prospect of a European war is uncertain, or the price of copper and the rate of interest twenty years hence, or the obsolescence of a new invention, or the position of private wealth-holders in 1970. About these matters there is no scientific basis on which to form any calculable probability whatsoever. We simply do not know. (Keynes, 1937, pp. 213–14)

Second, although subjective probability judgements may well be based on the available evidence bearing on the outcome of the resolved value of a higher level causal factor, they fail to capture considerations about the amount of evidence on which such probability judgements are based. This problem is nicely illustrated by an example in which a certain Miss Julie is invited to bet on the outcome of three different tennis matches (Gärdenfors & Sahlin, 1982). In Match A, she is very well-informed about the two players, knows the results of their previous matches, has watched them play several times, is aware of their current physical condition and so on. Based on this evidence, she predicts that it will be a very close match and that the outcome will be determined by chance. With respect to Match B, Miss Julie knows nothing about the players, has never heard their names before, knows nothing about their relative strength and has no additional evidence that might help predict the outcome of the match. Finally, Match C is similar to Match B except that she has just heard that the outcome of the match will be inevitable as one of the contestants is a professional tennis player and the other is an amateur. However, she does not know which is which.

If asked to attach probabilities to the possible outcomes of these three matches, Miss Julie might apply something like the principle of indifference, that is, proceed on the basis that, as she has no reason to prefer one player to the other in each of the three cases, each player should be assigned a 50% probability of winning in each of the three games. However, the amount of evidence upon which these judgements are based is clearly very different in each case, giving rise to different levels of uncertainty and perhaps affecting whether Miss Julie is prepared to take bets at all. Many people may be prepared to bet on Match A but not on Matches B or C, for example, as a bet on Match A involves less uncertainty than a bet on the others, despite the probabilities assigned being identical in each case.

There is however a non-probabilistic alternative. Recall that the purpose of Stage 5 of IL described in the preceding section is to identify the two higher level factors with the highest levels of associated uncertainty. We suggest that the relevant higher level factors be graded in terms of the *degree of completeness* of the evidence about how the driving forces in the associated cluster will combine to produce resolved outcomes. The degree of completeness of the evidence is low in respect of a higher level factor when the scenario planner suffers significant gaps in knowledge at the time the scenario planning exercise is being conducted, about the driving forces that will determine the resolved outcome of that factor at the relevant point of time in the future (5 years hence in our example). The lower the degree of completeness of the evidence, the higher the uncertainty.

At first blush, the degree of completeness of the evidence in respect of any contingency may sound odd and hard to operationalise. But it turns out that the idea has been discussed at some length before, under the heading of what Keynes calls 'evidential weight' in his 1921 *A Treatise in Probability* (Keynes, 1921/1973). We will argue that this measure is highly relevant to scenario thinking. But before we do so, it will be useful to summarise how it arises in Keynes' book and some places it has re-emerged in more recent research.

EW IN *A TREATISE ON PROBABILITY*

A Treatise on Probability is a contribution to the foundations of probability and statistical inference in the tradition of 'logical' probability. In this approach, probability is treated in epistemic terms as being concerned with degrees of belief in contingent hypotheses, rather than in terms of relative frequencies or some such. The guiding idea is that the probability of any contingent hypothesis is always relative to a given body of evidence, and probability as a branch of logic is concerned with the case in which the hypothesis is only partially entailed by the evidence bearing on it (Keynes, 1921/1973, p. 80). The theory was highly original and would have struck many as unusual, if not idiosyncratic, even when it appeared. One of Keynes' stated aims was to recapture the subject from mathematicians who 'have employed the term in a narrower sense … [often confining it] … to the limited class of instances in which the relation is adapted to an algebraical treatment' (Keynes, 1921/1973 p. 5). His insistence that probability judgements are often intrinsically non-numerical is one of the distinctive features of the book.

According to Keynes, the probability of any contingent hypothesis measures the strength of the logical relation between that hypothesis and the evidence bearing on it. He refers to this relation as the probability relation or 'argument' which he writes as *h/e*. The probability *P* this relation justifies can then be written as follows:

$$P(h/e) = x,$$

where x is the degree of rational belief that the probability relation between h and e justifies. If e implies h, $P(h/e) = 1$; if e implies not-h, $P(h/e) = 0$. Between these two extremes, e implies h to some degree (which is usually not numerically quantifiable). Since the probability of any conclusion is always relative to a particular set of evidential propositions, the acquisition of new evidence e_1 does not alter or affect the validity of the probability relation between h and e but gives rise to a new one $h/e\&e_1$.

According to Keynes, when judging the probability of some hypothesis, we should consider as much evidence as possible. The available evidence in any particular situation will depend on the circumstances at the time that estimate is made, and not all this evidence need to be relevant. There is thus a need for a definition of relevance, and here, it is useful to review the two basic ways in which two probability relations may be compared (Keynes, 1921/1973, pp. 58–59). In the first case, the probability relations involve different hypotheses relative to the same body of evidence, where h_1/e is compared with h_2/e. This case yields what Keynes calls judgements of preference where $P(h_1/e) > P(h_2/e)$ or judgements of indifference where $P(h_1/e) = P(h_2/e)$.

In the second case, the probability relations refer to the same hypothesis but are relative to different bodies of evidence. This case yields what Keynes calls judgements of relevance where $P(h/e\&e_1) > P(h/e)$ or $P(h/e) > P(h/e\&e_1)$, or irrelevance where $p(h/e) = P(h/e\&e_1)$. The rule that there must be no ground for preferring one alternative to another is an appeal to judgements of irrelevance. Keynes provides two definitions of irrelevance. We will restrict ourselves to the first 'simple' definition that e_1 is irrelevant to h if $h/e\&e_1 = h/e$,[3] which we can now use to define EW. In Keynes' own words: 'One argument has more weight than another if it is based on a greater amount of relevant evidence' (Keynes, 1921/1973, p. 84). Using our notation, this statement might be written as follows:

$$EW(h/e\&e_1) > EW(h/e),$$

where *EW* represents evidential weight. Note that probability and EW may move in different directions with the accretion of additional evidence e_1. If e_1 is favourably relevant to h, $P(h/e\&e_1) > P(h/e)$, if e_1 is unfavourably relevant to h $P(h/e\&e_1) < P(h/e)$. But either way, Keynes suggests, $EW(h/e\&e_1) > EW(h/e)$.

Keynes claims that two probability relations can always be ranked in terms of EW 'where the conclusion of the two arguments is the same, and the relevant evidence in the one includes and exceeds the evidence in the other' (Keynes, 1921/1973, p. 77). Where an argument has more weight than another, according to Keynes (1921/1973, p. 77), 'we have a more substantial basis upon which to rest our conclusion.'

This is, however, not the only interpretation of EW offered by Keynes. A somewhat different conception appears at the beginning of Chapter 6 of *A Treatise on Probability*, where EW is described, not in terms of the amount of evidence captured in the premises of a probability relation, but in terms of the balance of the absolute amounts of relevant knowledge and relevant ignorance on which a probability is based:

> The magnitude of the probability of an argument… depends upon a balance between what may be termed the favourable and the unfavourable evidence; a new piece of evidence which leaves the balance unchanged, also leaves the probability of the argument unchanged. But it seems that there may be another respect in which some kind of quantitative comparison between arguments is possible. This comparison turns upon a balance, not between the favourable and the unfavourable evidence, but between the absolute amounts of relevant knowledge and of relevant ignorance respectively. (Keynes, 1921/1973, p. 77)

The shift from talking about evidence to talking about relevant knowledge and relevant ignorance is significant for bringing in the limits of knowledge, what may not be known about things that would be relevant to h if they were known.

Some reconstruction is required to understand what Keynes may have in mind here. We take it that what he means by relevant knowledge is what is captured in the premises of a probability relation. Keynes does not define relevant ignorance, but it seems reasonable to infer that what he has in mind is the gap in knowledge about evidence that would be relevant if it were known. Further, being able to talk about arriving at a balance between the favourable and unfavourable evidence assumes that it is possible to arrive at some idea of the extent of our ignorance, or, as Keynes mentions when coming back to EW towards the end of the book, the *completeness of the evidence* relevant to some contingent hypothesis:

> In the present connection the question comes to this - if two probabilities are equal in degree, ought we, in choosing our course of

[3]The second definition is aimed at accommodating situations in which pieces of evidence are relevant individually but irrelevant in combination.

> action, to prefer that one which is based on a greater body of knowledge?… The question appears to me to be highly perplexing, and it is difficult to say much that is useful about it. But the degree of completeness of the information on which a probability is based does seem to be relevant, as well as the actual magnitude of the probability, in making practical decisions. Bernoulli's maxim, that in reckoning a probability we must take into account all the information which we have, even when reinforced by Locke's maxim that we must get all the information we can, does not completely seem to meet the case. If, for one alternative, the available information is necessarily small, that does not seem to be a consideration which ought to be left out of the account altogether. (Keynes, 1921/1973, pp. 345–346; emphasis added)

We will adopt the interpretation of EW as a measure of the degree of completeness of the evidence relevant to some contingent hypothesis in what follows. The question is whether it is possible to talk sensibly of knowing something about our ignorance, or, more precisely, of knowing something about the extent of our ignorance, about some hypothesis. The question is a difficult one,[4] but there are cases in which it seems natural and relatively straightforward to make judgements of EW, especially in view of such judgements typically being qualitative or comparative rather than quantitative in nature.

A simple example with a long history in probability and which appears in Keynes (1921/1973), Knight (1921) and Ellsberg (1961), is that of someone faced with two urns, one known to contain 50 red balls and 50 black balls, and the other known to contain 100 balls, each of which may be either red or black. With 101 possible distributions of red and black balls in the second urn, there is a sense in which our evidence is less complete than that in respect of the first urn where the distribution is known. The situation is more open, and the 'field of possibility' is relatively greater than in the case of the first urn.

Another instance in which intuitive judgements of EW seem possible is in 'before and after situations', where it seems natural to say that we are less ignorant about some topic or contingency after we have learned something about it, gathered evidence about it and so on. It is interesting that on the second interpretation of EW, EW can fall with the accretion of new evidence, if something is learned that leads to an upward revision of what one does not know (Runde, 1990), which leads to an increase in the 'field of possibility' (Keynes, 1921/1973, p. 84).

But there is also evidence of judgements of EW being made in practical decision situations in which the quality of decisions is crucial. A good example, albeit in a backward rather than forward looking way, arises in legal research on the meaning of 'burden of proof' and the limitations of standard Bayesian probabilities in courts of law. A prominent contributor to this literature is the philosopher of science L. J. Cohen (Cohen, 1977, 1986; see Schum, 1994, and, for a recent discussion of the importance of Keynes' work in legal settings, Nance, 2016). Cohen argued that judges cannot 'avoid using, implicitly or explicitly, an assessment of the completeness of the facts before the court' (Cohen, 1986, p. 639) and recommended Keynes' notion of EW as a method of assessing the inductive support for hypotheses in legal settings (Feduzi, 2010).[5]

These ideas have been taken up by other writers. For instance, Stein (1998) employed the distinction between probability and weight in the context of civil litigation. He argued that both are essential in adjudication, where probability 'should reflect the chance that the proposition at hand fits the actual event, which will be worked out from the existing evidence', whereas weight 'will be determined by the size of the ground covered by the evidence' or 'the extent to which the existing evidence encompasses the facts necessary for decision' (Stein, 1998, p. 314). The three possible verdicts of guilty, not guilty and not proven in Scottish criminal law reflect similar considerations. Although both the not guilty and not proven verdicts lead to acquittal, in the former case, the accused is adjudged not to have committed the crime, whereas in the latter, the accused's guilt is adjudged not to have been conclusively demonstrated. The not proven verdict is often due to there being insufficient corroborating evidence to convict, even where the jury, or the judge in a non-jury trial, believes the accused is indeed guilty (Duff, 1999, pp. 193–194; Camerer & Weber, 1992, fn. 7, p. 362).

ON THE PRACTICALITIES AND RATIONALE FOR USING EW IN SCENARIO PLANNING

We propose EW interpreted as the 'degree of completeness' of the evidence in respect of each higher level factor as the appropriate measure for ranking them in terms of the uncertainty about whether their resolved outcomes

[4] There is a large literature on the 'stopping problem' of when to stop gathering evidence prior to acting (Feduzi, 2010), but the solutions proposed invariably presuppose evidence about underlying probability distributions.

[5] Issues of EW are obscured in the subjectivist or personalist interpretation of probability that treats actors' probabilities as implicit in their propensity to act and inferable from bets they would be prepared to take on the relevant contingency being realised or true (Ramsey, 1931; de Finetti, 1937; Savage, 1954). On this approach, there is no clear separation between actors' feelings about the magnitude of the probabilities they are assigning on the one hand and their feelings about the quantity and quality of the evidence on which their probability judgements are based.

will be closer to the lower or higher extreme values attributed to them in Stage 4 of the IL process. The lower the EW in respect of a higher level factor, the higher the corresponding level of uncertainty. Ranking higher level factors in terms of EW would then amount to grading them in terms of a subjective assessment of how large the evidential gaps are with respect to the various driving forces that contribute to determining their future resolved outcome.

There are three categories of evidence to be considered.[6] The first comprises currently available evidence about driving forces and their associated resolved outcomes that is judged to be sufficiently comprehensive to be conclusive. For example, we know that inflation and unemployment are two key driving forces that would influence the Bank of England base rate 5 years hence, based on published evidence that these variables arise explicitly in the deliberations of the Monetary Policy Committee. We might also have evidence of the history of their past resolved outcomes, such as 12-month CPI inflation rising to 7.0% in March 2022 and unemployment falling to 3.8% in the 3 months to February 2022 (Bank of England, 2022).

The second category comprises currently available evidence pertaining to driving forces and their possible outcomes, but which is incomplete and therefore not conclusive. This evidence may be about driving forces regarded as having been in play in the past and likely to be so again in the future, or new driving forces suggested by the evidence that have not come to the fore before. Identifying driving forces at once entails being able to arrive at partial and sometimes even complete lists of their possible *hypothetical* outcomes (e.g., that the level of inflation 5 years hence will be 0%, 1%, 2%, etc.). But the evidence in this category is insufficient to determine the *resolved* outcomes in each case, for example, that the level of inflation 5 years hence will be 9.3%.

The third category comprises currently unavailable evidence of yet unimagined driving forces that will come into play in the future. Since such driving forces are not even in the mind to be contemplated at that point, it follows that the question of their associated hypothetical outcomes does not even arise. Although it may seem that there is not much to say about this category almost by definition, we believe that it is sometimes possible to grade situations in terms of their perceived capacity to reveal yet unimagined driving forces and potential outcomes of which there is as yet no trace in the currently available evidence (Svetlova, 2021). This is especially so when comparing cases with short time horizons with cases with longer term horizons that offer more scope for significant surprises in the future as it unfolds (Keynes, 1937, pp. 213–214), or when comparing the prospects of a mature business with those of a novel venture (Loch, Solt, & Bailey, 2008).

These three categories can be related to the trinity of 'known knowns', 'known unknowns' and 'unknown unknowns' often attributed to the late Donald Rumsfeld (2002a, 2002b, 2011). As interpreted by Faulkner, Feduzi and Runde (2017) and Feduzi et al. (2022), 'knowns' and 'unknowns' are epistemological categories, the former representing things we know and the latter things we do not know or gaps in our knowledge. That 12-month CPI inflation rose to 7.0% in March 2022, and unemployment fell to 3.8% in the 3 months to February 2022, thus falling into the category of known knowns, at least once we become aware of them. Known unknowns arise when we can identify a gap in our knowledge, such as whether the inflation rate will remain a driving force or what its resolved outcome will be 5 years hence. The possible outcomes that would fill any gap in knowledge associated with an unknown (…, −1%, 0%, 1%, … in our example of the inflation rate 5 years hence) correspond to the hypothetical outcomes mentioned above. Unknown unknowns then refer to gaps in knowledge we are not even aware of, and in respect of which, the question of possible hypothetical outcomes accordingly does not even arise.

Table 2 shows putative lists of the three categories of evidence in respect of higher level Factor B mentioned above, and we suggest that tables of this kind could be constructed for each higher level factor under consideration. Ranking higher level factors in terms of our preferred conception of EW would then come down to arriving at an assessment of the relative size of each of the three categories of evidence in each case.

Judgements of the kind we have in mind are always going to be qualitative, approximate and heavily dependent on the cognitive abilities, intuition and experience of the scenario planners involved. But it is important to remember that such judgements are only comparative and, as we have already argued, that people do sometimes appear able to gauge the extent of what they do not know in respect of specific issues they have identified (the known unknowns in the above list), as well as gauge situations in terms of how much scope they leave for developing in ways in which they cannot even imagine (the unknown unknowns in the above list). Such judgements might be represented visually as shown in Figure 3. The green areas represent currently available evidence that is sufficiently comprehensive to be conclusive and the orange areas currently available evidence that is incomplete and therefore inconclusive. The red areas represent the scenario planners' assessment of the possible scope for evidence yet to be revealed about yet unimagined driving forces.

Higher level Factor A represents a case of high EW in which the first category of evidence dominates and the potential for the emergence of evidence about potential, but as yet unknown and unimagined driving forces is

[6] In what follows, when we say that evidence is currently available, we mean that it is both available and known to the scenario planner.

TABLE 2 Currently available and unavailable (but relevant) evidence related to Factor B: Bank of England base interest rate in 5 years (assigned extremes: −2% and 15%)

Currently available evidence about driving forces and their resolved outcomes (known knowns)	Driving forces • Level of inflation • Level of unemployment • Tax levels • Level of government debt • Mortgage demand • … • … • …	Resolved outcomes • Current and past levels of inflation • Current and past levels of unemployment • Current and past tax levels • Current and past levels of government debt • Current and past demand for mortgages • … • …
Currently available evidence about driving forces likely to be in play in future, which is sufficient to determine a partial or sometimes even full list of associated hypothetical outcomes, but not sufficient to determine which of these will be the resolved outcome in each case (known unknowns)	Driving forces Level of inflation Level of unemployment Tax levels Level of government debt Mortgage demand Outcome of the Ukraine conflict Future modifications to the UK's Brexit agreement with the EU	Hypothetical outcomes Levels of inflation 5 years hence Levels of employment 5 years hence Tax levels 5 years hence Mortgage demand levels 5 years hence Levels of government debt 5 years hence Future courses of the Ukraine conflict Future modifications to the UK's Brexit agreement with the EU …
Currently unavailable evidence of yet unimagined driving forces that will emerge in future, and for which there is accordingly no call or basis to think about possible future outcomes (unknown unknowns)	Driving forces	Hypothetical outcomes

regarded as negligible. This case might be compared with a well-controlled experiment that has been run many times where the variability of outcomes is generally small and there is little risk of this being derailed by driving forces that have never been encountered or thought of before.

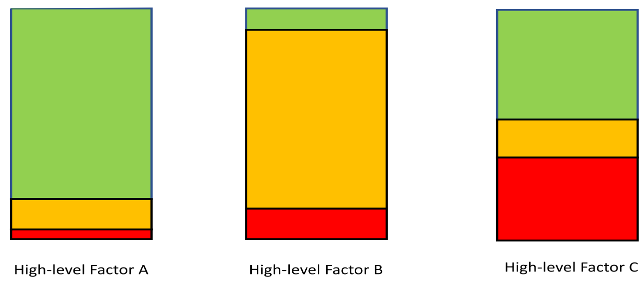

FIGURE 3 Visual aids for comparisons of evidential weight in respect of higher level factors

Higher level Factor B represents a case in which the second category of evidence dominates, EW is lower than in the case of higher level Factor A and there is also more scope for evidence about driving forces not yet identified to come in. Finally, higher level Factor C represents a putative third case in which the evidence is again highly incomplete and where the scope for complete surprises emanating from evidence yet to come in is regarded as relatively greater than with respect to higher level Factor B. Of the three cases shown here, then, higher level Factors B and C both have lower EW than higher level Factor A and would in this case be chosen to provide the axes of the 2 × 2 matrix.[7]

All of this leaves the important question of why the two higher level factors that are most uncertain in the sense just described should be the ones used to provide the axes of the 2 × 2 matrix to be used in the scenario writing. After all, this injunction seems to depart from what Keynes himself was recommending when arguing that '[i]t would be foolish, in forming our expectations, to attach great weight to matters which are very uncertain. It is reasonable, therefore, to be guided to a considerable degree by the facts about which we feel somewhat confident, even though they may be less decisively relevant to the issue than other facts about which our knowledge is vague and scanty' (Keynes, 1936/1973, p. 148).

However, as Keynes immediately recognised, following this logic implies that 'the facts of the existing situation enter, in a sense disproportionately, into the formation of our long-term expectations; our usual practice being to take the existing situation and to project it into the future, modified only to the extent that we have more or less definite reasons for expecting a change' (Keynes, 1936/1973, p. 148). The purpose of selecting the two higher level factors with the lowest EW, therefore, is

[7]We are of course aware that these comparisons may be ambiguous. For example, on the one hand, the green area for higher level Factor C is larger than it is for higher level Factor B. But on the other hand, higher level Factor C is regarded as relatively more open in offering more scope for evidence yet to come in of as yet unimagined driving forces. The question of which of the two has lower EW is therefore not obvious. It seems to us that there is little mileage in attempting to devise a mechanical criterion by which these matters could be decided. The ranking of higher level causal factors is something that must be thrashed out by the scenario planning group.

to do exactly the opposite: to make the possible drivers of future outcomes about which managers are less confident because the evidence is incomplete, enter disproportionately into the formation of their expectations.

Business history is littered with organisations that failed because management focused on anticipating the near future informed by more readily available evidence of past and present trends, rather than considering the more distant and opaque future. Consider Apple Inc.'s game-changing development of touchscreen and internet-enabled capabilities, which led to the innovation of the iPhone and the demise of Nokia at a time when the latter was by far the dominant manufacturer of cell phones and Apple not even in the market (Derbyshire & Giovannetti, 2017; Fenton-O'Creevy & Tuckett, 2021). Nokia spent years attempting to catch up with the companies that had overtaken it by introducing similar innovations that turned out to be inferior. These efforts floundered because of its failure to anticipate the need to develop the relevant capabilities. Further, the seeds of Nokia's failure to anticipate were sown years before in its past and then-present successes (Vuori & Huy, 2016). On the dimensions that then counted to customers, about which it had considerable evidence, Nokia's products were superior. However, this went on to count for nothing because Apple was competing in other dimensions: Rather than merely disrupting Nokia's existing market, Apple created an entirely new one by exploiting the rapid take-up of touchscreen and internet-enabled mobile telephony that Nokia was not part of. Yet, although evidence of the full prospects of this technology may have been scant at the time (at least to those in Nokia, if not Apple), the indications were there, and the technology as it developed did indeed go on to prove a critical driving force. Indeed, Nokia's then-CEO acknowledged that 'We fell behind, we missed big trends, and we lost time' and that this enabled Nokia's competitors to capture its market share (Fenton-O'Creevy & Tuckett, 2021).

As this comment demonstrates, when it comes to business success and failure, it is often driving forces that might have been identified but were missed for the evidence being incomplete that go on to play a fundamental role. Nokia's rapid decline from a dominant position may have seemed an unlikely and extreme possibility to its managers prior to its occurrence. Yet managers face a world in which such extremes may be the norm, and sometimes sources of bankruptcy and ruin, but sometimes also of great opportunity. The prevalence of extremes and the uncertainty they bring present a major problem for management decision-makers because most mainstream methods for decision-making assume a world in which uncertainty is regarded as something that is captured by the variation of past outcomes around the mean (McKelvey & Andriani, 2005; Andriani & McKelvey, 2007, 2009). But as the Nokia example demonstrates, managers cannot afford to restrict their attention to possible futures that fall within their limited range of prior experience (Ocasio, Laamanen, & Vaara, 2018). Neither can they afford to restrict their attention to possible futures about which they might have relatively more evidence, as this risks their being blindsided by those about which they currently know relatively little.

In this light, the purpose of using the conceptualisation of EW we have proposed, and the idea of selecting within the IL process the two broadest and most critical higher level factors with the lowest EW, is to help managers using axes-based scenario planning overcome these restrictions. That is to say, the aim is to derive four scenarios framed by the extreme outcomes of the higher level factors in respect of which the EW is least. There are at least three important benefits of proceeding in this way.

First, by forcing managers to focus on the two higher level factors with the lowest EW, the process counteracts an important deficiency of scenario planning highlighted in this journal by MacKay and McKiernan (2004, p. 70): that it can lead to a focus on 'overly common threads' about the future, in terms of the obvious trends and easily evidenced aspects of it, leading to the 'failure to spot in advance the weak signals that are going to emerge from the surrounding noise and change all our lives' (Economist, 2001). The conceptualisation of uncertainty based on EW directs attention to what are effectively the 'weak signals' concerning the resolved outcomes of the higher level factors used to frame the scenario matrix. More generally, using EW as the standard for comparing higher level factors encourages thinking beyond the currently available evidence, and keeping sight of how incomplete such evidence is and how much further evidence there is yet to accrue. Collective learning is thereby enhanced, by encouraging out-of-the-box thinking, helping uncover gaps in knowledge, surfacing implicit assumptions about causal relations in the environment under analysis and encouraging different, often conflicting, views of the future.

Second, focusing attention on the two higher level factors with the lowest EW in our sense encourages appreciation of just how open the scenarios and by extension the future are and therefore how much uncertainty is involved. This feature counteracts another important deficiency of scenario planning highlighted by Ramirez and Wilkinson (2014, p. 258): the tendency to 'too easily and too quickly rush to reduce anxiety associated with uncertainty and move participants too early to get to solutions by using either probability or plausibility to stop rather than to [open up] further inquiry'. Our conceptualisation of uncertainty based on EW ensures that the focus of the scenario planning exercise is the most 'open', and therefore the most difficult to prematurely or artificially 'close', aspects of the future (i.e., the higher level factors for which most relevant evidence is currently missing), consideration of which may therefore make managers uncomfortable about their prevailing assumptions about the future and the true extent of their knowledge of it, which is what scenario planning is intended to do.

Third, using EW in the way we have proposed may help reduce what is sometimes called ‘organisational myopia’ (Catino, 2013; Feduzi, Runde, & Schwarz, 2022). The COVID-19 pandemic and the Russia–Ukraine conflict are recent examples of developments that have dramatically affected the fortunes of organisations but that were typically not even seen as possibilities by most strategy makers prior to their occurrence. In response to the occurrence of such events—sometimes called ‘Black Swans’ (Taleb, 2007)—some strategic leaders and academics have recently suggested that organisations should rely on scenario planning when formulating strategy under extreme uncertainty (Scoblic & Tetlock, 2020). Our conceptualisation of uncertainty for scenario planning is particularly effective in reducing organisations’ exposure to what might otherwise be Black Swans because using EW in the way we have proposed counteracts the tendency many people have to disregard ‘low probability’ events that might be highly impactful and also counteracts well-known biases that often lead to tunnel vision in strategic decision-making such as the confirmation, overconfidence, availability and status-quo biases.

CONCLUSIONS

Scenario planning remains a popular tool designed to help strategic decision-makers formulate highly contingent but potentially highly impactful futures against which to test the assumptions inherent in their strategy-making. Although there has been some work on the theoretical foundations of scenario planning in the academic literature, there remains little agreement on the appropriate conception of uncertainty to use in selecting the two higher level factors used to frame the scenarios generated. Our aim in this paper has been to make the case for a non-probabilistic measure of uncertainty for this purpose, based on Keynes’ conception of EW. We have argued that this measure provides a conceptually coherent and practical measure for ranking causal drivers of change in terms of their uncertainty as required by axes-based approaches to scenario planning, and we have explained why relying on such a measure might help managers using axes-based scenario planning identify distinctive and extreme scenarios to inform their strategic decisions. We hope that this measure will contribute to strengthening the theoretical foundations of scenario planning, resolve some of the practical difficulties that arise in how it is conducted and allow organisations to benefit more fully from scenario planning in the ways we have identified.

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AUTHOR CONTRIBUTIONS

The authors of this paper contributed equally to it.

CONFLICT OF INTEREST

The authors confirm that they have no conflict of interest in the production of this article.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

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