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Benchmarking risk management within the international water utility sector. Part II: a survey of eight water utilities

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ABSTRACT

Risk management in the water utility sector is fast becoming explicit. Here, we describe application of a capability model to benchmark the risk management maturity of eight water utilities from the UK, Australia and the USA. Our analysis codifies risk management practice and offers practical guidance as to how utilities may more effectively employ their portfolio of risk analysis techniques for optimal, credible, and defensible decision making. For risk analysis, observed good practices include the use of initiation criteria for applying risk assessment techniques; the adoption of formalised procedures to guide their application; and auditing and peer reviews to ensure procedural compliance and provide quality assurance. Additionally, we have identified common weaknesses likely to be representative of the sector as a whole, in particular a need for improved risk knowledge management and education and training in the discipline.

KEYWORDS: maturity model, risk analysis, risk management, water sector

1. Introduction

1.1 RISK MANAGEMENT IN THE WATER UTILITY SECTOR

The water sector is witnessing a significant shift in the approach to managing risk to one that is increasingly explicit and broad in scope. Risk management strategies and techniques traditionally applied to occupational health and safety and public health protection are seeing application to corporate level decision making, asset management (Booth and Rogers, 2001; Lifton and Smeaton, 2003), watershed protection (IMPRESS Management, 2002; Lloyd and Abell, 2005; WHO, 2003) and network reliability (Stevens and Lloyd, 2004; Stahl and Elliott, 1999). This is in large part a response to the corporate governance, asset management, public health and environmental protection agendas, and represents a growing recognition that the provision of safe drinking water deserves to be treated as a "high reliability" societal service, subject to the sectoral and organisational rigours and controls inherent to the nuclear, offshore and aerospace industries (Pollard *et al.*, 2005). However, it is not the presence of risk management *per se* that governs the value derived, but its relative maturity of implementation within a utility. We have developed a capability maturity model for benchmarking and improving the *processes* that comprise risk management (MacGillivray *et al.*, 2006a). Here, we report its application to benchmark within the international water utility sector, the purpose of which was to identify good risk management practices and explore how they may be defined and controlled within organisational processes.

1.2 RISK MANAGEMENT CAPABILITY MATURITY MODEL (RM-CMM)

Our companion paper (MacGillivray *et al.*, 2006a) describes the development of a RM-CMM for the water utility sector. The model is a prescriptive codification of water sector risk management practice, within a process-based maturity hierarchy. The model was developed by abstracting the principles of capability maturity modelling observed in other disciplines, including software and systems engineering (Paulk *et al.*, 1993; Software Engineering Institute, 2002a), workforce development and management (Software Engineering Institute, 2002b), offshore design safety (Sharp *et al.*, 2002), reliability engineering (Strutt, 2003), and construction (Sarshar *et al.*, 2000). This was achieved through literature reviews (MacGillivray *et al.*, 2006b; Pollard *et al.*, 2004; Hamilton *et al.*, 2006), structured interviews with water utility managers, and prior knowledge of maturity modelling in similar utility sectors. We identified eleven risk management processes (Fig. 1). These processes are separated into five maturity levels, from learner to best practice. These maturity levels, characterised by reference to key attributes (Fig. 1), reflect the extent to which each process is defined, institutionalised and controlled. It is important to understand what these levels represent in practice as this is crucial to assessing the maturity of an organisation. Whilst the precise definition of the maturity hierarchy is process specific, a generalised description is provided in Table 1.

2. Methodology

Eight water utilities from the UK, Australia and the USA participated in this study. This was supplemented by the participation of an electricity utility regarded as best practice in risk management. However, an incomplete questionnaire return prevented its maturity assessment, and we restrict its discussion to key observations. The sample is intended to reflect good risk management practice, hence we do not suggest that our analysis is representative of the sector as a whole. The scope of analysis varies by utility, and includes organisational, business unit, and functional perspectives (Table 2). Sample selection drew upon existing industrial contacts and was further informed by prior reviews (MacGillivray *et al.*, 2006b; Pollard *et al.*, 2004; Hamilton *et al.*, 2006) of the academic, practitioner and grey literature.

A survey-type research design was adopted, whilst the research methods included questionnaire, interview and textual analysis. The questionnaire was comprised of a series of statements characterising the undertaking of each risk management process at each maturity level. These were responded to on a four point scale (fully agree; generally agree; partially agree; and disagree), with space provided for supporting comments. Process maturity was determined according to the highest “degree of fit”; a measure of the average level of agreement with the guideline statements at each maturity level for each process. The interview and textual analysis was concerned with identifying the specific risk management practices undertaken within the sample and correlating these with our model (*e.g.* how, practically, is risk analysis defined and controlled as a process). Semi-structured interviews were undertaken with each assessor following receipt of the questionnaire. The interview methodology was developed, tested and refined within a separate industrial case study. Interviews were conducted by ’phone, recorded, and subsequently converted into transcripts. These transcripts were returned to each interviewee, providing them an opportunity to comment. Finally, a range of pertinent supporting company documentation was requested from each participant. Those made available included risk management policies and frameworks, risk analysis procedures and techniques, and water safety plans.

Given the qualitative nature of the research, mechanisms to validate our findings were adopted. This was achieved through sample anonymity and triangulation. Anonymity removed the potential for conflicts with the fundamental goal of adding to the body of knowledge (as opposed, *e.g.*, to the participants' desire that the findings reflected positively upon their organisation). Triangulation sought to balance the lead author's principal analysis of the questionnaires, texts and interview transcripts with a blind scoping analysis conducted by a co-author. Additionally, each respondent was offered the opportunity to comment on all statements within the paper referring specifically to their utility. Diverging perspectives were resolved through consensus.

3. Results and discussion

Figs. 2 and 3 illustrate the sample process maturity profiles. Detailed discussion of these levels may be found in our companion paper. Here, we do not dwell on the maturity profiles as our scoring methodology is arbitrarily rather than scientifically derived and the sample is not intended to reflect the sector as a whole. We restrict ourselves to the following observations. The sample profiles are relatively mature for the core and supporting processes of risk management, in contrast to the long-term processes of education and training in risk management and risk knowledge management. Two explanations are offered. Firstly, the attention and resources dedicated to the design and execution of processes is correlated with their perceived criticality. Secondly, the long-term processes receive limited treatment within the academic and practitioner literature, leaving utilities bereft of guidance. The maturity of the supporting processes – supply chain risk management and change risk management – is particularly high. The strength in the former is likely a function of the increasing level of outsourcing within the sector. Similarly, we propose that mature change risk management is driven by evolving regulatory and governance structures and the commonality of internal restructuring.

We now discuss the observed risk management practices on a process-specific basis.

3.1 STRATEGIC RISK PLANNING

Here, we observed an even spread of our sample between L3 and L4. Strategic risk planning is primarily concerned with the development of a risk management framework. In essence, these frameworks were observed to set out the rationale, procedures and responsibilities for the discipline. At L3 and L4, we observed that their development may be characterised as the evaluation and adaptation of external risk management standards. For example, one manager described how the forbearer of their corporate-wide risk management framework was an adaptation of an occupational health and safety management system, which has evolved drawing upon the AS/NZS: 4360 (Council of Standards of Australia, 1999) standard and broader experiences of the sector. Another described how they were "trying to use the rationale, the basis of the COSO (COSO, 2004) standard, but the methodology is one that's been developed by us." We may consider the vetting of these frameworks (*e.g.* by the Board, internal audit, *etc.*) as a form of *output* validation, however, it was unclear whether the *process* by which they are developed, or more precisely adapted, is subject to oversight.

3.2 ESTABLISHING RISK ACCEPTANCE CRITERIA

This process involves the development of criteria for evaluating the tolerability and significance of risk. Here, we observed five L3 organisations, and one each at L2, L4 and

L5. At L2, risk acceptability is largely set with reference to regulations and standards. Expanding on this, the L2 manager stated that "the corporate risk appetite is primarily perceptual and based upon broad guidelines established by upper management, the Board, external auditors, stakeholders and bond-holders."

An observed L3 practice was the allocation of risk tolerability criteria in operational and financial areas. These included design standards informed by hazard and operability (HAZOP) analyses; operating and maintenance practices informed by reliability modelling; as low as reasonably practicable (ALARP) criteria for evaluating dam safety risk; the use of risk-based criteria to determine raw water treatment requirements; and risk-adjusted discount rates applied within financial analysis models to balance investment returns with uncertainty. However, it appeared that the processes through which these criteria are established reside within organisational functions (*e.g.* engineering, finance) and thus lie outside the remit of the corporate risk manager. As one manager noted, tolerability criteria may exist "within discrete areas of the business…but they exist as islands with no…overlaying risk management policy or strategy."

Further, we observed the development of risk ranking techniques which outline the criteria by which organisations assess the significance of risk both at the corporate level and, in some cases, specific to organisational functions such as asset management. Tolerability criteria were often embedded within these techniques (*e.g.* low risk: manage by routine procedures; high risk: management response required). These techniques were typically derived from risk management standards. Observed adaptations included the alignment of consequence criteria with corporate objectives (*e.g.* environmental, financial, *etc.*); the tailoring of impact descriptors; and the assignment of costs to impact categories.

3.3 RISK ANALYSIS

Here, five utilities were evaluated at L3, three at L4. Risk analysis involves the identification and assessment of risk. Our sample indicates two distinct categories of risk analysis: a generic strategic technique; and a series of discrete methods applied in operational areas. The former may be characterised as the application of qualitative risk ranking techniques to analyse the risks inherent to managing a water utility as a business. The latter included a raft of industry standard and best practice tools, both qualitative and quantitative. Those observed included HAZOP studies; hazard analysis and critical control points (HACCP) evaluations; failure mode, effect and criticality analyses (FMECA); and monte carlo simulation of financial variables.

A prerequisite for process definition (L3) is that the application of these techniques is guided by formalised procedures – a practice intended to ensure the consistency and rigour of analysis. Regarding strategic risk analysis, best practice may be described with reference to the electricity utility. Here, a range of risk identification techniques are available, and their selection depends upon "the depth and breadth of activities under review and the extent to which the business context is new." Listed techniques include strengths, weaknesses, opportunities and threats (SWOT) analysis; scenario analysis; value chain analysis; benchmarking; control self assessments; audit reports; *etc*. Risk categories are used as a further prompt for identification (strategic, regulatory, financial and operational). It was common practice across our sample to assess strategic risks via a combination of expert judgement and, where available, historic data to determine a range of parameters (*e.g.* probability, consequence, development time, triggers, control design and usage, *etc.*). The electricity utility's use of the Delphi technique (Dalkey and Helmer, 1963) in risk assessment is notable. Here, facilitated discussions and iterative anonymous voting were applied to generate expert consensus. The method's explicit recognition of human judgment as a legitimate input is particularly valuable where data is limited. Furthermore, characterised as it is by group participation, anonymity and feedback loops, it minimises bias and dogmatism (*i.e.* reduces the reluctance of staff to abandon previously stated views). A caveat: it appears that in many cases strategic risk analysis tends to be as one manager stated "shepherded by the corporate risk team" rather than guided in a mechanistic manner. This contrasts with the more procedural approach adopted operationally (*e.g.* in occupational health and safety), and perhaps reflects the perceived value of creativity in strategic risk analysis.

A further observed L3 characteristic was the use of criteria for the selection *and* application of risk analysis techniques. The strategic risk ranking tools were typically initiated within business and strategic planning as well as on an *ad hoc* basis as new risks arise, whilst various nodes (*e.g.* the concept design stage for application of HAZOP) served as initiating criteria for the various operational methods. Observed selection criteria included the use of financial thresholds to delineate the application of Monte Carlo simulation from simple checklists to evaluate financial risk within programme management. Basic verification mechanisms are a further L3 characteristic. This is reflected in one utility's requirement for supervisors to review risk assessments of minor construction and maintenance works prior to "sign off." Similarly, one manager highlighted the role of their "systems certification process" in ensuring procedural compliance. Here, a taskforce "conducts certification audits, checking the business practices of each system, making sure that they're in concert with our way of doing business; one element of which is that they're doing risk assessments and that they're doing it properly." Another interviewee described a tri-partite approach to auditing. Here, in addition to external auditing by their parent company, “internal audit come in every year, to check that we’re process compliant by drilling down from risk reporting at the highest level, right down through identification, assessment…also as a [risk management] team, we do our own local audits to make sure that people are up to speed…and [we] tackle non compliance.” The importance of such checks and balances was highlighted by one participant’s contrasting of the inconsistencies surrounding their locally managed sanitary surveys with the consistency of their centrally managed barrier surveys. Furthermore, several managers related concerns that analyst bias may lead to distortions of risk analysis outputs. Whilst underscoring was the most commonly noted threat, one manager revealed that their adoption of a risk-based capital investment programme has led to a significant likelihood of asset managers “over-egging” their analyses to attract greater funding for their regions. To address this, verification should extend to audit the quality of analysis undertaken.

This enhanced role for verification was observed at L4, as reflected in one utility’s “quality assurance consistency checks” within asset management. Here, risk analysis outputs and their underpinning assumptions were systematically reviewed and challenged by a multi-disciplinary team of experts. The interviewee noted that the value of this procedure extends beyond quality assurance of analysis outputs to highlighting common errors in applying the methodology itself: “we’ve had some problems with people using [the methodology], some were misinterpreting it, we spotted this from the data and [the consistency checks]. Some asset managers score the probability of an asset failing, some score the probability of an asset failing and [leading to a defined] impact; the latter is what we want.” We now highlight the subtle distinction between verification, which seeks to evaluate whether the process has been followed correctly, and validation, which is concerned with whether the process itself is correct (*e.g.* validating the risk analysis techniques). Both of these aspects were enshrined in one utility's application of a "common sense screen" at the end of their water quality risk analysis process. Here, if analysis outputs appeared at odds with experienced operational knowledge, the reason behind the "false" score was investigated, and the process and score adapted where appropriate.

Although engagement of a broad range of stakeholders is characteristic of L4 maturity, broad internal stakeholder engagement was characteristic of each utility's approach to strategic risk analysis, which was typically conducted within cross-functional forums. However, the engagement of external stakeholders appears to occur on a far more selective basis. One L3 manager commented that there were "no formal procedures for external risk reporting" and that, beyond the outcomes of security-related risk assessments, the "regulator has shown little interest". Two of the L4 interviewees expressed a greater recognition of the need to engage external actors in risk analysis, both where risks have high external stakeholder implications (*e.g.* political or environmental) and where expert guidance is required. In contrast, one manager explained their reticence to engage external bodies by noting that "risk assessments are a risk for ourselves, if we identify something as a business risk, particularly if its environmental, hazardous, or regulatory, that's out there, if you don't address that, it's going to come back at you."

Finally, the sufficiency of resourcing within each L4 company was evidenced by their active research and development in risk analysis. One was researching the integration of predictive GIS tools with continuous and event-based monitoring data for application in catchment risk analysis. In contrast, one L3 interviewee highlighted resource constraints as a limitation: "one issue is the complexity of our analyses, we have ten water systems and thirteen catchments [which are] diverse in [size and] nature…for a small organisation that serves only about 15,000 customers, resourcing these sorts of studies is not easy."

3.4 RISK BASED DECISION MAKING AND REVIEW

Risk based decision making involves the identification and evaluation of solutions to manage individual risks. Here, six of our sample were evaluated at L3 maturity, with one each at L2 and L4. At L3 maturity, we observed procedures to ensure that risk analysis outputs explicitly inform decision making. These ranged from the integration of the risk analysis and decision making processes within strategic risk management workshops, to the risk analysts' role of briefing non-technical decision makers in operational areas. We further observed decision making frameworks. This is reflected in one utility's adoption of a predefined hierarchy of occupational health and safety hazard control measures: elimination (does the work have to be done); substitution (can it be done in a less hazardous way); engineering controls (isolation, containment); administration (procedures, trained staff); personal protective equipment (respirators, helmets); and warning signs. This structures the identification of solutions. In a more generic context, the electricity utility categorizes risks by the extent to which their exposure can be managed: controllable (*e.g.* financial or health and safety risks) and influenceable (*e.g.* competition, regulation). Seven "risk treatment" options are then applied to structure the identification of solutions: retain; retain but change mitigation; increase (risk exposure is increased, for example, where the current controls are not cost-effective); avoid (*e.g.* withdrawal from a business area); reduce likelihood; reduce consequences (*e.g.* through emergency preparedness); and transfer (*e.g.* through insurance or outsourcing). However, inherent in many risk assessment methodologies is a decision making structure. Consider one utility's catchment to tap methodology. Here, the assessment links hazard type (*e.g.* physical – turbidity and colour) to their causes (erosion) and to events (landslip, storm). Clearly, by identifying the underlying mechanisms through which hazards are realised, rather than simply evaluating their probabilities and consequences of occurrence, the identification of preventative measures (*e.g.* stabilise gullies, isolate draw-off) is facilitated.

A further L3 characteristic is the establishment of objectives for risk based decisions. However as one manager stated “with the exception of large projects, the majority of the goal-orientation will focus on cost and physical output”, rather than risk reduction. In contrast, one L3 utility adopted a goal setting regime for risk reduction at both the asset and strategic level. In the former, asset planners attached cost estimates *and* risk reduction targets to a range of potential capital, operating or maintenance strategies to address risks across their sites, which were then prioritised on the basis of risk reduction per pound spent.

Quality assurance of decisions, whilst characteristic of L4, was observed to an extent within each utility, ranging from the peer review format of cross-functional strategic risk management workshops to more formalised challenge processes. For example, one manager noted that a central role of their “executive leadership team” – comprised of the president, vice presidents and union leader – and “business owners’ council” – comprised of business unit representatives – was to provide input to and at times critique risk management decisions taken at the corporate and business unit levels respectively.

3.5 RISK RESPONSE

Risk response is the implementation of risk based decisions. Here, six of our sample were evaluated at L3 maturity, with one each at L2 and L4. An L3 characteristic is the systematic allocation of responsibility, tasks, timescales, guidelines and resources for the implementation of risk based decisions; this was observed, *e.g.* within the development of "action plans." Within the electricity utility, these include a description of the: risks to be mitigated; business objectives threatened; required actions; risk champion; target date of completion; residual risk rating; cost estimate; ease of implementation; and what could go wrong. Returning to a more operational context, we observed emergency management plans detailing the procedures required to minimise the impacts of, for example, plant failure (check component connections, check for blockages, review raw water for turbidity, taste, odour and algae, *etc.*). In practice, we observed that implementation processes were often not unique to risk based decisions, *i.e.* there existed models for implementing capital or operational solutions, not models for implementing risk based decisions *per se*. Indeed, the electricity utility manager emphasised that his role as a risk manager was not to act as a "central policeman," and that implementation was a matter for individual business units and functions.

3.6 RISK MONITORING

The sample contains one L2, five L3, and two L4 companies in risk monitoring. The L2 interviewee characterised risk monitoring as "the weaker part of our scheme; we don't do much beyond the quarterly reviews, the exception being some particularly critical risks".

Our sample indicates that risk monitoring may be partitioned into two tiers: the first involving the re-evaluation of risk analyses outputs, the second relating to the tracking of discrete parameters which describe the evolution of risks. The former was observed to occur by procedure at L3 and L4, through both cyclical requirements and event-driven initiators (*e.g.* changes to technical processes). The importance of such procedures was emphasised by one manager's revelation that prior to their introduction of a central asset risk register with clear requirements for cyclical reviews of analysis outputs, risk analyses were not regularly updated, instead being performed for a specific purpose at decision making points. Good practice was further illustrated in one utility's adoption of reporting protocols for communicating the results of strategic risk re-evaluations; here: co-ordinators reported on the evolution of significant exposures at monthly management meetings; significantly increased risks were escalated to unit directors within thirty six hours; and the risk management function reported to the Board on a monthly basis. We further observed verification of procedural compliance, most commonly achieved through risk register oversight.

One might argue that this first tier of risk monitoring is indistinct as a process from risk analysis, as the revision of previous risk assessments is an element of the feedback loop within the latter process. The distinct second tier was observed to be most prevalent within drinking water quality management and network planning and operation. In the former context, risk monitoring includes both the standard regulatory-driven tracking of primarily lagging water quality parameters (*i.e.* verification of water quality, *e.g.* coliform testing at customer taps), and, where the water safety plan approach is adopted, extends to include leading indicators devised in accordance with the HACCP (Havelaar, 1994; Deere *et al.*, 2001) model (*i.e.* operational parameters describing the effectiveness of control measures designed to mitigate water quality hazards, *e.g.* ph residuals at and post disinfection). It should be noted that HACCP has the inherent characteristics of L4 maturity. To illustrate, within one adopter we observed: weekly reviews supported by in-depth periodic audits to ensure compliance with the established monitoring protocol (*i.e.*

verification: ranging from requirements to review online turbidity data to the calibration of analysis and measurement equipment); formal peer reviews of established operational parameters and their target and action limits (*i.e.* validation: exploring, for example, the rationale behind setting 2000 cells/mL of cyanobacteria as an action limit for controlling taste and odour related hazards); and annual reviews of the protocol taking account of modifications to processes, industry standards, regulatory guidelines and operating licenses (*i.e.* feedback mechanisms).

3.7 INTEGRATING RISK MANAGEMENT

Here, seven of our sample were evaluated at L3, with one at L4 maturity. Our discussion is restricted to one facet of integration: institutionalisation. Our model views institutionalisation as dependant on risk management “enablers” and “evaluators.” Enablers include the provision of guidelines, procedures, systems, tools and training for the discipline (L3), whilst evaluators include verification, validation and feedback mechanisms (L4). We have explored these within the context of each individual process, here, we seek to evaluate whether this is a sufficient explanation.

Indeed, the influence of culture on institutionalisation, an aspect not explicitly represented within our model, was highlighted by several participants. One noted how staff perceptions ranged from “those going through the motions, to those more cognisant of how [risk management] supports the broader organisational processes.” The participant further noted the importance of engaging and empowering operational staff in creating a risk management culture. Here, this took the form of expert practitioners supporting front-line staff to fulfil their risk management obligations (*e.g.* jointly conducted risk assessments) and actively seeking and considering their feedback in revising existing processes (*e.g.* adapting risk evaluation criteria to reflect operational expertise). We further observed that a prerequisite for cultural change is commitment from executive and senior management, which is often dependent on external events. One manager noted that "[the risk management team] have finally got the attention of our organisation; early on we couldn't get much dignity…then a series of events occurred in the [United States] which made risk assessment more important, which resulted notably in the Sarbanes Oxley legislation, we have several members of our board who are very much attuned to that…once we got top level buy in, the rest followed." Similarly, one participant reflected that "Enron, Barings…showed that companies can go under if their controls fail, [whilst] Railtrack showed that companies could lose their [license to operate]. [Another] wake up call was the idea of corporate manslaughter; [this] made us focus our efforts on…assets with low likelihood of failure but high consequence, for example critical reservoirs."

3.8 SUPPLY CHAIN RISK MANAGEMENT

This process addresses both the way utilities obtain the raw components required to develop products and the management of services provided by organisations throughout the supply chain (*e.g.* outsourcing agreements). Here, we observed two L2, two L3, and four L4 utilities. One L2 manager revealed that supply chain risk management was primarily "left to procurement," with formalised approaches to risk management tending to apply only to larger, discrete projects. Similarly, one L3 interviewee stated that risk management was only explicitly involved in supply chain management in relation to products and services critical to their continued operation, further noting that "although [we] evaluate, qualify and support [our] critical vendors and suppliers, this is not within the context of a formal risk based process." In contrast, within one L3 utility risk management was explicitly interwoven within procurement policies and procedures. Inspection of their contracting and tendering policy revealed that in contrast to the traditional approach of selecting lowest cost suppliers once basic standards are met, a broad range of pre-qualification standards are applied as appropriate, including those that address risk explicitly (*e.g.* occupational health and safety, commercial risk, delivery risk) and implicitly (*e.g.* quality management accreditation). Furthermore, prior to binding acceptance, the probability of failure of the chosen tender to satisfactorily adhere to the contract, and the potential effects of such a failure, were formally assessed and reported.

We obtained limited data on the practices of those L4 utilities, however, we observed that one required all contractors to utilise a formal risk management framework, whilst another adopted criteria to ensure that the "risk attitude" of capital partners aligned with their own.

3.9 CHANGE RISK MANAGEMENT

This process is concerned with identifying and managing the risk implications of organisational (*e.g.* re-engineering) and technical change. Here, we evaluated one utility at L2, and three each at L3 and L4. We observed the expected lack of process definition within the L2 utility, whose respondent noted that where changes to *e.g.* operating or asset standards are considered, "risk would be part of the decision making process, although the level of formality would vary". Regarding organisational change, the interviewee stated that "whilst the utility has a team dedicated to providing support and education for the implementation of business process improvements, it does not focus on the risk implications of change." At L3 and L4, we observed the undertaking of risk analysis to evaluate the expediency of planned technical changes; the use of SWOT analysis to evaluate the "business environment" for changes that may constrain utility operations and management; application of environmental impact assessments for projects that modify existing processes or introduce new processes, activities or equipment; and regular analyses and reviews of risks and interdependencies within organisational change programmes.

3.10 EDUCATION AND TRAINING IN RISK MANAGEMENT

Here, we observed one L1 organisation, two at L2, and five at L3. An *ad hoc* approach was observed within the L1 utility, with no formal process in place to develop or maintain risk management skills and knowledge, and limited cognisance of the required competencies for effective undertaking of the discipline. As the L1 manager noted "we recognise we have an issue here…we took over one hundred people through risk training in 2000/01, [but we've] done nothing since…the next logical step was to cascade it across business…which we haven't." Emphasising the importance of this deficiency, he noted "we recognise some people have no knowledge of the [risk management] process, yet are expected to prioritise capital investment on the back of it; [but the] only hint of training is when they get shot down at [the consistency checks]."

The defining characteristic of the L2 organisations was their limited process scope, with limited internal training in risk management (*e.g.* addressing occupational health and safety), supported by attendance of externally delivered courses for key managerial and operating staff (*e.g.* risk management conferences, HACCP training for operating staff). For example, one L2 utility's site induction procedures sought to ensure that staff understood site-specific hazards and the precautions required to protect their safety and the quality of service. These covered basic issues such as the isolation and lock out procedures required for machinery during maintenance works, site emergency procedures, confined space entry procedures, and the location of the first aid kit. This was supplemented by video-based training on: risk management planning for drinking water supplies; job safety analysis; and safety leadership. Indeed, this emphasis on "on the job" training was a common theme at L2, the logic perhaps being that staff learn best through real life, hands on examples, rather than lectures and presentations. As the electricity utility interviewee noted, "most of the education and indoctrination was [achieved] by running [risk management] workshops. At one time my staff were running forty to fifty workshops a year, so all the executives and managers were constantly exposed to this whole methodology of identifying, prioritising and mitigating risk; [towards the end], they'd come and borrow our anonymous voting equipment and run their own workshops."

Valuable insights regarding the formalisation of education and training may be gleaned from one L3 utility. Here, two dedicated risk management training packages were observed: an introductory course provided to key strategic members of the business, and a more comprehensive programme delivered to "team leaders". Of greatest interest is the latter, which was structured around a formal definition of the competencies required for effective risk management, ranging from an understanding of corporate governance to a grasp of the technical aspects of the risk assessment techniques adopted. Both packages were initiated by procedure, with oversight from local management and the risk management team to verify compliance. Furthermore, effective delivery of the process was verified through cyclical evaluations of the ability of staff to act on the training received. These evaluations partly underpinned succession routes, providing a strong catalyst for learning. Supplementing these programmes, *ad hoc* training workshops were provided by risk management staff on request.

In a more operational context, one L3 manager described how in addition to externally delivered HACCP training for key staff, internal training on the fundamentals of drinking water quality management focussed specifically on embedding the risk-based approach inherent in their operating and management principles. Furthermore, their post-incident analyses included an explicit evaluation of the *a priori* risk management strategy, which the interviewee emphasised breeds familiarity with the methodologies and processes of risk management and, by focussing on real examples (or plausible scenarios), highlighted the practical implications of the discipline to front-line staff.

3.11 RISK KNOWLEDGE MANAGEMENT

Here, we observed three utilities at L2, and five at L3. Risk knowledge management may be considered as the collection, storage and access of the data underpinning and accumulated from the broader risk management processes, *i.e.* the input and output data. One L2 manager stated that input data requirements for risk management were not well defined, and noted that they "do not maintain detailed risk information beyond that which is accumulated during risk assessments or that inherent in the normal conduct of business". The interviewee assigned this to both a "resource driven inadequacy" and inadvertent constraints imposed by legislation: "in the public sector…we're subject to open records request…you don't want [your risk analyses appearing] in the newspaper the next day, how we store those documents and record our decisions is a strategy in itself, we try to limit circulation, which may be counter-productive to traditional risk management".

At L3, we observed procedures governing the use of software packages which serve as tools for the collection, storage and access of output data collected throughout the life-cycle of risk management. However, pre-defined strategies of input data collection were restricted to select operational risks, particularly those whose management was underpinned by formal analytical methodologies (*e.g.* reliability modelling), or, as one manager noted, subject to regulatory drivers (*e.g.* asset management, drinking water quality management). The electricity utility interviewee suggested that this is dictated by pragmatism, as "raw data requirements are fluid and evolve with the perceptions of management." However, we contend that in the absence of predefined requirements, risk data collection is likely to be *ad hoc*, and largely restricted to the requirements of "business as usual." Indeed, one manager described a reliance on "expert judgement; without senior experienced people, I'm not sure we have the data to underpin [risk management]". A further observed L3 characteristic was the lack of expertise for validation (*i.e.* to ensure that the correct data is being collected); to the extent that it is applied, it is informal and *ex-post*.

4. Conclusions

We have described the application of a capability maturity model to benchmark risk management within eight water utilities. The findings provide utility managers, technical staff, chief finance officers and regulatory officials with a systematic understanding of how to implement and improve risk management. This is timely work for a sector grappling to adapt to evolving regulatory and governance arrangements. Furthermore, the research provides a basis for evolving the model from a prescriptive to a descriptive state, which will ultimately render it fit for industrial ownership.

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Maturity level	Process Characteristics
Level 5 – Optimising	The process is a continual, explicit component of organisational activities, forming part of the 'culture'. Feedback is actively used to improve both the philosophy and execution of the process, and the adaptation of organisational structures and practices to optimise its ability to undertake the process (double loop learning). Management continually establishes measurable targets for process improvement, with systems in place to verify their achievement and to validate the means through which they are pursued. Active innovation, development and piloting of new ideas and technologies to optimise the process.
Level 4 – Controlled	Verification mechanisms extend to provide quality assurance, and are supplemented by the capacity for process validation. Feedback is actively used to improve process execution, albeit within the constraints of existing process strategies (single loop learning). Broadly spread competencies enable the process to reside within affected disciplines, although stakeholders work together to achieve an integrated approach, capitalising on synergies and collective knowledge. Sufficient resources are available, with limited internal R&D.
Level 3 – Defined	Process scope exceeds regulatory requirements, extending across core business areas. Documentation details procedures, criteria, methods and guidelines for process undertaking, whilst basic audit mechanisms verify compliance. Feedback limitations restrict process evolution to learning from 'events' (open loop learning). Processes reside within the responsible unit, with limited cross-functional or external consultation. Adequate resources in place.
Level2 – Repeatable	Basic process in place, focused on meeting regulatory requirements and addressing 'mission-critical' risks. Initiated reactively, often in response to an event or situation. Limited capacity to evolve based on experience.
Level 1 – Initial	No formal process; *ad-hoc* approach. Reliance on individual heroics. Limited awareness of regulatory requirements or relevant standards.

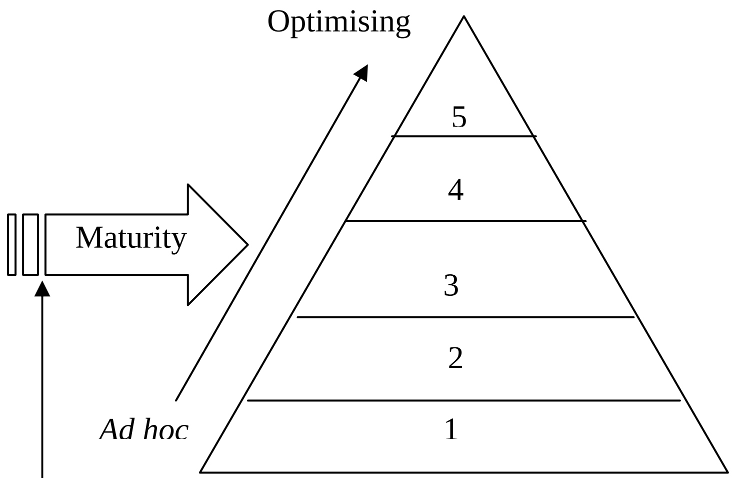
Table 1. Generalised representation of the process maturity hierarchy.

Descriptor	**Respondent***	**Unit of study**	**Scope of analysis**
Utility A	Corporate risk manager	Corporate	Water supply, sewerage services and electricity distribution
Utility B	Water quality manager	Corporate	Water supply and sewerage services
Utility C	Water quality manager	Corporate	Water supply and sewerage services
Utility D	Corporate risk manager	Corporate	Water supply
Utility E	Asset manager	Corporate	Water supply and sewerage services
Utility F	Corporate risk manager	Corporate	Water supply and sewerage services
Utility G	Asset manager	Business unit	Water supply
Utility H	Water quality manager	Function	Drinking water quality management
Utility I**	Corporate risk manager	Corporate	Electricity transmission and distribution

* Respondent denotes the interviewee; in most cases, the questionnaire was undertaken in consultation with other staff. ** Data limitations prevented the maturity evaluation of Utility I.

Table 2. Sample characteristics.

	Processes
Core	Strategic risk planning (SRP)
	Establishing risk acceptance criteria (ERAC)
	Risk analysis (RA)
	Risk based decision making and review (RBDM)
	Risk response (RR)
	Risk monitoring (RM)
	Integrating risk management (IRM)
Supporting	Supply chain risk management (SCRM)
	Change risk management (CRM)
Long-term	Education and training in risk management (E&T)
	Risk knowledge management (RKM)



Attributes
Scope
Integration
Verification and validation
Feedback and organisational learning
Stakeholder engagement
Competence
Resources
Documentation and reporting

Fig. 1. Overview of the RM-CMM (after Strutt *et al.*, 2005).

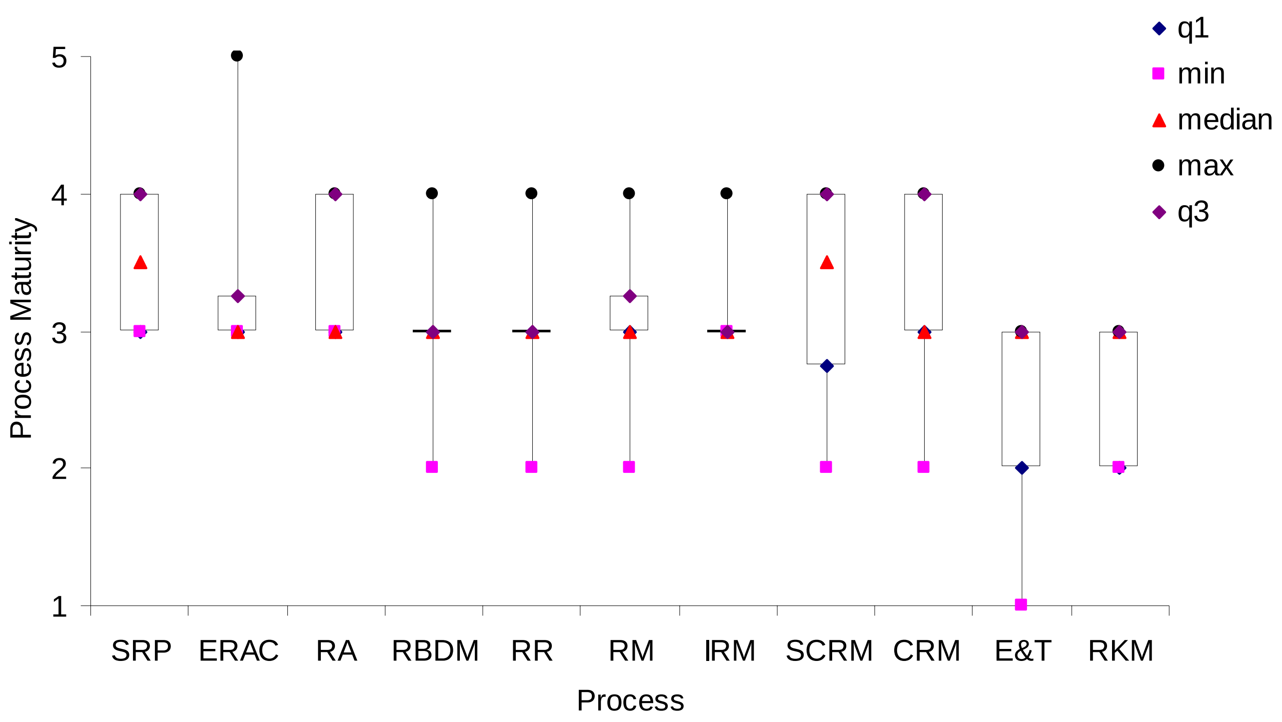
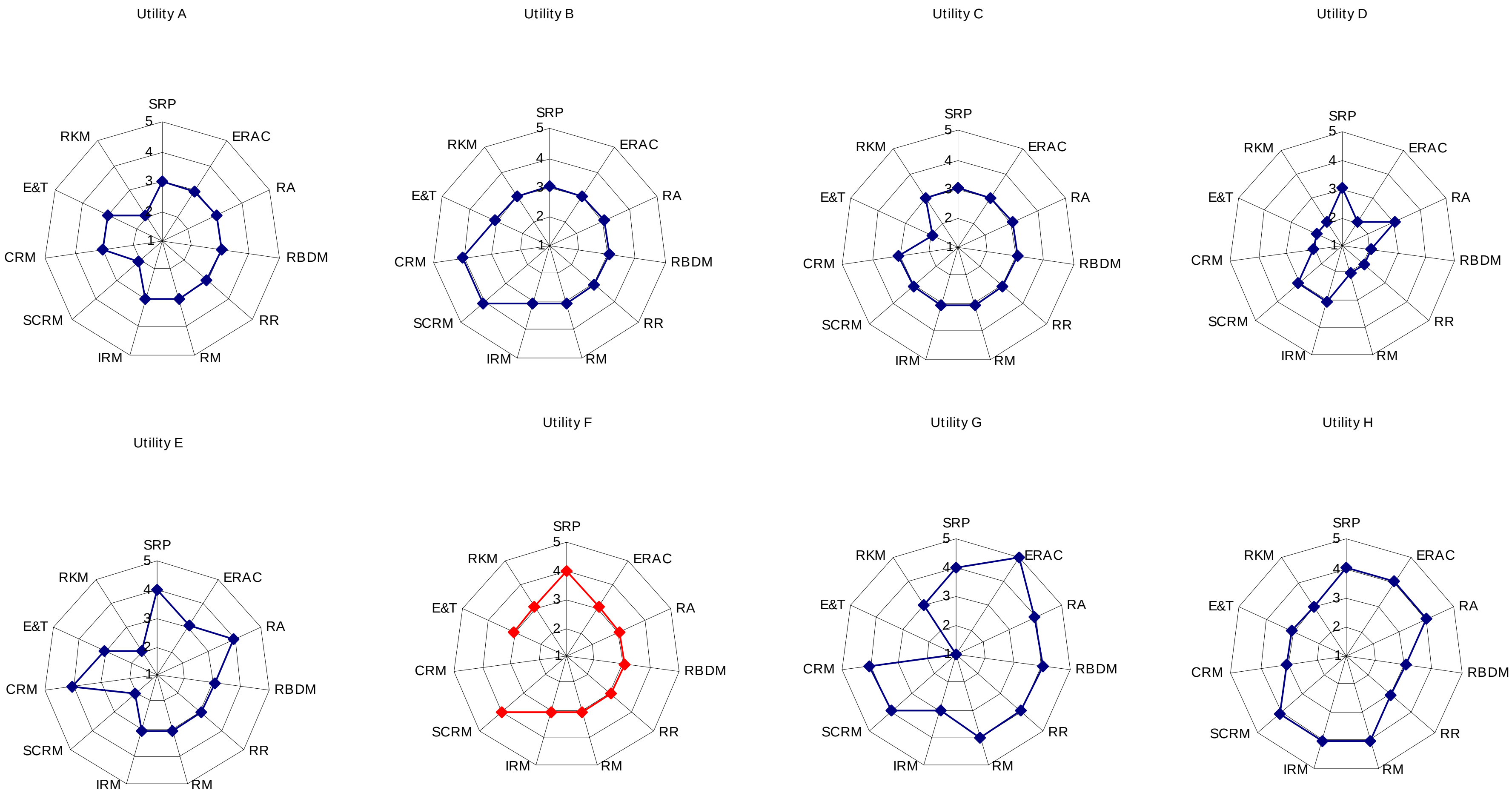


Fig. 2. Boxplot of the sample risk management process maturity by self-assessment.



* Red indicates uncertainty arising from incomplete questionnaire data.

Fig. 3. Spider diagrams of organisational maturity by self-assessment.