An Application of Modern Social Sciences Techniques to Reverse Stress Testing at the U.K. Pension Protection Fund

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ABSTRACT

The U.K. Pension Protection Fund (PPF) was established in April 2005 to protect the pensions of members of U.K. private sector defined benefit pension schemes that have insufficient assets and whose corporate sponsor fails. The Fund takes over the pension scheme assets and assumes responsibility for the payment of compensation to the former members of the scheme. The PPF is funded by a levy on the population of eligible schemes. To improve its ERM framework, the PPF has undertaken a reverse stress testing exercise. This analysis provided the organization with new insights into its risk profile, the scenarios leading to the PPF's potential "failure," and interactions between these scenarios. This paper discusses the principles and objectives of reverse stress testing in the special case of the PPF and then illustrates the application of complex system science techniques for the purpose of reverse stress testing.

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1. Introduction

In the United Kingdom the Pension Protection Fund (PPF) is a public corporation led by an independent board. The PPF is not regulated and does not benefit from an explicit government guarantee. It is subject to the Pensions Act and is accountable to the U.K. Parliament.

The PPF covers the risk that the sponsor of an eligible pension scheme becomes insolvent, leaving the scheme with insufficient assets to fund the scheme's benefits. In such cases, the PPF pays compensation to former members of the scheme. Broadly speaking, where members have reached their retirement age at the insolvency event, compensation is paid based on full scheme benefits, whereas for members under retirement age at insolvency, compensation is based on 90 percent of scheme benefits and is subject to a cap.

The PPF, therefore, resembles an insurer, both in providing cover against corporate insolvency and in managing what could be viewed as a pension annuity book. However, the PPF is not subject to financial services regulation nor required to maintain minimum regulatory capital.

The purpose of this paper is to describe how a reverse stress test exercise was undertaken to help the organization better understand the scenarios that may render the organization no longer economically viable and/or lead the stakeholders of the PPF to lose confidence in the organization.

The U.K. Financial Services Authority strongly advises insurance companies to carry out a reverse stress test as part of their Own Risk and Solvency Assessment. Although the PPF is not regulated by the FSA and will not be subject to the EU's Solvency II Directive, the organization has felt the need to conduct a reverse stress testing exercise to enhance its enterprise risk management (ERM) framework.[1] Section 2 describes the risk profile of the PPF and discusses the principles of a reverse stress test and its objectives in the case of the PPF.

A key question for the organization was whether the reverse stress test could offer new insights into the risks faced by the PPF and overcome a common perception that such tests merely confirm the organization's own understanding of the risks it faces.

[1] The ERM framework of the PPF is described in detail in Charmaille and Clarke's paper that was presented at the 2012 ERM Symposium.

Reverse stress testing presents a big challenge primarily because an expert in the business can think of so many ways that the business might fail. In the face of so many possibilities the problem feels intractable and practitioners often default to simply considering big impact events, and nearly always financial ones. For an institution like the PPF, financial stresses are serious, but the political and reputational aspects of its critical success factors mean that failure could very well come from other directions. A classical financial stress is, therefore, only one of the ways in which strategic failure could occur. Actuarial models are very powerful, typically constructed in a granular way to permit the exploration of simultaneous variations in multiple parameter values. However, for reverse stress testing the challenge is to know which scenarios should be considered. We are no longer simply looking for the 999th worst economic scenario, for example. Failure in the reverse stress scenario could occur while the financials still look, prima facie, quite healthy. The model simply cannot tell us which scenarios to look at. We must decide which scenarios to look at ourselves and then use the model to evaluate them.

To overcome these potential prejudices and avoid institutional "group think," an objective approach to the preparation of the test was undertaken with the help of an external consultancy (Milliman) and a thorough engagement process with internal subject matter experts and key external stakeholder groups including government departments, employer representative groups, and professional bodies.

The continued operation of the PPF requires careful management of a wide range of interrelated stakeholders and a complex series of real-world interactions. Understanding the many and varied ways in which situations might arise that could cause the PPF to become unviable is challenging. Section 3 describes how Milliman helped the PPF use complex systems science to rigorously express the key dynamics of its strategy and operations and then to articulate specific scenarios that could trigger those dynamics.

The PPF Board was able to consider a number of scenarios that combined financial, operational, and reputational failure of differing degrees and assess how the organization's existing ERM processes captured and processed these risks. Section 4 summarizes the results and the outcomes within the limits of business confidentiality.

The exercise reinforced the PPF's existing risk identification process but did raise questions about the potential interaction of separate risk incidents to create a more substantial crisis. Overall the following conclusions can be made:

1. A methodology that systematically captures and processes a wide range of opinions and perspectives can both assist in understanding dynamics in the risk map and help avoid institutional "group think."
2. The test supported the existing risk map but provided helpful insights into the relative importance of those risks already identified.
3. Complex scenarios are far from unlikely. Double or triple whammies, whereby an organization suffers a financial catastrophe at a time when reputationally or organizationally it is least well equipped to handle it effectively, should be more frequently considered.
4. Risk systems should be capable of anticipating and responding to the threat of such multi-incident scenarios.

2. Definitions and Objectives

In order to fulfil its statutory objectives, the PPF must have sufficient funds to pay compensation to the members it protects. Income currently derives from four sources: the assets of pension schemes that transfer into the Fund, recoveries from the insolvent sponsoring employers of those schemes, the annual Pension Protection Levy charged to eligible pension schemes, and returns on invested assets. At the end of March 2012, the PPF reported liabilities of £16.2 billion and assets of £17.3 billion, a current funding surplus of £1.1 billion.

2.1. Risk Profile of PPF

Charmaille and Clarke (2012) described the ERM system in place at the PPF and described the seven risk areas the PPF Board had identified in its overall management of the PPF:

1. *Funding and Investment Strategy*—the risk that the PPF becomes underfunded, either because the investment strategy is not appropriate or because the PPF incurs claims that exceed levy collections by a large amount
2. *Investment Operations*—the risk that the PPF's investment strategy is not adequately implemented, leading to financial losses and/or reputational damage
3. *Strategy/Environmental*—the risk that changes in the economic, regulatory or political environment in which the PPF operates damages the PPF

4. *Legal*—the risk that the PPF fails to operate within its legislative framework, or that changes to that legislative framework have an adverse effect
5. *Operational*—the risk that the PPF's internal systems and processes deteriorate or fail, such that the PPF cannot meet its statutory requirements to stakeholders
6. *Reputational*—the risk that the PPF's reputation is damaged and
7. *Organizational Design/Culture*—the risk that poor operational design or culture renders the PPF ineffective or inefficient.

2.2. Principles of Reverse Stress Testing

Reverse stress testing starts from an outcome of organizational failure and seeks to identify the circumstances where this might occur, thus exposing potential vulnerabilities. It is a risk management technique that is distinct from stress testing. Whereas a stress test looks at the impact of a particular adverse scenario, a reverse stress test starts from a negative outcome and seeks to discover the series of events that may lead to this outcome. Reverse stress testing covers plausible scenarios outside the normal stress testing requirements.

Reverse stress testing is as much of a qualitative exercise as a quantitative one, because failure is really defined as the point at which stakeholders, such as investors, media, or regulators, lose confidence in the organization. It is most likely that this point will occur well before an organization actually becomes insolvent or loses its license to operate.

2.3. Objectives of the PPF's Reverse Stress Testing Exercise

Given the statutory role of the PPF, the Board's appetite for risk is generally low. In its reverse stress testing exercise, the Board sought, first, to test this risk map for completeness and relevance and, second, to assess the interactions between risks in bringing about scenarios that might potentially render the organization unviable. In more detail, the objectives of the exercise were as follows:

1. *Completeness and relevance*—to assess the appropriateness of the current seven risk areas that had been identified. During the process, no new strategic risks were identified, but the frequency with which the existing risks were referenced in discussions and workshops was an interesting outcome of the exercise.
2. *Comprehensiveness and inclusivity*—the PPF's unique status means that a wide range of stakeholders, ranging from government departments right through to

those in receipt of compensation, and including levy payers and the wider pensions industry, take a keen interest in the PPF's operations. Their support is critical to the future success of the PPF. Therefore, understanding what would lead them to withdraw their support was a key objective of the exercise.

3. *Objectivity*—discussing risks in group workshops and explicitly giving participants the license to imagine the worst aimed to generate fresh thinking about existing risks, such as what the drivers of these risks might be.
4. *Connectivity*—ownership of the various risks is devolved right across the PPF under various governance arrangements and with an evident danger of "risk silos" being created. One of the aims of the exercise was, therefore, to highlight links between different risk areas and identify how these links could be better monitored and understood.
5. *Accessibility*—presenting the risk map to the Board as real-world scenarios was intended to help bring the PPF's risk profile to life for the members of the Board, and allow them to draw on their wider experience to provide commentary and suggestions.

Although the exercise was predominantly qualitative, some quantitative modeling was performed to assess the financial impact of certain risks to help calibrate the scenarios being created. This was intended to clarify how bad the economic and financial conditions would need to become for the PPF to have virtually no chance of meeting its long-term funding objective. This enabled a realistic comparison of the impact of different risks on the business to be made and avoided.

3. Methodology

3.1. Describing the "System"

A typical challenge that practitioners face in describing systems such as those representing organizations is that they combine both "hard" and "soft" systems. Checkland (1999) introduced this terminology to help bridge two different types of systems:

1. Hard systems of the world are characterized by the ability to define purpose, goals, and missions that can be addressed via engineering methodologies in attempting to, in some sense, “optimize” a solution.
2. Soft systems of the world are characterized by extremely complex, problematical, and often mysterious phenomena for which concrete goals cannot be established and that require learning in order to make improvement. Such systems are not limited to the social and political areas and exist within and among enterprises where complex, often ill-defined patterns of behavior are observed that are limiting the enterprise’s ability to improve.

In order to capture the “soft” systems aspects of the PPF’s strategy a technique called cognitive mapping was employed. As described in Allan et al. (2012), “A concept map is a model which allows complex interconnected factors to be shown in a simplified diagrammatic form, so that the overall picture can be understood and communicated to a wide audience. Such maps are particularly useful for identifying and analyzing strategic issues, as these are often complex in nature and contain a wide range of factors interacting in a nonlinear manner. Also they can help visualize the complex and nonlinear relationships between different concepts.” The approach used was derived from Personal Construct Theory (Kelly 1991) and Cognitive Mapping (Eden 1988).

The technique essentially permits the structured compilation of the PPF strategy from knowledgeable stakeholders in such a way that their individual contributions can be recombined to form a holistic view. In this objective way, individual biases are largely removed and any gaps in narrative identified.

To understand specific trends that could result in a reverse stress scenario for the PPF, the system was considered at different levels. It is important to recognize these different layers because they will involve trends operating at different scales in space and time. In the strategic level, for example, trends would be expected to evolve more slowly. This provides a “base” understanding of the features that a reverse stress scenario might take and from which the more granular operational layers follow where trends can be more rapid in their evolution. Exercises that remain only at the strategic level may miss important detailed features about how reverse stresses may occur, and exercises that start in the operational layer may get stuck in the minutiae and miss a number of larger generic possibilities. By explicitly recognizing these different layers,

the resulting scenarios are more complete and individually more realistic. This, in turn, helps to ensure that the resulting conclusions are more meaningful in terms of recommended management actions or risk management system alterations.

3.2. The Strategic Layer

A series of workshops were held with key PPF stakeholders, including internal subject matter experts and external parties such as government departments, consultants, and representative bodies. Stakeholders were asked to discuss the PPF and the features of, and influences upon, its strategic delivery. They were also asked to identify the outcomes that would be achieved through successful strategic delivery.

Each discussion was converted by the PPF's consultants (Milliman) into a cognitive map where each key concept is represented by a node and is linked to other nodes to reflect the manner in which the experts made verbal links between them in the discussion. The map is organized into a hierarchy so that concepts tend to flow upwards toward the outcomes of the scenario. An example of such a map is shown in Figure 1 to illustrate the structure of such a map. (Note that node descriptions have been blurred for reasons of business confidentiality.) Figure 2 shows a small section of a map to illustrate the types of nodes created.

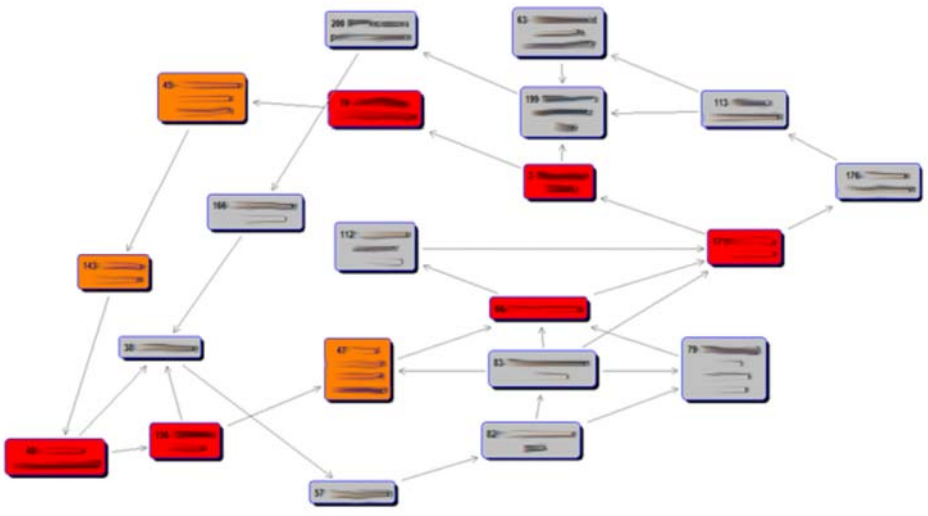

Figure 1: Sample Cognitive Map That Structures Narrative as a Series of Interconnected Nodes

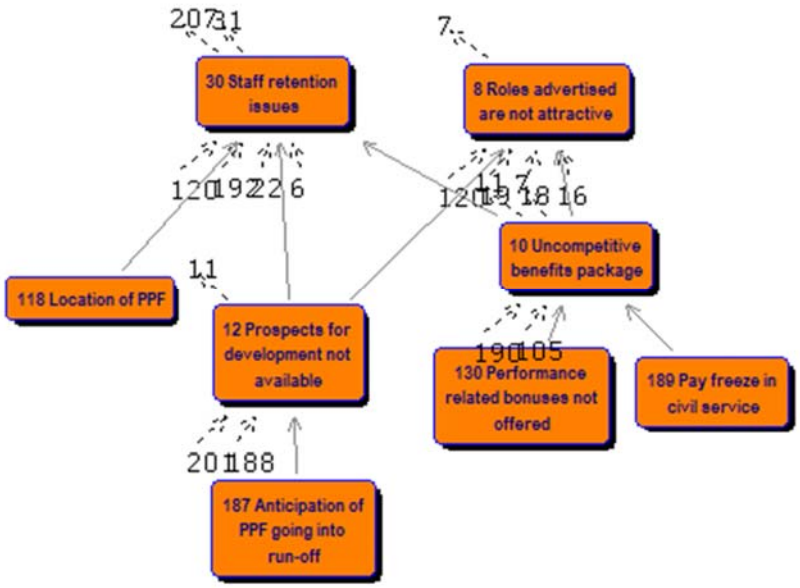

Figure 2: Extract from a Map Showing the Kinds of Relationships That Are Captured

The cognitive maps of individual discussions were combined to form an aggregate map representing the collective input of all stakeholders, shown illustratively in Figure 3.

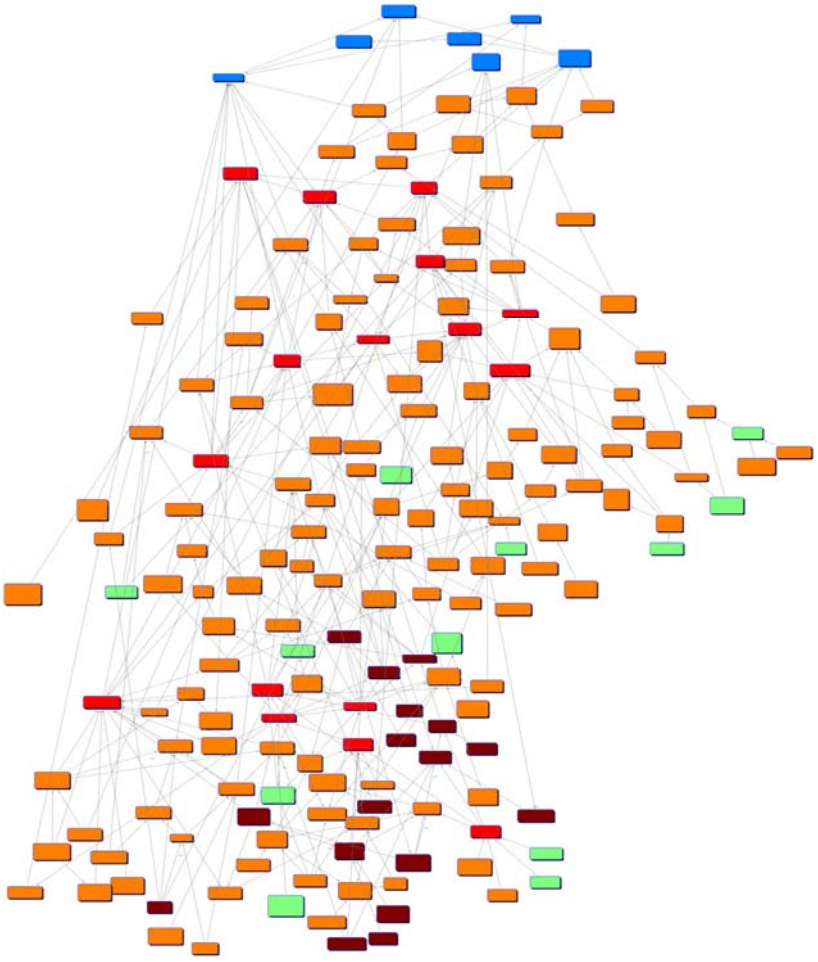

Figure 3: Aggregate Cognitive Map Combining All Stakeholder Input

The cognitive map now represents a form of system description of the PPF's strategy that shows the nonlinear interactions between relevant factors and the ways in which they combine to produce strategic outcomes.

The original narrative necessarily contains a lot of "context" that is useful but not essential to the understanding of the underlying system mechanism producing strategic outcomes. It is, therefore, helpful to reduce the summary to a "minimally complex" form that removes as much context as possible without losing the critical dynamic features that the experts have explained. This is achieved by identifying the most highly connected nodes in the map and their most common precursors. See Figure 4.

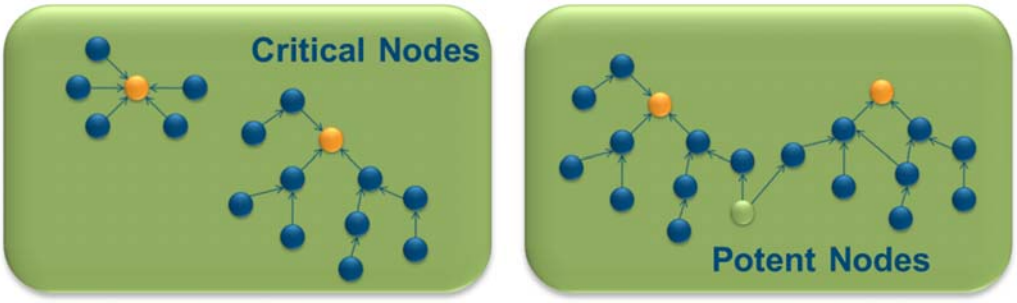

Figure 4: Critical nodes Are Highly Globally and/or Locally Connected; Potent Nodes Often Lead to Such Critical Nodes

Nodes can be important (highly connected) if they are referenced immediately by many other nodes, and if many nodes from the overall map ultimately link to them. This high level of connectivity implies that they are "critical" to the narrative of PPF's strategic dynamics because many parts of the story link to them. Identifying the "potent" nodes, which lead to a number of these "critical" nodes, captures the beginnings of dynamics, which could lead to critical behaviors unfolding. By focusing on the smaller set of critical, potent, and outcome nodes, it is possible to make the most important behaviors of PPF's strategic dynamics more visible.

It was also possible during the analysis phase to identify elements of the discussion where "leaps of logic" had occurred. These are typically areas of a story that are either less well understood, or where there was insufficient discussion during the workshop to fully capture the narrative. These points were, therefore, validated with PPF stakeholders to ensure that the full context of the narrative had been included.

3.3. Creating Scenarios

The cognitive map of the PPF's strategy was then further analyzed to elicit an understanding of the key features that reverse stress scenarios might have. Concepts were clustered into broad themes, which helped to identify the nature of developments that could lead to reverse stress situations. For example, some nodes related particularly to political considerations, others to internal operations, and others to economic considerations. Studying the dynamics in this way reveals not only the obvious "large

event" causes of reverse stress (e.g., large market falls) but also more subtle combinations of factors that, in themselves, are not obviously leading to a disastrous outcome, but that create a sensitivity to otherwise benign conditions (e.g., a series of operational processes may take paths that combine to generate sensitivity to a political event).

A series of "strategic" scenarios was then created that included different collections of the critical and potent nodes, and particularly the combinations of more subtle factors. The full cognitive map was used to provide additional context for the resulting scenarios where appropriate to make the stories easier to follow. The scenarios created at this stage did not seek to identify very specific causes of particular factors, but rather set an overall theme of how a reverse stress may have occurred.

PPF Board members were then invited to participate in a more detailed discussion of how these strategic events may actually take place and create the more granular scenarios involving features in the operational layer.

3.4. Engaging the Board

The Board was provided with six scenarios that framed a strategic-level outline of how reverse stress might occur. Members of the Board were invited to consider these and provide their thoughts about the specific manner in which such strategic trends could occur. For example, one scenario included an element described as follows:

> The PPF is unable to increase its resource level to adequately cope with the increased workload arising from the additional responsibility. In particular, the quality of the PPF's Defined Benefit scheme acceptance process deteriorates.

In this scenario, the Board discussed how this inability to increase resources might arise and the potential actions that could be taken to reduce the chances of this being the case. Through detailed discussions such as this, the Board identified specific ways in which operational or other processes may give rise to the scenario, identified mitigating actions that might be considered before, during and, after the onset of the trend, and thought about the types of indicators that may be monitored to alert the PPF to such a scenario emerging.

The key items identified in each workshop are referenced back to the existing risk management and operational management processes to identify whether opportunities for refinement exist or to confirm that such a scenario would be identified through existing measures.

In summary, the use of complexity science in developing the methodology outlined in this section helps to achieve several crucial things:

1. A complete view of the "system" that drives strategic success/failure is derived up front; this helps ensure that the scenario set is complete and covers the full range of possibilities
2. By using a "systems" view of the strategy it is possible to identify both the obvious ways in which the PPF could fail and the less obvious or more subtle ways
3. By recognizing the different layers in such a system stakeholders such as the Board can be engaged in developing detailed narratives and challenging the operational/risk processes without sacrificing coverage of the reverse stress landscape and
4. Using an operational system layer based upon a strategic system layer ensures that the scenarios are realistic, meaningful, and significant. The operational layer ensures that the outputs can be directly fed back into operating practices of the PPF.

4. Results and Conclusions

A comprehensive series of risk discussions with both internal and external stakeholders of the PPF combined with the application of advanced cognitive mapping techniques has allowed the PPF to improve its understanding of its risk universe without hiding its complexity. The cognitive map (Fig. 3) did not reveal any new risks that had not previously been identified, but it unveiled the high level of connectivity between the risks.

The cognitive mapping also showed how risks and events can conspire to create a "perfect storm" that might bring the organization down. The creation of a set of reverse stress scenarios from this analysis provided a good coverage of the PPF's risk profile.

4.1. Analysis of the Cognitive Map

The cognitive mapping exercise revealed the complexity of the risk profile of the PPF. From the transcripts of the workshops, 176 concepts or nodes were identified, and these were connected by 349 links or edges.

Table 1 shows how the concepts discussed by the subject matter experts in the workshops relate to the PPF's strategic risk areas that were described in Section 2. It shows the number of nodes per risk category as well as the number of connections between each pair of risk categories. For example, the cell intersecting the row "Reputational" and the column "Investment Operations" shows that there are four connections between these two risk categories.

Table 1

Frequency and Interconnectivity of Strategic Risk Themes

	Number of Nodes	Funding and Investment Strategy	Investment Options	Strategy/ Environmental	Legal	Operatio
Funding and Investment Strategy	21	1	3	18	3	
Investment Operations	11	3	6	13	1	
Strategy/Environmental	50	18	13	40	3	
Legal	6	3	1	3	0	
Operational	44	35	14	41	2	
Reputational	27	15	4	45	2	
Organizational Design/Culture	17	24	2	15	1	

Detailed analysis of the cognitive maps was carried out by identifying the critical nodes. These were defined in more detail in Section 3 but can be best described as the key risk drivers of the PPF because they are the most connected nodes.

Critical nodes represent risk events that are referenced by a large number of other events, and hence they are very significant in understanding the ability of the PPF to meet its objectives. In the case of the PPF, for example, where the maintenance of stakeholder confidence is key to success, these included “Reputational Damage” and “Stakeholders Lose Confidence in the PPF.” In all, there were 16 critical nodes identified on the cognitive maps. Each is directly connected to at least eight neighboring nodes and connected indirectly (within three connections) to at least 20 percent of the whole map.

For risk management purposes it is also useful to understand which are the “potent” nodes that have the most influence on the set of critical nodes. In the case of Reputational Damage, for example, the risk is an outcome that cannot itself be controlled directly; it arises as a result of other events that might be controllable. With the knowledge of all the main precursors to Reputational Damage, that is, the potent nodes connected to Reputational Damage, the organization can be better equipped to mitigate the risk of Reputational Damage by applying risk mitigation strategies to the drivers of the risk. Seventeen potent nodes were identified in total. Table 2 provides an overall summary of the PPF cognitive map and includes examples and definitions of the various features described in this paper.

Table 2

Summary of PPF Cognitive Map

Cognitive Map Feature	Definition	Number	Example
Nodes	Represent each of the ideas or concepts mentioned in the risk discussions	176	• Inappropriate people recruited • Payment mechanism failure
Edges	The link between nodes, elicited from way in which ideas/concepts were discussed in the context of one another	349	• Weak candidate selection process –> Inappropriate people recruited • Low GDP –> Economic environment worsens

Critical nodes	The drivers and mitigants that are key to describing the risk scenario, and that are identified by looking for the most connected nodes within the map	16	• Knowledge gaps • PPF deficit increases
Potent nodes	The nodes that influence the most *critical* nodes	17	• PPF staffing cuts • Increase in interest rates
Loops	Indicate connected subsets of the map that represent processes or systems that could spiral out of control or quickly reach an extreme state	>1,000	See Figure 5

4.2. Loops and Scenario Construction

Loops are subsets of the cognitive map that are cyclical: They can start and end on the same node. Of particular interest in risk management are the loops containing several critical nodes and potent nodes. Taken individually, the risk represented by any one node of the loop may not necessarily be very detrimental. But when these events are combined together they could easily spiral out of control or reach an extreme state. It is also instructive to understand the forces that generally prevent the loop from spiralling out of control because an absence of these factors could potentially lead to highly undesirable outcomes.

The cognitive map developed for the PPF's risk exposure contains more than 1,000 loops indicating there to be a high degree of complexity within the system, as defined by the workshop participants. Figure 5 represents an example of a loop, where the red boxes correspond to critical nodes and the dark red boxes to potent nodes.

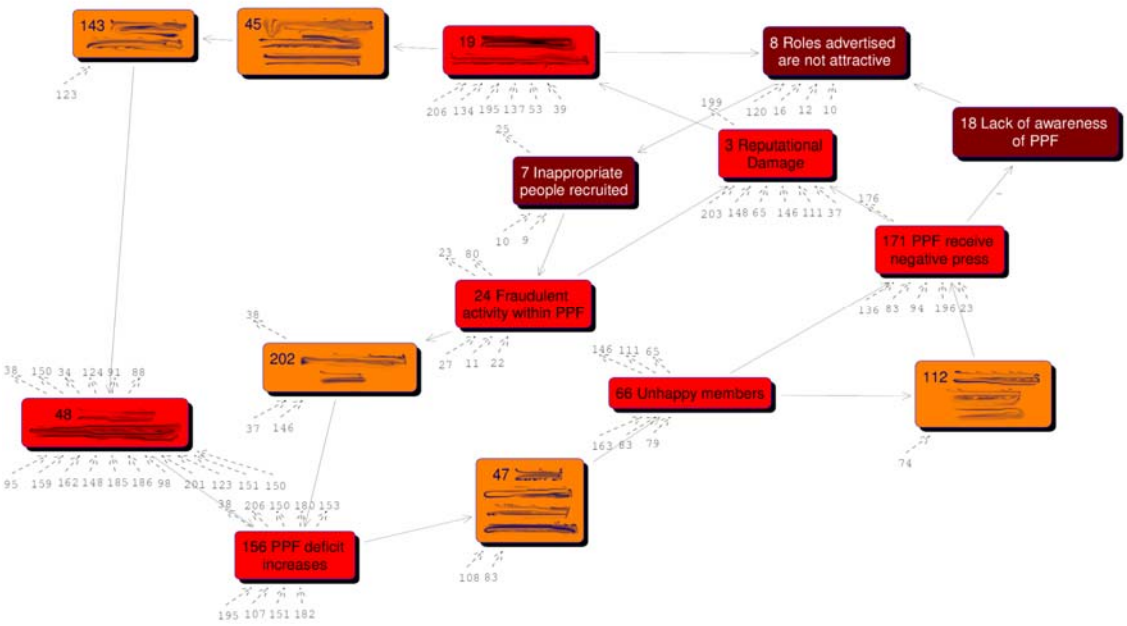

Figure 5: Example of a Loop within the Cognitive Map

The loops were used to enhance the features of some scenarios so that they might be seen to be closer to "real-life" examples of failures than, for example, simply the obvious scenario of a number of very large claims on the PPF caused by many companies with large defined benefit schemes becoming insolvent. Because of their greater complexity and realism, the six reverse stress scenarios that were derived from the cognitive analysis proved to be more engaging for members of the Board. An example of such a scenario is where operational failure spirals out of control:

> The PPF has become the subject of a concerted media campaign against it by its members, following repeated systemic errors in compensation payments on a particular type of scheme. The largest affected scheme is based in the Parliamentary constituency of the Minister of State for pensions.
>
> A system failure at the PPF's payroll provider means that all PPF members go unpaid for three months in a row. The Government Department for Work and Pensions (DWP) has recently successfully taken back managing another pension compensation scheme for which the PPF had been responsible.

The Minister decides that “enough is enough” and, after commissioning a critical independent report, decides to dissolve the PPF and take payment management and levy collection into DWP.

4.3. Conclusions

The scenarios that were derived from the analysis of the cognitive map include not only those related to specific extreme circumstances or failures to which the PPF is exposed but also scenarios in which simultaneous, or consecutive, moderate failings in a number of related areas could severely constrain the PPF’s ability to operate successfully and/or exist in its current form. These more complex scenarios contain information about more subtle trends and developments that will need to be monitored. Attention to these issues will improve the risk indicators that are monitored by the organization.

Identification and calibration of the reverse stress scenarios allows the PPF to make a quantitative assessment of the financial impacts associated with the occurrence of severe or catastrophic events. The detailed consideration of the reverse stress scenarios has also enabled the PPF to begin to identify the steps that it can take now to limit the damage that might occur should such a scenario materialize, or the plans it must put in place to be able to manage the fallout effectively. Consideration of the PPF’s key exposures will also allow the organization to enhance its existing controls and governance framework and reduce the probability of failures occurring.

The Board’s discussion and review of the scenarios identified specific areas where further work and improvement is required to better understand the PPF’s internal operations and its relationship with the wider economic and business landscape. However, looking across these areas it is possible to highlight some common themes emerging from the exercise in terms of where potential enhancements or actions can be taken to mitigate the risk of failure of the PPF. For example, one of such enhancements is that, as part of its ongoing risk management processes, the PPF is going to test multiple system failures in addition to testing the failure of each system individually.

In summary, the reverse stress test exercise using cognitive mapping techniques was a very valuable addition to the PPF’s risk management toolkit:

1. The thorough discussions with internal and external stakeholders followed by the cognitive mapping improved the understanding of the PPF’s risk profile by

showing how the risks were connected. This knowledge in turn allowed a more accurate assessment of the impact of each risk as well as the effectiveness of the controls.

2. The visibility of dynamics in the cognitive map is extremely useful for developing reverse stress scenarios that are at the same time complex and realistic. The analysis of the scenarios and the Board discussion will lead to actions that will improve controls and understanding on how the PPF might deal with crises that may occur in "real life."

Reverse stress testing and the application of cognitive mapping techniques is a useful risk management tool for any organization. It allows a thorough review of the risk profile of the organization for the following reasons:

1. It helps ensure that all risks are identified.
2. It improves the assessment of the impact of the various risks allowing for their interconnections.
3. Often external stakeholders are key to whether or not an organization is viable. To construct a realistic cognitive map, it is essential to engage with external stakeholders. This can provide valuable insight and may be overlooked in standard risk management processes.
4. Because of the cognitive mapping that explores the connections between all the risks, it upgrades a risk register from a simple list of risks assessed on a stand-alone basis to a true ERM tool that takes into account all the risks with their interrelations.
5. The analysis of reverse stress scenarios obtained from a cognitive map can help organizations understand how they would respond to realistic scenarios of crisis and identify where risk controls could be improved.

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