Water Research, Volume 74, 1 May 2015, pp. 213–226
DOI:10.1016/j.watres.2015.02.021

Assessing interdependent operational, tactical and strategic risks for improved utility master plans

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Abstract

Risk management plays a key role in water utilities. Although risk tools are well-established at operational levels, approaches at the strategic level are rarely informed by systemic assessments of the water supply and lack a long-term perspective. Here, we report a baseline strategic risk analysis, founded on a systemic analysis of operational risks developed 'bottom-up' and validated in a large water utility. Deploying an action-oriented research method, supported by semi structured interviews with in-house water utility risk experts, deep connections are established between operational risk and strategic risk that surpass those existing elsewhere in the sector. Accessible presentational formats - influence diagrams, risk "heat-maps" and supporting narratives are used to promote Board-level risk discussions, and characterise a baseline set of strategic risks core to forward utility master planning. Uniquely, the influence of operational events, exposures and potential harms, together with the mitigating measures in place to mediate these risks are linked to corporate objectives on business sustainability, profitability, water quality, water quantity, supply disruption and reputation.

Keywords: Strategic risk analysis, interdependent risks, cognitive mapping, master planning

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1. Introduction

Managing risk well is a key competency for water utilities, and many utilities have established risk manager roles to coordinate their efforts (MacGillivray *et al*., 2006; Hrudey *et al.*, 2006). An essential requirement for utilities is to develop a preventative and anticipatory approach to risk and opportunity that ensures they are resilient to threats, whilst equally alive to opportunities (Pollard *et al.*, 2013). In practice, this means developing an organisational capability to connect operational activities to utility-wide risk management programmes; to understand the impact of risk on a utility's corporate priorities; and then forecast future risks into the mid- and long term so stakeholders can be confident in the master plans designed to manage risk over the planning cycle. A growing research agenda has developed around this need (MacGillivray and Pollard, 2008; Schiller and Prpich, 2013; Allan *et al.*, 2013); one that straddles the engineering, decision and social sciences in the context of water utility management.

One observation we have is that engineering and asset risk analyses, including the human dimensions of managing risk (Wu *et al.*, 2009), rarely appear to inform strategic risk management activity directly. Often, operational and strategic risk analyses are performed in isolation of one another for a host of reasons (e.g. the engineering versus a managerial focus), and there is rarely a truly systemic approach to assessing the water supply system. What can then occur is a potential disconnect between the view of strategic risk and the operational reality of risks in the business. In seeking to address this deficiency, our research interest here is in how a systemic analysis of risk can inform the corporate priorities set by a utility now (in a baseline assessment) and then, by projecting risks forward in time, for decades to come - linking a utility's thinking on risk *and* futures, as expressed by their master plans. Can we better align operational and strategic risk to improve insight at the top of a utility, and then better inform long-term master planning?

Analytically, assessing the interdependencies between operational, tactical and strategic risk, and then projecting risks forward in time, is not straightforward and requires applied research to investigate how it can be achieved in a meaningful way that adds business value. Intellectual contributions to this agenda are coming from the risk sciences (Lindhe *et al.*, 2009), from the environmental assessment and water planning communities (Kumar *et al.*, 2013) and from specialists in regulation and governance (Pegram *et al.*, 2009). The broader goal of our research efforts over the last 10 years has been to improve the maturity of the water sector's capabilities in risk governance; a principal motivation being to build stakeholder confidence in the sector's capacity to manage the substantive changes it faces in the short-, medium - and long-term. These include (i) dealing with multiple dimensions of risk and multidisciplinary knowledge; (ii) managing tightly coupled risk interdependencies; (iii) the pressing need for better cross-departmental communication on risk across business 'silos'; and (iv) accepting high degrees of unresolvable decision uncertainty, due to the spatial and temporal variability of many utility risks.

Here then, we present a novel approach to support strategic risk management in water utilities that employs a 'bottom-up' analysis, involves all levels of the organisation and that addresses interdependent risks in a systemic fashion. The research tool was developed and tested in EPAL – Empresa Portuguesa das Águas Livres, the largest and oldest water supply company in Portugal. We believe it has wide applicability across public, private and corporatized water utilities, and for asset rich organisations more broadly.

2 Material and methods

Our research deployed an action-oriented research framework (Coghlan and Brannick, 2005) and a combination of methods, including (i) brainstorming (International Standards Organisation, 2009); (ii) observation, conversation, interviews and document analysis to generate qualitative data (Robson, 2002); (iii) cognitive mapping (Waal and Ritchey,

2007); (iv) semi-quantitative risk assessments (Pollard *et al.*, 2004a; MacGillivray and Pollard, 2008); and (v) the development of risk visualisation tools (Prpich *et al.*, 2013). This framework was deemed essential because of the need to process authentic risk data in a live decision context, using EPAL as the case-study. Founded in 1868, EPAL supplies wholesale quality water to approximately three million people (more than one-quarter of the Portuguese population), as well as retail water to approximately 500 thousand inhabitants in the city of Lisbon. With approximately 700 staff, EPAL has assets with a net fixed value of around 900 million EUR and has been generating profits of around 40 million EUR. Over recent years, structured risk management practices have been adopted at operational and tactical levels of decision-making at EPAL (e.g. health and safety procedures, water safety planning, capital investment planning, reliability centred maintenance), but an integrated approach for managing risks at the strategic level has been lacking.

The team involved in this research encompassed a risk co-ordinator, the management Board (n=3), senior risk managers (n=14) and technical domain risk experts (n=24). Senior risk managers were 'Heads' of the following departments at EPAL: asset management, planning and control, finance, customer relations, human resources, infrastructure maintenance, operations, water quality control, supply chain management, legal compliance, design and works, information systems, general secretariat, and organisational development. External researchers from Cranfield University (n=5) had a discrete participation in the project, moderating group discussions in a one-day workshop.

2.1 'Top-down' and 'bottom-up' approach

We employed a 'top-down' / 'bottom-up' approach to assess strategic risks, as depicted in Figure 1.

Figure 1 The "top-down" / "bottom-up" approach interconnecting operational and strategic risks

The process was initiated at a strategic level, with the identification of EPAL's corporate objectives by the Board; it then cascaded down to tactical and operational levels, where risk managers and individual risk experts performed a systemic analysis of strategic risks; and finally, it escalated up to the strategic level again, for the assessment of the results by the Board.

2.2 Corporate objectives identification

EPAL's corporate objectives were identified in a Board meeting. Translating organisational values into corporate objectives is often not consensual, so a preliminary clarification of basic concepts was made, by distinguishing *means objectives* from corresponding *fundamental objectives* and from *corporate, strategic objectives*; the latter defined as the utility decision makers' core objectives running through all utility decisions (Keeney, 1992).

2.3 Systemic analysis of strategic risk

Since strategic risks are those that express a likelihood and consequence of not meeting the corporate objectives of a utility, the model to assess strategic risks was based on the steps presented in Table 1.

Table 1: Actions to build systemic model of strategic risks.

2.3.1 Preliminary risk screening and securing buy-in

A workshop was held with the participation of risk managers, where the research project was explained and their role emphasized, thus contributing to securing their buy-in. Moreover, risk brainstorming was used to collect a broad set of ideas and a preliminary risk screening. The question posed was: "what do you consider to be the strategic risks of EPAL?"

2.3.2 Preliminary influence diagram

Responses from the brainstorming exercise were sorted into categories related to each corporate objective, and pathways that characterised threats to these were drafted by the risk co-ordinator; incorporating *events* (definable root cause activities by time and place), *exposures* (resulting from progressive challenge from one or more events) and *harms* (actual impacts, effects or consequences that result from one or more exposures; Gormley *et al.*, 2011). This exercise illustrated the interdependence of risks – individual risks impact on more than one corporate objective, may cascade from one another, sometimes with positive feedback. These interactions were represented graphically, with causal factors and preventative barriers (the risk management measures in place to mitigate against the causation) identified. To better characterise each of the components of the influence diagram, a complementary database was created, registering all relevant information associated with each event, exposure and harm. The barriers in place along each pathway were pre-identified by the risk co-ordinator and the schema completed with inputs from supporting research studies related to one or more of the strategic risks (e.g. possible contamination of the main supply reservoir due to landslide in Panasqueira mine; seismic vulnerability of water tanks; reports from the pipe bursts' research group; water quality modelling in the distribution network; risk based water safety and capital investment plans; etc.).

2.3.3 Pre-definition of the scales to assess likelihood and consequences' magnitude

Semi-quantitative scales were employed, regarded as defensible given the multidimensional nature of these risks (Altenbach, 1995; Andrews *et al.*, 2003; Food and Agriculture Organisation and World Health Organisation, 2009). A logarithmic scale was used to characterise the likelihood of an EPAL-specific consequence occurring in the following 18 months (starting in 2012), consistent with similar scales employed elsewhere for strategic risk appraisal (Food and Agriculture Organisation and World Health Organisation, 2009; International Standards Organisation, 2009). Definition of the consequences scale requires value judgements specific to the organisation (Keeney, 1992; Renn, 2008). Moreover, choosing a set of consequence attributes that comprehensively describes impacts whilst keeping the list of impacts concise enough to be understood constitutes a major challenge (Willis *et al*., 2004; Pollard *et al.*, 2004b; Prpich *et al*., 2011). In this work, consequences were described by their type, extension (magnitude) and duration (including irreversibility) – "TED". Thresholds for these classes of consequence were defined, taking into account plausible worse case situations. Taking the reliability of supply as example, we asked: "what would be the worst case of a critical infrastructure failure? Could it be considered 'catastrophic'?" We also considered the reaction time, or the so called risk 'clock speed' (Caldwell, 2012) – for example, the threshold of six months for the consequences of not having enough water to supply took into account the estimated time to implement new abstractions or transfers from other water sources or transport systems. Finally, we considered the significance across all consequence categories. Two options were analysed: (i) classifying all consequences on a Likert scale of 1 to 5 (Likert, 1932) and then ranking the relative (pairwise) importance of the objectives, assigning weights and recalculating the value of each class; and (ii) reflecting the relative significance

of consequences on a matrix or risk "heat-map", constructing a narrative for each strategic risk (Prpich *et al.*, 2013). The second approach was adopted, since it is easier for decision-makers to understand.

2.3.4 Meetings with risk managers

Having completed the preliminary influence diagram as well as the preliminary definition of the likelihood and consequences' scales, a series of 14 meetings was convened with each of the risk managers at EPAL, in order to elicit their feedback. Risk managers were asked to appoint the risk experts in their teams that could provide more detailed information about the events, exposures, harms and the barriers along the pathways.

2.3.5 Meetings with risk experts

Following individual semi-structured interviews (n=12, *ca.* 2 hr. duration) with risk experts, the influence diagram was progressively enhanced, adding (and sometimes removing) events, exposures and harms and their respective interactions and control barriers. Experts were asked to evaluate the likelihood of the events, exposures and harms to strategic risks, drawing on the conclusions of existing studies at EPAL and on empirical knowledge (Wall and Ritchey, 2007). For example, the likelihood of occurrence of a severe drought was informed by a comprehensive study regarding climate change scenarios, impacts and adaptation, elaborated by four Portuguese universities for the water supply system of EPAL. Experts' comments and discussions were recorded in the database (Table 2).

Table 2 Extract of influence diagram supporting database

2.3.6 Triangulation of the results and evaluation of the consequences of harms

Triangulation of the interview results involved analysing all the information compiled during the interviews and by identifying inconsistencies and gaps. The principal factors contributing to inconsistencies were either an incomplete understanding of the risks being analysed or of the supporting arguments for its characterisation. These conflicts were resolved by a second-round of selected interviews with risk experts.

Having stabilized the influence diagram and classification of the likelihood of events, exposures and harms, the risk co-ordinator assessed the consequences of harms, thus allowing the comparison of strategic risks in a "heat-map". These were represented by ellipses, where the length of the axes provides an indication of a mix of aleatory (due to the natural variability of the events) and epistemic (due to lacks in knowledge) uncertainties around the likelihood and consequences estimation (e.g. regulatory uncertainty, demand uncertainty). Decision uncertainties were recorded in the database according to the following criteria (adapted from Gormley *et al.*, 2011):

- "Low" – there is empirical or scientific evidence;
- "Medium" – there is no empirical or scientific evidence, but there is a high level of agreement among experts;
- "High" – there is no empirical or scientific evidence and there is a low level of agreement among experts.

2.3.7 Validation workshop

Validation of the influence diagram and risks evaluation was achieved in a one-day workshop where groups of 8 to 10 people were formed, integrating the relevant risk managers and experts from different departments related to each of the strategic risks, as well as members of the research team, who facilitated the discussion. Some minor

adjustments were proposed, such as renaming some of the events, exposures and harms to secure consistency, as well as their descriptions in the database records. Furthermore, risk managers and experts were asked to evaluate the strength of the existing control barriers. The following questions were raised (a) has the analysis missed any existing barriers? If so, where?; (b) how effective are existing barriers at mitigating risk to EPAL's corporate objectives?; (c) which barrier(s) are most critical?; (d) which barrier(s) are most vulnerable, irrespective of their effectiveness?; (e) should there be additional barriers in the system?

2.3.8 Elaboration of final presentational documents

The outcomes of the workshop enabled the risk co-ordinator to prepare the final documents for the Board, namely (i) the influence diagram and corresponding database; (ii) the risk "heat-map"; and (iii) one narrative per each strategic risk – a two-page document synthesising all the relevant information that led to the evaluation of the risk.

3 Results

3.1 General overview

The overall result of this research is the development and validation of a novel holistic approach to assess risks at the strategic level, as expressed in Figure 1. The outcomes include identification of six corporate objectives; the design of an influence diagram incorporating 29 events, 20 exposures and 12 harms to those objectives; the identification of 43 barriers along the pathways to risk; a supporting database with 66 records containing relevant information about the components of the influence diagram; and the elaboration of a "heat-map" to allow the comparison of the strategic risks' evaluation, complemented by a narrative per each risk.

3.2 Corporate objectives identification

In line with the financial, regulatory, physical and reputational water risks drawn from Orr *et al.* (2011), Morrison *et al.* (2010) and Levinson *et al.* (2008), corporate objectives for EPAL were to guarantee: 'business sustainability', 'business profitability', 'adequate water quantity', 'adequate water quality', 'reliability of supply' and 'reputation and trust', thus meeting the expectations of customers, shareholders and the regulator.

3.3 Systemic analysis of strategic risk

3.3.1 Likelihood and consequences' scales

The likelihood scale was defined in terms of occurrence / no. years, which fitted well given the type of events related to the strategic risks – Table 3.

Table 3: Likelihood scale.

The consequence scale is presented in Table 4, evidencing the corporate objectives' values hierarchy (Vlek, 2013). For example, compromising "reputation and trust" as well as "business profitability" do not present "catastrophic" consequences when compared to the other objectives.

Table 4: EPAL-specific consequences' scale

3.3.2 Systemic model – influence diagram

Figure 2 shows the influence diagram for EPAL's strategic risks, coloured according to the likelihood of events, exposures and harm.

Figure 2 Influence diagram for EPAL's strategic risks, coloured according to the likelihood of events, exposures and harms

The vertical bars spanning all strategic risks, prior to the remaining events, refer to low likelihood / high consequence events (earthquakes, tornados, flooding and terrorism). These present specific challenges, because through cascade effects, they may affect all corporate objectives. They are often conceptually plausible but unpredictable (Cox, 2012; Renn, 2008) and their consequences may be '*catastrophic and more devastating than envisaged*' (Vlek, 2013). There are few control barriers robust enough to completely prevent exposures emanating from these events, thus risk management strategies differ from those for non-catastrophic events (Klinke and Renn, 2002), being addressed by contingency plans to assure business continuity (HM Treasury, 2004; Pollard *et al.*, 2004b). Given the wealth of information contained in the diagram, it constitutes a powerful tool for analysis, as described in section 4.2, and it may be considered the main outcome of this research.

3.3.3 Identification and characterization of barriers

An important cognitive outcome of the workshop was the identification of existing barriers that were missing in the diagram, as well as the comprehensive characterisation of the barriers in terms of their efficacy, vulnerability and criticality. The results were recorded in the database, allowing management practices and its relationship with strategic risks to be evaluated (Figure 3).

Figure 3 Example of queries in the database supporting the systemic model, using the filtering function to highlight: (on the left) the critical barriers with maximal vulnerability and varying efficacy; and (on the right) the critical barriers which are most effective and less vulnerable

3.3.4 Evaluation of likelihood and consequence of risks

Assessing a likelihood for each of the events, exposures and harms was captured in the semi-structured interviews with risk experts, the result conditional on the outcome of earlier steps in the diagram (Wall and Ritchey, 2007; Gormley *et al.*, 2011) taking into consideration the efficacy of existing barriers (Pollino and Hart, 2008). Moreover, the efficacy of existing barriers may be subject to factors (Hokstad and Steiro, 2006) as discussed in section 4.2.5. The contributing factors identified in this research as well as the respective likelihood of occurrence (using the scale presented in Table 3) are indicated in Figure 4.

Figure 4 Risk contributory factors' likelihood

The "heat-map" presented in Figure 5 resulted from the evaluation of the likelihood and consequence of the risks.

Figure 5 "Heat-map" of EPAL's strategic risks

3.3.5 Strategic risk assessment

A suite of risk schematics enabled rich discussions on risk management with the Board. These included (i) the influence diagram, with and without the control barriers in place, providing the opportunity to emphasise their importance; (ii) the influence diagram coloured green, amber and red, reflecting the likelihood of the events, exposures and harms (Figure 2); and (iii) the "heat-map" (Figure 5). Supporting these visuals was a

comprehensive set of information in a database (allowing the production of individual forms; Figure 6), summarised as a narrative for each of the risks on the ”heat-map”.

Figure 6 Influence diagram supporting database: example of an individual form

4 Discussion

4.1 Connecting operational, tactical and strategic risk

Relationships between operational, tactical and strategic risk tend to be disjointed and interfaces between these risk types poorly informed (Strategy Unit, 2002; Allan *et al.*, 2013). Many of the existing risk based approaches are developed at tactical (e.g. asset management) and operational levels (e.g. water safety plans) only, not reaching the strategic level (Wijnia and Herder, 2009). Conversely, many strategic risk assessments are supported by external advisors who elicit risk appraisals from internal audiences, resulting in cursory analyses coordinated by the external party alone, often in isolation of deep organisational knowledge.

The significance of the “top-down” / “bottom-up” approach employed in this research is clear. Although the need to interconnect risk management at the three different levels has been acknowledged (Pollard *et al.*, 2004a), practical illustrations of how this can be achieved are scarce. Here, the “top-down” process initiated with the identification of the corporate objectives of the company. This should be made prior to the discussions with risk experts, providing a focus for the analysis (Keeney, 1992). Following Frigo and Anderson (2011), we considered strategic risks as those preventing an organization from achieving its corporate objectives. Drawing on decision theory (Keeney, 1992), we also refer to ‘strategic, corporate objective’ – a decision maker’s ultimate end objective, which should be stable over years, as providing common guidance to all decisions; and

distinguished this from a ‘fundamental objective’ - an essential reason for interest in the decision situation; and from a ‘means objective’ - a means to achieve the fundamental objectives. This is an important distinction because the semantics of the term ‘strategic’ quickly give way to different interpretations, such as ‘critical for the business mission’ or ‘critical for accomplishing the strategies in place’, even though ‘strategic risks’ and ‘risks to the strategy’ do not have the same meaning. Next, the process progressed with the identification and structuring of the fundamental objectives: “what are the immediate causes for guaranteeing this strategic objective?” (Keeney, 1992; Waal and Ritchey, 2007). We then combined the methods for structuring objectives with those for constructing influence diagrams to develop a systemic model incorporating the events, exposures and harms to those corporate objectives, where “harms” are associated with the consequences of failing to meet the fundamental objectives. Despite the fact that identifying and structuring objectives is focused on those objectives to be attained, and the influence diagram is focused on what can happen that poses a threat to these objectives, both methods involve the identification of causal relationships and so can be combined to form a holistic model of strategic risks; understood here as the risk of not meeting the objectives. Building the systemic model was an iterative process, moving back and forward until it was stabilized. This process was primarily informed by risk experts and risk managers and was complemented with an identification of the existing control barriers along the pathways from the events to harms and with the characterization of the barrier effectiveness, criticality and vulnerability.

The process then addressed the strategic level again, through the evaluation of likelihood and consequence of the risks. While the analysis of the likelihood associated with the events, exposures and harms was based on existing studies and on operational knowledge of the system (including the effectiveness of the existing barriers and the results

374 of risk analyses held for specific business functions), the consequence scale reflected the
375 strategic character of the assessment. Two main insights arose from this observation.
376 Firstly, the consequence scale constitutes a critical issue in the linkage between strategic
377 and operational levels, because "harms" may be realised several times without affecting
378 strategic risks at all. For example, pipe bursts happen every week in the city of Lisbon, but
379 that does not compromise the objective "reliability of supply" from a strategic point of view
380 – where consequences are expected to be much higher. Secondly, we turn to the
381 controversial issue raised by MacGillivray and Pollard (2008), regarding whether risk
382 analysis should be viewed as an over-arching discipline, normalised across the organization
383 to fit a common format as advocated by the Enterprise Risk Management (ERM) concept,
384 or, instead be function-specific, fit for purpose. The approach here represents a high-level,
385 overarching risk analysis methodology, in the sense that it spans across all corporate
386 objectives. However, it does not claim to replace function-specific approaches (e.g.
387 engineering; drinking water quality management; asset management; emergency
388 management; occupational health and safety; financial analysis) that should be held at
389 operational or tactical levels, but rather to evaluate their outcomes at a higher, strategic
390 level of analysis.

391 Implementing this process, engaging both the Board and risk experts, building the
392 systemic model with identification and characterization of the existing barriers along the
393 pathway and developing an appropriate scale of consequences for the strategic level to
394 guide the risk assessment, can be considered key to addressing the challenge of connecting
395 strategic with tactical and operational levels of risk management, demonstrating how a
396 'golden thread' connecting operational and strategic risk in organisations may be achieved.
397 To our knowledge, no such approach has been implemented before.
398

4.2 The power of cognitive mapping

4.2.1 Capturing risks interdependencies

At the strategic level, risks are best assessed across a whole system (International Standards Organisation, 2009). However, strategic risks have been appraised in isolation, leading to a growing recognition of the need to integrate and harmonize these analyses (Means *et al*., 2010; Hamilton *et al.*, 2006; Renn, 2008; Larson *et al.*, 2009; International Standards Organisation, 2009; Prpich *et al*., 2011). Attempts to relate physical or environmental risks like water quality, supply and resource have existed for over a decade (Bouwer, 2000; Hamilton *et al.*, 2006; Pollard *et al.*, 2004b; Powers *et al.*, 2012), but a step change is still required to further integrate physical water risks with regulatory, financial and reputational risks (Frigo and Anderson, 2012). Despite the limited scientific literature on these water risks as a corporate concept (Orr *et al.*, 2011), the ERM concept is gaining popularity (Hoffman, 2008) even though its practical implementation presents some weaknesses, as it does not take into account that most risks are interdependent (Schiller and Prpich, 2013; Caldwell, 2012).

Recent developments in the COSO framework point out that "understanding risk interactions and then managing them requires breaking down 'silos'" (Curtis and Carey, 2012). These authors suggest "a simple way to consider risk interactions is to group related risks into a broad risk area […] and then […] three explicit ways to capture risk interactions […] are risk interaction maps, correlation matrices, and bow-tie diagrams". When applied to a broad risk area, typically in the field of engineering, these methods are effective ways to capture interactions between events, allowing the implementation of detailed probabilistic (quantitative) risk assessments (Lindhe *et al.*, 2009; 2012). However, at corporate level, interactions occur between several "broad risk areas", including the ones related to business and reputational risks, making the application of these techniques

difficult for the global analysis. Our systemic model, where interactions between physical, financial and reputational risks are captured and analysed using semi-quantitative methods addresses this challenge. For example, 'inadequate long-term planning' was found to influence business sustainability (leading to poor resource allocation), business profitability (by making it difficult to secure returns on investments in case of asset overcapacity), water quality (in case of asset overcapacity) and water quantity (in case of asset under capacity). It should be noted that the semi-quantitative methods used in the approach allow the incorporation of fully quantitative risk assessments (e.g. those associated to the estimation of critical infrastructures' failure).

4.2.2 Establishing a multi-barrier approach

Capturing the interactions between risks and establishing a multi-barrier approach to risk management is a tenet of good utility management in the water sector, since incidents are frequently characterised by multi-causality and interdependence in their effects (Pollard *et al.*, 2013; Hrudey and Hrudey, 2004). However, multi-barrier approaches are usually developed at operational levels and, to our knowledge, no such approach has been developed before at corporate level. Existing methodologies, like COSO (2004), seek to identify controls for risk reduction, but these are appraised in isolation, not taking into account risks interdependencies. Here, we identify existing control barriers and interdependencies expressed in the influence diagram. A deep characterization of these barriers was deemed essential, because keeping them robust is the essence of risk management (Carter, 2012). In this research, besides characterizing the control barriers in terms of their effectiveness and criticality (MacGillivray and Pollard, 2008), we also described them with respect to their vulnerability, because this constitutes a powerful input

448 to devise risk management strategies and priorities, supporting decisions from risk
449 managers and the Board about which barriers should be reinforced, maintained and relaxed.
450
451 **4.2.3 Generating corporate knowledge for risk management**
452 Though initially developed with the purpose of recording the outputs of the semi-
453 structured interviews, the database constitutes a powerful tool for risk management,
454 because it allows (i) the registering of the different inputs; (ii) the detection of
455 inconsistencies between experts' views; (iii) the statistical analysis of the control barriers
456 (e.g. which barrier is the most frequent?); and (iv) the automatic production of records for
457 each of the events, exposures and harms of the diagram (n=66). Ultimately, the database
458 enables the generation of traceable corporate knowledge. For example, querying the
459 supporting database (Figure 3) shows a number of critical barriers at EPAL that are not
460 performing at their highest efficiency and that are highly vulnerable, such as increasing the
461 water supply system flexibility, having readily available alternatives in case of a failure in
462 the supply of chemicals and other materials, having robust contingency plans, etc.,
463 suggesting that management strategies should address these issues. Additionally, Figure 3
464 shows that keeping a good relationship with the media, maintaining the robustness of online
465 monitoring (SCADA) and keeping water treatment plants efficient are the most effective,
466 critical and less vulnerable barriers.
467
468 **4.2.4 The stable model enabling a dynamic appraisal**
469 By reference to existing methodologies, Vlek (2013) pointed out the need for a
470 transactional model, where risks are not appraised in a static way, but in dynamic relation to
471 internal controls. Our approach meets Vlek's call for such a model, because though the
472 influence diagram should remain stable for many years – since corporate objectives are set

for the long term – the systematic revisiting of existing barriers provides the dynamism, countering complacency which is one of the major causes of incidents (MacGillivray and Pollard, 2008; Carter, 2012). We suggest that the influence diagram should be revised with the same frequency as that of the utility master plan (in EPAL: every 10 years), whereas the efficacy, vulnerability and criticality of the barriers should be challenged within a one to three year period. We highlight that the influence diagram enables the process to be transparent and repeatable under the same basis of analysis, which is a proxy for its credibility (Wiedemann *et al.*, 2013; Food and Agriculture Organisation and World Health Organisation, 2009; International Standards Organisation, 2009; Hokstad and Steiro, 2006).

4.2.5 Informing the likelihood estimation of strategic risks

The influence diagram plays an important role in estimating the likelihood of strategic risks. Firstly, the causality between events, exposures and harms, as well as the characterization of existing barriers and the factors that inform the likelihood of risks, differs from existing strategic risk frameworks that focus on the likelihood of harms regardless of the underlying processes, impeding risk reduction measures being targeted at their root causes (MacGillivray and Pollard, 2008). Secondly, a visualisation of the influence diagram (Figure 2) allows an intuitive distinction between risks with a natural low likelihood – e.g. "Water Quantity" – and those where the likelihood is low due to the maintenance of control barriers – e.g. "Water Quality". This is an important observation, because focusing only on the likelihood of risks in isolation of why they are low, might lead the Board to pay less attention to the maintenance of barriers.

We also highlight the inclusion of risk factors in the analysis, i.e. contributing factors that may alter the respective likelihood (Hokstad and Steiro, 2006; International Standards Organisation, 2009). Whilst not novel, the fact these were assessed separately

from the events, exposures and harms represents a different approach from ERM frameworks, which allow for secondary risks to be added directly in the analysis. In fact, rather than being considered as initiating events that pose harm to strategic risks, these factors act as "meta-risks", affecting the robustness of existing barriers and, consequently, the likelihood of events, exposures and harms. For example, in this research keeping abreast of asset management best practice might be viewed as a highly vulnerable barrier influenced by "poor human resources management", given that 200 out of the 700 employees (approximately) of EPAL are aged 55 or more, thus being expected to retire within the next ten years. No transmission of knowledge to new employees is foreseen, due to legislative measures that impede state owned companies recruiting new staff. This could have an adverse impact on diverse exposures and harms to strategic risks (Wu *et al.*, 2009).

4.2.6 A natural starting point for discussion with the Board

A further strength of the influence diagram is that it constitutes a natural starting point for discussions between the Board and risk managers. Ultimately, the influence diagram is used to inform a Board, who are not expected to perform a detailed analysis of enterprise risk, but rather to oversee what drives strategic risk and ensure these drivers are managed, which is often the most challenging and important aspect of oversight (Caldwell, 2012).

4.3 "Heat-map" as a basis for discussion

Despite the strengths of the influence diagram, it does not show the consequences associated to risks. Hence, there is still a need to construct a "heat-map", presenting the evaluation of likelihood and impact of each strategic risk, which, in this research, was depicted by the central position of an ellipse, where the length of the vertical and horizontal

axes reflect a mix of aleatory and epistemic uncertainty of the respective assessment. We avoided the use of risk matrices where risk would be tightly classified as 'high', 'medium', 'low' or similar, because of the variety of data and the respective range of uncertainty the nature of this analysis embodies (Cox, 2008). Instead, the 'heat-map' is offered as a high-level risk diagram that enables a Board to compare the relative positioning and size of the risk ellipses, and to promote discussion, supported by narratives on the character of the risk and the effectiveness of current risk management strategies (Prpich e*t al.*, 2013). Of course, beneath each risk ellipse there is a golden tread of data and information resulting from an analytic-deliberative approach that encompasses a synthesis of scientific expertise and value orientations (Klink and Renn, 2002; Willis *et al.*, 2010).

4.4 Deliberative approach, enhancing organizational risk culture and avoiding bias

Both in risk management and in futures' planning, the process through which decisions are achieved is as important as the strategies themselves (Wack, 1985 in Brummell and Greg MacGillivray, 2008; Koivisto *et al.*, 2009). Although these two aspects overlap, the framework developed in this research provides a holistic, systematic way to manage strategic risks, and the process affords a transparent and structured means to engage diverse expert and stakeholder perspectives in judging the implications of risk information (Powers *et al.*, 2012). This research employed an action-oriented approach, involving various levels of the organization (Coghlan and Brannick, 2005) because the setting of corporate objectives suggested almost every department at EPAL should be involved in the analysis. The value of conducting this in 'testing mode', unfolds in various ways.

First, it requires high levels of engagement among the researcher's colleagues which, despite being hugely challenging to undertake (Coghlan and Brannick, 2005),

548 contributes to raising risk management awareness and pervasiveness in the company (Allan
549 *et al.*, 2013). This research confirmed that the involvement of the Board from the
550 beginning, as well as the knowledge the researcher had of the organization – two of the
551 key-drivers for successful ERM implementation (Frigo and Anderson, 2011) – proved
552 pivotal to securing the necessary commitment from risk experts and to implementing the
553 methodology, promoting dialogue and making adjustments when necessary.

554 Secondly, this approach allowed the unveiling of tacit risk knowledge, alongside
555 formal codified information, contributing to knowledge generation. Stakeholder
556 consultation is a golden opportunity, forming one of the key outputs of the risks and futures
557 approaches involving people networking, where the developed knowledge is more than the
558 sum of its elements (Koivisto *et al.*, 2009). Furthermore, by engaging a wide range of
559 Departmental managers, this process contributes to breaking down 'silos', which are crucial
560 to implementing risk management in organizations (MacGillivray and Pollard, 2008;
561 Summerill *et al.*, 2010; Allan *et al.*, 2013). The EPAL case-study showed this process
562 helped unifying the assumptions about the performance of the system across the different
563 departments, including the destroying of some myths. For example, it was thought that the
564 two free-surface flow trunk mains presented a very high likelihood of contamination, but
565 the investigation carried out by the water quality risk experts under this research showed
566 that the number of water quality non-compliances with legal requirements over recent years
567 was negligible on these trunk mains.

568 Finally, the approach can provide high levels of political confidence that there is a
569 firm understanding (and active management) of strategic risk within the company, now and
570 for the future. This said, the action research approach may lead to some bias, as well.
571 Maxwell (2009) calls attention to the fact that despite the inherent advantages, bringing the
572 experience and knowledge of the researcher into the research may lead to distortions in the

methods and in the interpreting of the results. On the other hand, there is also the possibility for cognitive bias in the assessment of causal chains, barriers and their effectiveness by risk experts and managers, either by failing to recall relevant events, by misperceiving causal chains (Vlek, 2013) or even by exaggerating or underplaying the likelihood and consequences evaluation (Slovic, 1998; Renn, 2008). Furthermore, 'group think' (as it happened in the validation workshop) may cause less vocal participants to be dominated by opinionated leaders (Vlek, 2013; Powers *et al.*, 2012) and while individual interviews reflect consistent and coherent opinions (even if deliberately exaggerated), the need to reach consensus in a group may cause opinions to become incoherent (Cox, 2012).

In this methodology, the researcher adopted a "critical subjectivity" attitude (Reason, 1988 in Maxwell, 2009), i.e., an awareness in which her primary experience was not suppressed nor allowed to overwhelm the research, but rather seen as raising consciousness and used as part of the process. Given the interactions among strategic risks, experts from different departments critically analysed the same risks, which smoothed possible biases. Triangulation of the results allowed the detection of inconsistencies, which were subsequently solved. Then, transparency and validation were assured by joining managers and experts from different departments in the same groups and by providing each group with the same influence diagram and set of records characterizing the events, exposures and harms associated with the strategic risks. Positive group dynamics (Johnson and Johnson, 2000) was secured by external researchers who moderated each group.

Given the extent of validation achieved through what Maxwell (2009) refers to as intensive, long-term involvement of the researcher; gathering "rich" data; validation of responses by peers and triangulation; we claim that this approach minimizes the possibility for bias - which is also a proxy for the credibility of risk assessments (Wiedemann *et al.*, 2013).

4.5 Evolving strategic risk

Corporate objectives do not vary from day-to-day. They should be stable over years (Keeney, 1992). Master planning in utilities should therefore aim for the mid and long-term, and this is particularly more relevant for the water sector, where the assets are designed to last around 25 to 50 years. Therefore, we have complemented the methodology presented here to include an assessment of how these baseline risks may evolve in the long-term, including an extension of the visualisation tools to improve communication with the Board. This analysis will be offered in a future communication.

5 Conclusions

The demonstrable management of risk and opportunity - expressed by a pragmatic and positive organisational commitment to risk management across the portfolio of risks that a utility faces - has become an expectation of responsible utility management. By assessing the interconnectedness of operational, tactical and strategic risks, and representing them using accessible visuals that executives and Boards can engage with, this analysis is shown to be of value in appraising the multiple threats to corporate objectives. This forms a clearer basis for water utility master plans that, in part, provides assurance to stakeholders that threats (and opportunities) can be managed by progressive and resilient water utilities.

The approach was successfully tested at EPAL, which suggests a potential for replication in other water utilities or sectors. We speculate that: (i) strategic objectives will not differ much from water utility to water utility; recognizing utilities from other sectors may have different strategic objectives; (ii) the influence diagram, as well as the definition of the consequences‘ scale, is EPAL-specific, although they are easily adaptable to other water utilities; in other sectors, relevant events, exposures and harms are expected to significantly change, but the base concepts of the approach developed may be applied. All

this implies that although context is crucial, it is possible to generalize the lessons from this case study in a wider range of utilities.

Acknowledgements

This research has been funded by EPAL and received an Honour Award for the Planning Projects Category of the 2014 IWA Europe and West Asia Regional Project Innovation Awards. The authors thank members of EPAL's Board, the risk experts and risk managers (EPAL) that participated in validating the approach, and Patrícia Duarte and Luis Marçal (EPAL) for assisting with database management and the influence diagrams.

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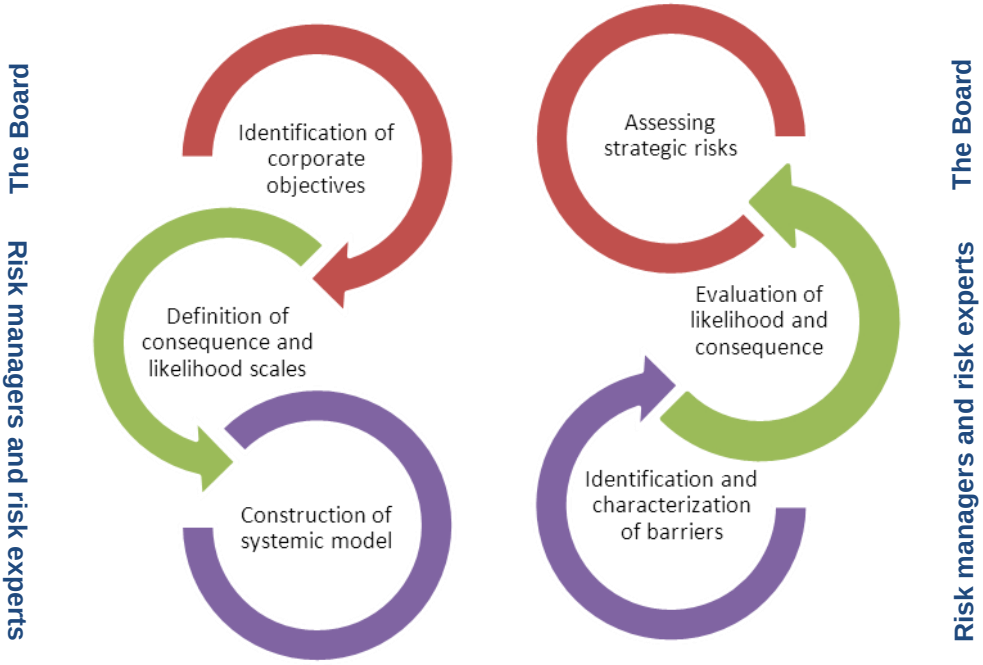
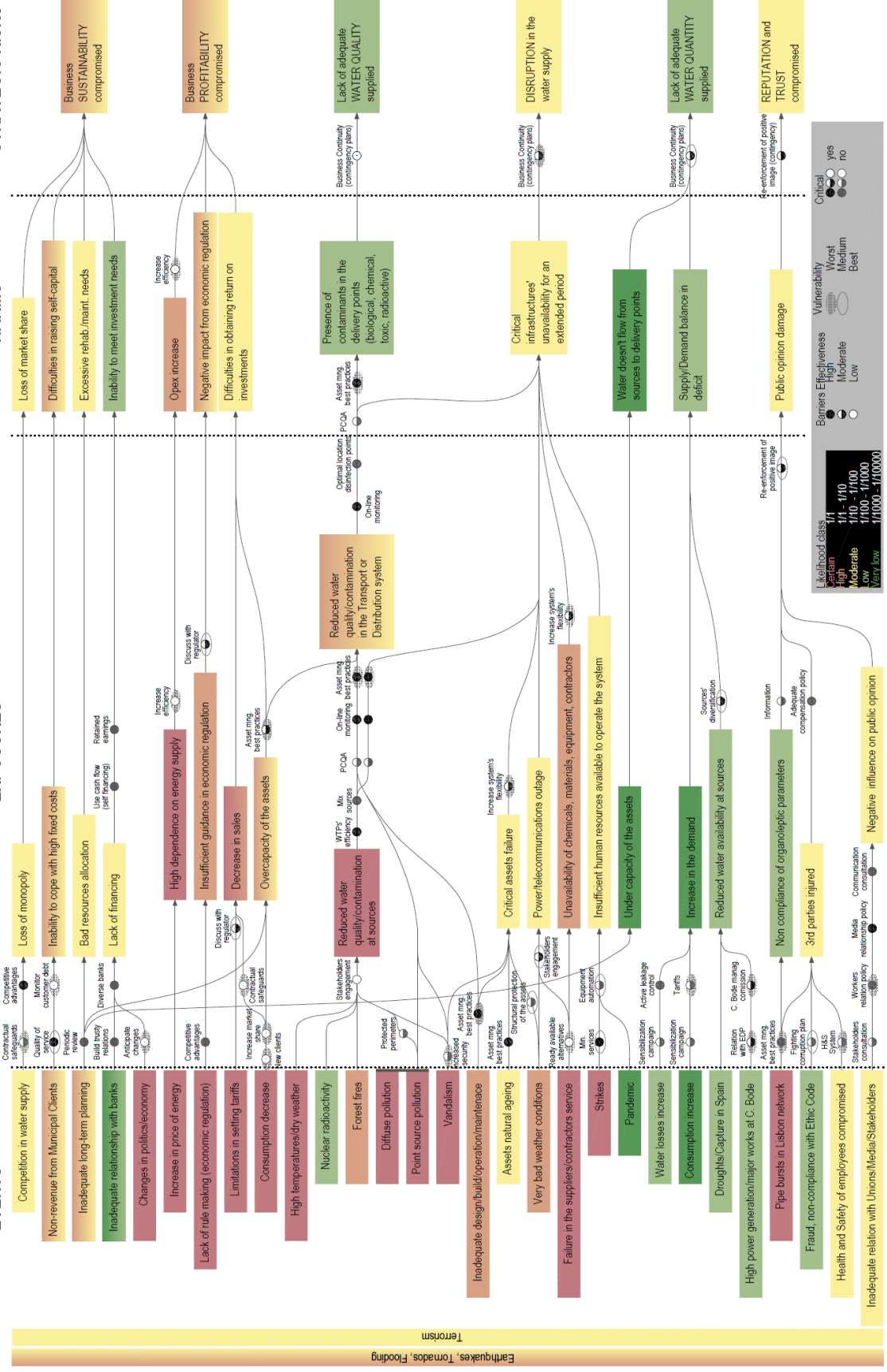


Figure 1 The "top-down" / "bottom-up" approach interconnecting operational and strategic risks


STRATEGIC RISKS
HARMS
EXPOSURES
EVENTS
Business SUSTAINABILITY compromised
Business PROFITABILITY compromised
Lack of adequate WATER QUALITY supplied
DISRUPTION in the water supply
Lack of adequate WATER QUANTITY supplied
REPUTATION and TRUST compromised
Loss of market share
Difficulties in raising self-capital
Excessive rehab./maint. needs
Inability to meet investment needs
Opex increase
Negative impact from economic regulation
Difficulties in obtaining return on investments
Presence of contaminants in the delivery points (biological, chemical, toxic, radioactive)
Critical infrastructures' unavailability for an extended period
Water doesn't flow from sources to delivery points
Supply/Demand balance in deficit
Public opinion damage
Loss of monopoly
Inability to cope with high fixed costs
Bad resources allocation
Lack of financing
High dependence on energy supply
Insufficient guidance in economic regulation
Decrease in sales
Overcapacity of the assets
Reduced water quality/contamination at sources
Reduced water quality/contamination in the Transport or Distribution system
Critical assets failure
Power/telecommunications outage
Unavailability of chemicals, materials, equipment, contractors
Insufficient human resources available to operate the system
Under capacity of the assets
Increase in the demand
Reduced water availability at sources
Non compliance of organoleptic parameters
3rd parties injured
Negative influence on public opinion
Competition in water supply
Non-revenue from Municipal Clients
Inadequate long-term planning
Inadequate relationship with banks
Changes in politics/economy
Increase in price of energy
Lack of rule making (economic regulation)
Limitations in setting tariffs
Consumption decrease
High temperatures/dry weather
Nuclear radioactivity
Forest fires
Diffuse pollution
Point source pollution
Vandalism
Inadequate design/build/operation/maintenace
Assets natural ageing
Very bad weather conditions
Failure in the suppliers/contractors service
Strikes
Pandemic
Water losses increase
Consumption increase
Droughts/Capture in Spain
High power generation/major works at C. Bode
Pipe bursts in Lisbon network
Fraud, non-compliance with Ethic Code
Health and Safety of employees compromised
Inadequate relation with Unions/Media/Stakeholders
Earthquakes, Tornados, Flooding
Terrorism
Likelihood class
Certain 1/1
High 1/1 - 1/10
Moderate 1/10 - 1/100
Low 1/100 - 1/1000
Very low 1/1000 - 1/10000
Barriers Effectiveness
High
Moderate
Low
Vulnerability
Worst
Medium
Best
Critical
yes
no

798 *Figure 2 Influence diagram for EPAL's strategic risks, coloured according to the likelihood of*
799 *events, exposures and harm.*
800

BARRIERS	Efficacy (1=best)	Vulnerability (1=less)	Criticality (Yes/No)
- AM (asset management) best practices	1	5	Y
- Business continuity - contigency plans	3	5	Y
- C.Bode reservoir management commission	3	5	Y
- Increase system's flexibility	3	5	Y
- Ready available alternatives	5	5	Y
- Relation with EDP	3	5	Y

BARRIERS	Efficacy (1=best)	Vulnerability (1=less)	Criticality (Yes/No)
- Media relationship	1	1	Y
- Online monitoring	1	1	Y
- WTPs' efficiency	1	1	Y

Figure 3 Example of queries in the database supporting the systemic model, using the filtering function to highlight: (on the left) the critical barriers with maximal vulnerability and varying efficacy; and (on the right) the critical barriers which are most effective and less vulnerable.

RISK FACTOR	LIKELIHOOD	RATIONALE
Inadequate data / information	**High (1/10 – 1/1)**	•*Not enough accurate or available data* •*Difficult to extract information out of data*
Legal non-compliance	**Moderate (1/100 – 1/10)**	•*Compliance with laws* •*Lack of stability in laws*
Lack of communication	**Certain (1/1)**	•*Within departments* •*Between departments* •*Outside the company*
Poor HR Management	**Certain (1/1)**	•*Difficult knowledge transfer (more than 200/740 employees are aged 55+)* •*Difficult to capture talents*
Inadequate governance	**Moderate (1/100 – 1/10)**	• *Excessive and unstable rulemaking from government*

Figure 4 Risk contributory factors' likelihood

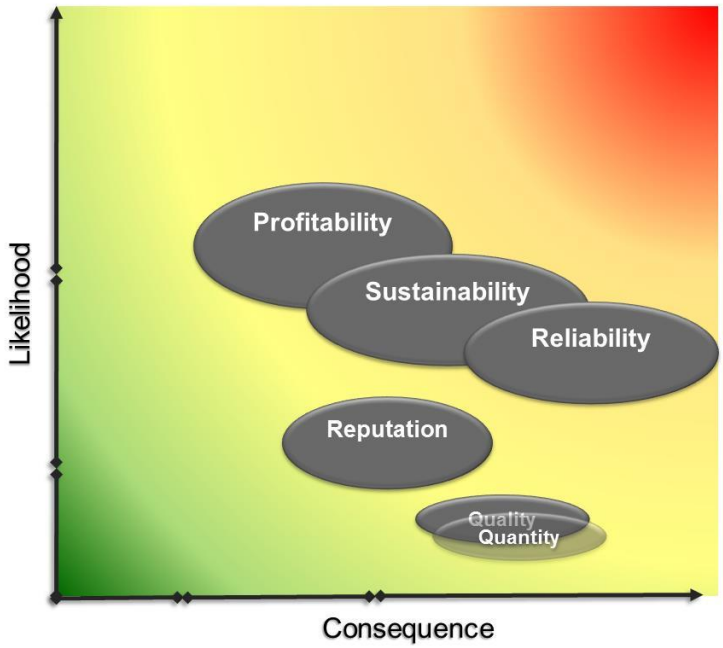


Figure 5 "Heat-map" of EPAL's strategic risks.

1	**Competition in water supply** *Event*	
	Municipalities may start producing their own water (in case the price of water gets too high for them, for example)	
	Influenced by: n/a	with the following barriers: n/a
	Probability class: **Moderate (1/100 - 1/10)** -	*Confidence: High*
	Impact on: 6 - Loss of monopoly (Exposure)	with the following barriers: - Contractual safeguards (E=3, V=4, NC) --> 6 - Competitive advantadges (E=2, V=2, C) --> 6
	Related with the following strategic risk(s): Business Sustainability compromised	

Figure 6 Influence diagram supporting database: example of an individual form

Table 1: Actions to build systemic model of strategic risks

Step #	Action	Basis of the action	People involved	Time frame
1	Preliminary risk screening and securing buy-in from Risk Managers	Brainstorming	Risk co-ordinator + Risk Managers	April 2011
2	Identification of the events, exposures and harms to each corporate objective and of the respective interconnections (preliminary influence diagram).	Knowledge of the system; Existing studies; Literature review.	Risk co-ordinator	Feb. 2012 / Nov. 2012
3	Pre-definition of the scales to assess likelihood and consequences' magnitude.	Knowledge of the system; Literature review.	Risk co-ordinator	Feb. 2012 / Nov. 2012
4	Meetings with Risk Managers, in order to elicit feedback of the: • systemic analysis; • likelihood and consequences' scales; • risk experts to be appointed.	Preliminary influence diagram; Preliminary likelihood and consequence scales.	Risk co-ordinator + Risk Managers	Nov. 2012
5	Meetings with Risk Experts, in order to: • Discuss the influence diagram; • Evaluate the likelihood of each risk.	Existing studies; Expert knowledge.	Risk co-ordinator + Risk Experts	Nov. 2012 / Jan. 2013
6	Triangulation of the results: compilation of the information gathered during the meetings with Risk Experts and identification of inconsistencies or gaps. Evaluation of the consequences associated to the strategic risks.	Information gathered in step 5	Risk co-ordinator	Jan. 2013
7	Workshop with Risk Managers and Risk Experts in order to: • Validate the influence diagram; • Validate the likelihood and consequences evaluation; • Discuss the completeness, efficacy, criticality and vulnerability of the existing barriers.	Information gathered in the previous steps	Risk co-ordinator + Risk Experts + Risk Managers + External researchers	Jan. 2013
8	Elaboration of the final documents, including: • Narratives (one per each risk); • Influence diagram (final version); • Risk "heat-map".	Outcomes of the workshop	Risk co-ordinator	Feb. 2013 / May 2013

Table 2: Extract of influence diagram supporting database

No.	Box	Type	Evidences	Notes	Likelihood	Likelihood Notes
1	Competition in water supply	Event	Experience with Águas do Oeste	Municipalities may start producing their own water (in case the price of water gets too high for them, for example).	Department A: 1/10 - 1/100 Department B: 1/10 - 1/100	-

Table 3: Likelihood scale

Likelihood classification	**Occurrence per nº of years**
Certain	1/1
High	1/10 – 1/1
Moderate	1/100 – 1/10
Low	1/1000 – 1/100
Very low	1/10000 – 1/1000

Table 4: EPAL-specific consequences' scale

	Quality	**Reliability**	**Quantity**	**Sustainability**	**Profitability**	**Reputation**
Catastrophic	**50 or more** customers will present **non-reversible health problems**, including the **possibility of death**	**2.0 million or more** customers **will not be supplied** at all during 4 days or more	**50% or more** of the daily average flow will not be supplied during **6 months or more**	The company **will not be able** to accomplish its mission in the **next 10 years**		
Very bad	**Less than 50** customers will present **non-reversible health problems**, including the **possibility of death OR more than 5000** customers will present **reversible health problems**	**0.1-2.0 million** customers **will not be supplied** at all **OR 2.0 million or more** customers **will be partially supplied** during 4 days or more	**50% or more** of the daily average flow will not be supplied during **1-6 months**	The company **will not be able** to accomplish its mission in the **next 20 years**	The company will be **in deficit**	**One breaking news OR more than one non breaking news** per year defaming the **quality of the water** supplied
Bad	**Less than 5000** and **more than 500** customers	**0.1 million or less**	**25%-50%** of the daily	The company **will be able** to accomplish its	The company will	**One breaking news OR more than one**

	will present **reversible health problems**	customers **will not be supplied** at all **OR 0.5-2.0 million** customers **will be partially supplied** during 4 days or more	average flow will not be supplied during **6 months or more**	mission in the **next 20 years** but will struggle with **high economic or financial constraints**	**decrease its profits by more than 75%** up to 100%	**non breaking news** per year related to **3rd party or H&S injuries**
Moderate	**Less than 500** and **more than 50** customers will present **reversible health problems**	**0.1-0.5 million** customers **will be partially supplied** during 4 days or more	**25%-50%** of the daily average flow will not be supplied during **1-6 months**	The company **will be able** to accomplish its mission in the **next 20 years** with **moderate economic or financial constraints**	The company will d**ecrease its profits by more than 25% and less than 75%**	**One breaking news OR more than one non breaking news** per year defaming the **reliability** of the water supplied
Minor	**Less than 50** customers will present **reversible health problems**	**0.1 million or less** customers **will be partially supplied** during 4 days or more	**Less than 25%** of the daily average flow will not be supplied during **more than 1 month**	The company **will be able** to accomplish its mission in the **next 20 years** with **minor economic or financial constraints**	The company will **decrease its profits by less than 25%**	**One breaking news OR more than one non breaking news** per year defaming the **governance of the company**

841

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2015-02-20
Elsevier
https://doi.org/10.1016/j.watres.2015.02.021
Luís A, Lickorish F, Pollard S. (2015) Assessing interdependent operational, tactical and strategic risks for improved utility master plans. Water Research, Volume 74, May 2015, pp. 213-226

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