

Research Paper on Operational Risk

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Operational Risk Subcommittee of the Research Committee

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COMMONLY USED ACRONYMS

There are numerous acronyms used by insurance regulatory bodies and actuarial organizations around the world. This list is provided at the introduction of the research paper to facilitate reading. Not every acronym used in the paper is included in the following list; the list tends to include those that are used more frequently. Generally (though not always), the acronym is introduced in the research paper at its first reference in the text as opposed to in a section heading or list. The following list is presented in alphabetic order and not in the order in which the acronyms are found in the paper. Where it is not evident by the name, a country is identified with an acronym parenthetically.

ABI	Association of British Insurers
AMA	Advanced Measurement Approaches of Basel II
APRA	Australian Prudential Regulatory Authority
BIA	Basic Indicator Approach of Basel II
BMA	Bermuda Monetary Authority
BSCR	Bermuda Solvency Capital Requirement
BSCR	Basic Solvency Capital Requirement (as used by Solvency II and the FSB)
CIA	Canadian Institute of Actuaries
CIRA	Commercial Insurer Risk Assessment (as used by the BMA)
EIOPA	European Insurance and Occupational Pensions Authority, formerly known as the Committee of European Insurance and Occupational Pensions Supervisors (CEIOPS)
FSA	Financial Services Authority (United Kingdom) ¹
FSB	Financial Services Board (South Africa)
IAA	International Actuarial Association
IAIS	International Association of Insurance Supervisors
ICA	Individual Capital Assessment (as used by the Prudential Regulation Authority, United Kingdom)
ICM	Internal Capital Model (as used by the BMA)
ICP	Insurance Core Principles published by the IAIS
IFoA	Institute and Faculty of Actuaries
MAS	Monetary Authority of Singapore
MCR	Minimum Capital Requirement (as used by Solvency II)

¹ The FSA was abolished by the UK government effective April 1, 2013 and replaced with two separate regulatory authorities, the Financial Conduct Authority and Prudential Regulation Authority.

NAIC	National Association of Insurance Commissioners (United States)
ORIC	Operational Risk Consortium
ORSA	Own Risk and Solvency Assessment
ORX	Operational Riskdata eXchange Association
ORC	Operational risk categories
OSFI	Office of the Superintendent of Financial Institutions (Canada)
PPG	Prudential Practice Guide of the APRA
PRA	Prudential Regulation Authority (United Kingdom)
RBC	Risk-Based Capital (as used by the NAIC, the MAS, and in Korea)
SA	Standardised Approach of Basel II
SCR	Solvency Capital Requirement (as used by Solvency II and by the FSB)
SST	Swiss Solvency Test

INTRODUCTION

Operational risk losses are high profile, uncertain, and headline-grabbing. Despite the best endeavours of companies, material operational risk losses keep occurring. In the insurance sector, operational risk losses tend to be less dramatic than in banking, measured in the hundreds of millions rather than billions, and with losses crystallising over a longer period. It is therefore appropriate from an economic perspective, and mandatory from a regulatory perspective, to hold capital against this risk.

For Canadian federally regulated insurers, operational risk is a key risk that is required to be explicitly addressed within their own risk and solvency assessment (ORSA). Some provincial insurance regulators have also adopted the federal or similar ORSA guidelines as part of their supervisory framework. In addition, Québec-regulated insurers are required to account for operational risk when establishing their target capital ratio.

Research and surveys indicate that (globally) insurers have not historically directed as much time and effort to analyzing, modeling, and quantifying operational risk as they have for other categories of risk, such as insurance risk and asset-related risks. There is, however, a trend towards greater regulatory attention directed at the potential effect of operational risk for financial institutions; and as a result, insurers have recently begun to focus on how operational failures can affect their business. Consequently, methods for modeling operational risk capital are being developed, and the literature supporting such methods is being published at a greater rate than in the past.

The Canadian Institute of Actuaries (CIA) Committee on Risk Management and Capital Requirements (CRMCR) issued a request for proposals (RFP) in the fall of 2013 for the publication of a research paper addressing approaches to modeling operational risk capital for insurers.² Funding for this research project is provided by the CIA Research Committee.

Objectives of the Research Paper as Specified by the CIA

As part of the RFP, the CRMCR Operational Risk Subcommittee (CORS) was given the responsibility of overseeing the research project on behalf of the CIA. The CORS identified the requirements of the research paper by articulating three key research areas of concentration:

- Identification and categorization
 - Identification of a mutually exclusive and collectively exhaustive list of operational risks that affect insurers;
 - Inclusion of definitions for various key operational risk terminology (specifically definitions used in different regulatory regimes around the world);

² Throughout this research paper, the term “insurers” includes life, health, and property and casualty (P&C) insurers. P&C insurers are also known as general insurers or non-life insurers, particularly outside of Canada and the United States (U.S.). In this research paper, unless specifically noted otherwise, *insurers* refers to both primary insurers and reinsurers. Generally, the term “insurers” is used in this research paper instead of firms, which is the common term found in banking regulations and research related to operational risk for banks and financial institutions.

- Categorization of operational risks into those that are quantifiable in an economic capital context and those that require alternative treatment; and
- Description of a process to review and update the list of operational risks after the publication of the research paper, including the identification and categorization of emerging operational risks.
- Quantification methods
 - Description of different methods used to quantify operational risk capital including the advantages and disadvantages of each approach;
 - Discussion of implementation considerations, including model calibration methods, methods for reflecting offset due to strength of operational risk management programs, reporting, and other considerations;
 - Inclusion of a bibliography outlining the published literature (e.g., academic, regulatory, actuarial, business, and surveys) used in the preparation of the research paper; and
 - Description of a process for augmenting the summary of methods after the publication of the research paper.
- Contrast and compare
 - Existing quantification methods currently being used to determine regulatory capital; and
 - Emerging internal model³ approaches to operational risk quantification for capital purposes other than regulatory capital.

Organization of the Research Paper

To meet the objectives of the CIA, this research paper is organized in the following major sections and sub-sections:

- Introduction.
- Definitions of Key Operational Risk Terminology:
 - Basel Committee on Banking Supervision;
 - International Association of Insurance Supervisors;
 - Canada – Office of the Superintendent of Financial Institutions;
 - Europe – European Insurance and Occupational Pensions Authority;
 - Australia – Australian Prudential Regulation Authority;
 - Bermuda – Bermuda Monetary Authority;
 - United States (U.S.) – National Association of Insurance Commissioners; and

³ The term internal model is used in this research paper to refer to an economic capital model, also known as an internal capital model.

- Boundary between operational risk and other risk categories.
- Categorization of Operational Risks:
 - Basel II;
 - Institute and Faculty of Actuaries;
 - Australian Prudential Regulatory Authority;
 - Operational Risk Consortium; and
 - Operational Riskdata eXchange Association.
- Quantification Methods.
- Regulatory Regimes:
 - Basel II;
 - Australia;
 - Bermuda;
 - Canada;
 - Europe (Solvency II);
 - South Africa;
 - The U.S.; and
 - Other Countries.
- Next Steps.
- Bibliography.
- Appendices.

Research Approach

To conduct this research assignment, we began with the collection of numerous papers prepared by KPMG globally on the topic of operational risk. Next, we identified other key papers and publications through extensive internet research. We reached out by email to actuaries at the professional actuarial societies in:

- Australia;
- Ireland;
- South Africa;
- The United Kingdom (U.K.); and
- The U.S.

In addition, we contacted (by email and telephone) actuaries working in the area of operational risk from the International Actuarial Association (IAA). We reached out to representatives at insurance regulatory and industry bodies in Canada, the U.S., and at the International Association of Insurance Supervisors (IAIS).

We want to express special thanks to the following individuals who shared their time and provided links to valuable papers that they or their organizations had produced on the topic of operational risk:

- Peter Boller and Dave Sandberg, representing the IAA Regulation Committee;
- Joshua Corrigan, representing the Actuaries Institute Risk Management Practice Committee in Australia;
- Lou Felice, representing the National Association of the Insurance Commissioners in the U.S.;
- Yvonne Lynch and Eamonn Phelan, representing the Society of Actuaries in Ireland;
- Sarah Mathieson, Kevin McIver, and Patrick Kelliher representing the Institute and Faculty of Actuaries; and
- The Operational Riskdata eXchange Association for sharing the ORX Operational Risk Report and additional information about its risk classification approach.

A Word about Spelling and Quotes Used in the Research Paper

There are different practices with respect to spelling in the major English-speaking countries. This research paper represents a summary of regulatory requirements related to operational risk and approaches to quantifying this risk from around the globe. In describing the requirements of a particular regulatory regime, such as Basel II or Solvency II, the spelling set out by the governing body is used in this research paper. In all direct quotes, the spelling and punctuation are taken directly from the original source. Where not clear, acronyms contained within quoted material are defined in brackets.

Process to Review and Update Research on Operational Risk

It is expected that the major actuarial organizations around the world will continue to produce thought leadership on the topic of operational risk for insurers. The most efficient means to share the results of such work would be to create forums for ongoing communications in the area of economic capital modeling in general and operational risk specifically. Actuarial forums could use email, conference calls, web-based technology, and seminars for sharing not only the results of completed research efforts but also plans and priorities for future activities. Ideally, the actuarial organizations would work together to leverage off one another's efforts and not reproduce work that has already been undertaken.

DEFINITIONS OF KEY OPERATIONAL RISK TERMINOLOGY

This section includes definitions of key operational risk terminology from the following organizations:

- Basel Committee on Banking Supervision;
- International Association of Insurance Supervisors;
- Canada – Office of the Superintendent of Financial Institutions;
- Europe – European Insurance and Occupational Pensions Authority;
- Australia – Australian Prudential Regulation Authority;
- Bermuda – Bermuda Monetary Authority;
- South Africa – Financial Services Board; and
- The U.S. – National Association of Insurance Commissioners.

The formal definitions adopted by all of these organizations are essentially the same and are based on the definition originally set out for the regulation of international banks. In “Copulae and Operational Risks”, Dalla Valle et al. offer the following definition of operational risk:

A more precise definition of operational risks includes the direct or indirect losses caused by the inadequacy or malfunction of procedures, human resources and inner systems, or by external events. Basically, they are all losses due to human errors, technical or procedural problems or other causes not linked to the behavior of financial operators or market events.⁴

A discussion of the importance of identifying boundaries between operational risk and other risk categories concludes this section.

Basel Committee on Banking Supervision

The website of the Bank for International Settlements describes the Basel Committee on Banking Supervision (Basel Committee) as follows:

The Basel Committee is the primary global standard-setter for the prudential regulation of banks and provides a forum for cooperation on banking supervisory matters. Its mandate is to strengthen the regulation, supervision and practices of banks worldwide with the purpose of enhancing financial stability.⁵

⁴ L. Dalla Valle, D. Fantazzini, and P. Giudici, “Copulae and Operational Risks”, *International Journal of Risk Assessment and Management*, Vol. 9, No. 3, 2008.

http://economia.unipv.it/pagp/pagine_personal/dean/FDG_final%20copula%20operational%20risk.pdf.

⁵ <http://www.bis.org/bcbs/about.htm>, accessed January 13, 2014.

Through the implementation of Basel II, the Basel Committee sought to achieve international convergence for the supervisory regulations that govern the capital adequacy of internationally active banks.

Section V.A.644 of Basel II defines operational risk:

Operational risk is defined as the risk of loss resulting from inadequate or failed internal processes, people and systems or from external events. This definition includes legal risk, but excludes strategic and reputational risk.⁶

Legal risk is also defined within Basel II.

Legal risk includes, but is not limited to, exposure to fines, penalties, or punitive damages resulting from supervisory actions, as well as private settlements.⁷

Although the definitions of operational risk and legal risk set out by the Basel Committee were developed for the banking sector, they are also important for the insurance sector. Insurance regulations around the world are essentially using these same definitions.

Three Measurement Approaches for Banks Under Basel II

Basel II specifies three methods that banks can use to calculate operational risk capital charges. These methods represent a continuum of increasing sophistication and risk sensitivity and include: “(i) the Basic Indicator Approach, (ii) the Standardised Approach, and (iii) Advanced Measurement Approaches (AMA).”⁸ These three approaches are described in greater detail in the Regulatory Regime section of this research paper.

The Basel Committee's Definitions of General Operational Risk Terms

Operational Risk – Supervisory Guidelines for the Advanced Measurement Approaches (referred to as the *Basel Guidelines for the AMA*), published by the Basel Committee in July 2011, contains a glossary of the following key operational risk terms.

Basel II – “Basel II Framework” and “Basel II”, used interchangeably in this report, refer to the Basel Committee’s *International Convergence of Capital Measurement and Capital Standards: A Revised Framework* (June 2006).

⁶ Basel Committee on Banking Supervision, “International Convergence of Capital Measurement and Capital Standards – A Revised Framework – Comprehensive Version”, Bank for International Settlements, June 2006: s. 644. <https://www.bis.org/publ/bcbs128.pdf>.

⁷ Ibid. Legal risk can be further described as “... the risk of loss resulting from exposure to 1) to non-compliance with regulatory and/or statutory responsibilities and/or 2) adverse interpretation of and/or enforceability of contractual provisions. This includes the exposure to new laws as well as changes in interpretations of existing law(s) by appropriate authorities and exceeding authority as contained in the contract.” The source of this description is ORX Association, “Operational Risk Reporting Standards (ORRS) – Edition 2011”, Revised 12 July 2012: s. 3.1.2.

⁸ Basel Committee on Banking Supervision, “International Convergence of Capital Measurement and Capital Standards – A Revised Approach – Comprehensive Version”, Bank for International Settlements, June 2006: s. 645. <https://www.bis.org/publ/bcbs128.pdf>.

Operational risk capital – Unless explicitly mentioned otherwise, this term refers to the capital requirements for the AMA under pillar 1 of Basel II, as stated in paragraph 655 of the Basel II Framework.

Operational Risk management function (CORF) – This term refers to the independent operational risk management function that is responsible for the design and implementation of the bank's operational risk management framework, as mentioned in paragraph 666(a) of the Basel II Framework.

Operational Risk management framework (ORMF) – The ORMF consists of a bank's:

- (a) risk, organisational and governance structure;
- (b) policies, procedures and processes;
- (c) systems used by a bank in identifying, measuring, monitoring, controlling and mitigating operational risk; and
- (d) operational risk measurement system.

Operational Risk measurement system (ORMS) – A bank's ORMS consists of the systems and data used to measure operational risk in order to estimate the operational risk capital charge. Figure 1 in the Governance section of this paper illustrates the relationship between an ORMF and an ORMS.

Operational Risk Category (ORC) – An Operational Risk Category (ORC) or unit of measure is the level (for example, organisational unit, operational loss event type, risk category, etc.) at which the bank's quantification model generates a separate distribution for estimating potential operational losses. This term identifies a category of operational risk that is homogeneous in terms of the risks covered and the data available to analyse those risks.

Risk appetite and tolerance – "Risk appetite" is a high-level determination of how much risk a firm is willing to accept taking into account the risk/return attributes; it is often taken as a forward looking view of risk acceptance. "Risk tolerance" is a more specific determination of the level of variation a bank is willing to accept around business objectives that is often considered to be the amount of risk a bank is prepared to accept. In this document the terms are used synonymously.⁹

Definition of Operational Risk Gross Loss

A key finding in *Observed range of practice in key elements of Advanced Measurement Approaches (AMA)* published by the Basel Committee in July 2009 was that the absence of definitions in the Basel II text for

⁹ Basel Committee on Banking Supervision, "Operational Risk – Supervisory Guidelines for the Advanced Measurement Approaches", Bank for International Settlements, June 2011: 54-55. <http://www.bis.org/publ/bcbs196.pdf>.

“gross losses” and “recoveries” could lead to potentially large differences in capital calculations by banks.¹⁰ The Basel Committee reported: “The range of practice is broad, particularly with regard to how AMA banks use ‘net losses (gross loss net of non-insurance recoveries)’ for risk quantification purposes.”¹¹

As a result, the Basel Committee defined “gross loss” in its June 2011 publication *Operational Risk – Supervisory Guidelines for the Advanced Measurement Approaches*.

Gross loss definition

21. An operational risk loss can only arise from an operational risk event. The scope of operational risk loss refers to the type of events, whether or not having an impact on the financial statement, to be included in the operational risk database, and the purposes for which they are included (eg for management and/or measurement purposes).

22. A gross loss is a loss before recoveries of any type. Net loss is defined as the loss after taking into account the impact of recovery. A recovery is an independent occurrence, related to the original loss event, separate in time, in which funds or outflows of economic benefits are received from a third party. For an operational risk event, a bank should be able to identify gross loss, recoveries and any insurance recoveries.¹²

The *Basel Guidelines for the AMA* also includes details as to the items that should be included in or excluded from the gross loss computation.

International Association of Insurance Supervisors

The International Association of Insurance Supervisors (IAIS), established in 1994, “is a voluntary membership organization of insurance supervisors and regulators from more than 200 jurisdictions in [nearly] 140 countries.”¹³ The IAIS has more than 130 observers that include international institutions, professional associations, insurers, consultants, and other professionals participating in its activities. The IAIS is responsible for the establishment of international regulatory standards for insurance. In addition, the IAIS develops and assists in the implementation of principles and other supporting guidance for the supervision of the insurance sector.¹⁴

The IAIS Glossary defines operational risk as “the risk arising from the inadequacy or failure of internal systems, personnel, procedures or controls leading to financial loss. Operational risk also includes custody

¹⁰ Basel Committee on Banking Supervision, “Observed range of practice in key elements of Advanced Measurement Approaches (AMA)”, Bank for International Settlements, July 2009: 6. <https://www.bis.org/publ/bcbs160b.pdf>.

¹¹ Ibid.

¹² Basel Committee on Banking Supervision, “Operational Risk – Supervisory Guidelines for the Advanced Measurement Approaches”, Bank for International Settlements, June 2011: 6. <http://www.bis.org/publ/bcbs196.pdf>.

¹³ <http://www.iaisweb.org/About-the-IAIS-28>, accessed January 6, 2014.

¹⁴ Ibid.

risk.”¹⁵ Similar to the Basel Committee, the IAIS excludes strategic and reputational risk from its definition of operational risk.¹⁶

Throughout the world, insurance regulators are re-evaluating their existing frameworks for insurance regulation in light of the IAIS’ actions, particularly following the publication of the Insurance Core Principles (ICPs). In the “Introduction” section of *Insurance Core Principles, Standards, Guidance and Assessment Methodology*, (1 October 2011, including amendments 12 October 2012 and 19 October 2013) (referred to as ICPs-October 2013), the IAIS describes the ICPs and the hierarchy between ICP statements, standards, and guidance material.

The *Insurance Core Principles* (ICPs) provide a globally accepted framework for the supervision of the insurance sector. The ICP material is presented according to a hierarchy of supervisory material. The ICP statements are the highest level in the hierarchy and prescribe the essential elements that must be present in the supervisory regime in order to promote a financially sound insurance sector and provide an adequate level of policyholder protection. Standards are the next level in the hierarchy and are linked to specific ICP statements. Standards set out key high level requirements that are fundamental to the implementation of the ICP statement and should be met for a supervisory authority to demonstrate observance with the particular ICP. Guidance material is the lowest level in the hierarchy and typically supports the ICP statement and/or standards. Guidance material provides detail on how to implement an ICP statement or standard. Guidance material does not prescribe new requirements but describes what is meant by the ICP statement or standard and, where possible, provides examples of ways to implement the requirements.¹⁷

Canada – Office of the Superintendent of Financial Institutions

The Office of the Superintendent of Financial Institutions (OSFI), established in 1987 as an independent agency of the Government of Canada, “supervises and regulates federally registered banks and insurers, trust and loan companies, as well as private pension plans subject to federal oversight.”¹⁸ OSFI defines operational risk and legal risk in precisely the same manner as Basel II in its *Discussion Paper on OSFI’s Proposed Changes to the Regulatory Capital Framework for Federally Regulated Property and Casualty Insurers*.

OSFI expands its description of operational risk in Appendix A – Inherent Risk Categories and Ratings of its revised Supervisory Framework:

Operational risk arises from potential problems due to inadequate or failed internal processes, people and systems, or from external events. Operational risk includes legal risk i.e., potential unfavourable legal proceedings. Exposure to operational risk results from either

¹⁵ IAIS Glossary, accessed January 6, 2014, <http://www.iaisweb.org/index.cfm?pageID=47&vSearchLetter=o##>.

¹⁶ IAIS, “Insurance Core Principles, Standards, Guidance and Assessment Methodology”, (1 October 2011, including amendments 12 October 2012 and 19 October 2013): s. 16.1.13 and 17.7.5, accessed on February 27, 2014, <http://www.iaisweb.org/Insurance-Core-Principles-material-adopted-in-2011-795>.

¹⁷ Ibid.: s.6.

¹⁸ <http://www.osfi-bsif.gc.ca/Eng/Pages/default.aspx>, accessed January 16, 2014.

normal day-to-day operations (such as deficiencies or breakdowns in respect of transaction processing, fraud, physical security, money laundering and terrorist financing, data/information security, information technology systems, modeling, outsourcing, etc.) or a specific, unanticipated event (such as Enron-like litigation, court interpretations of a contract liability, natural disasters, loss of a key person, etc.).¹⁹

Europe – European Insurance and Occupational Pensions Authority

The European Insurance and Occupational Pensions Authority (EIOPA)²⁰, a part of the European System of Financial Supervision, is an independent advisory body to the European Parliament, the Council of the European Union, and the European Commission. “EIOPA’s core responsibilities are to support the stability of the financial system, transparency of markets and financial products as well as the protection of insurance policyholders, pension scheme members and beneficiaries.”²¹

Solvency II, first adopted by the Council of the European Union and the European Parliament in November 2009, is a major regulatory initiative applicable to insurers operating in the European Union. A detailed description of Solvency II is contained in the Regulatory Regimes section of this research paper.

In this research paper, the text of *Directive 2009/138/EC of the European Parliament and of the Council of 25 November 2009 on the taking-up and pursuit of the business of Insurance and Reinsurance* is referred to as the *Solvency II Directive*. In Article 33 – Definitions of the *Solvency II Directive*, operational risk is defined in a manner similar to the Basel II definition.

Operational risk means the risk of loss arising from inadequate or failed internal processes, personnel or systems, or from external events.²²

In the context of Solvency II, operational risk “shall include legal risks, and exclude risks arising from strategic decisions, as well as reputation risks.”²³

Australia – Australian Prudential Regulation Authority

The Australian Prudential Regulation Authority (APRA), established in 1998, “is the prudential regulator of the Australian financial services industry. It oversees banks, credit unions, building societies, general insurance

¹⁹ OSFI, “Supervisory Framework”, December 2010: 12, accessed on February 27, 2014, <http://www.osfi-bsif.gc.ca/Eng/fin/rai-eri/sp-ps/Pages/sff.aspx#18>.

²⁰ EIOPA was formerly known as the Committee of European Insurance and Occupational Pensions Supervisors (CEIOPS).

²¹ <https://eiopa.europa.eu/>, accessed January 1, 2014.

²² European Parliament and the Council of the European Union, “Directive 2009/138/EC of the European Parliament and of the Council of 25 November 2009 on the taking-up and pursuit of the business of Insurance and Reinsurance (Solvency II)”, *Official Journal of the European Union*, November 2009: Article 33. <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:335:0001:0155:EN:PDF>.

²³ CEIOPS, “CEIOPS’ Advice for Level 2 Implementing Measures on Solvency II: SCR standard formula – Article 111 (f) Operational Risk”, October 2009, CEIOPS-Doc-45/09: 4. https://www.ceiops.eu/fileadmin/tx_dam/files/consultations/consultationpapers/CP53/CEIOPS-L2-Final-Advice-on-Standard-Formula-operational-risk.pdf.

and reinsurance companies, life insurance, friendly societies, and most members of the superannuation industry.”²⁴

In Prudential Practice Guide (PPG) *GPG 230 Operational Risk* (February 2006), the APRA defines operational risk for general insurers.

Operational risk is the risk of financial loss resulting from inadequate or failed internal processes, people and systems or from external events. An insurer may determine a definition of operational risk appropriate to the size, business mix and complexity of its activities and operating environment. APRA envisages that this definition of operational risk would be clearly understood throughout the insurer in order to effectively identify and manage this risk.²⁵

The definition is similar for life insurers and is set out in *PPG LPG 230 Operational Risk* (March 2007).

Operational risk is defined as the risk of loss (including to policy owners) resulting from inadequate or failed internal processes, people and systems or from external events. This definition includes legal risk but excludes strategic and reputational risk. A life company would typically apply this definition as appropriate to the size, business mix and complexity of the life company’s activities and operating environment. APRA envisages that the definition and application of operational risk would be clearly understood throughout the life company in order for the life company to effectively identify and manage this risk.²⁶

Bermuda – Bermuda Monetary Authority

The Bermuda Monetary Authority (BMA), established under the Bermuda Monetary Authority Act 1969, supervises, regulates, and inspects financial institutions operating in or from within Bermuda. The BMA develops risk-based financial regulations for the supervision of Bermuda’s banks, trust companies, investment businesses, and insurance companies.²⁷

Definitions of operational risk can be found in the *Insurance (Prudential Standards) (Class C, Class D and Class E Solvency Requirement) Rules 2011* as well as in *Guidance Note #17 Commercial Insurer Risk Assessment* November 2008 (*CIRA Guidance Note*), which is applicable to class 4 insurers.²⁸ The definitions differ just slightly:

²⁴ <http://www.apra.gov.au/Pages/default.aspx>, accessed January 6, 2014.

²⁵ APRA, “Prudential Practice Guide GPG 230 – Operational Risk”, February 2006: s. 1.

<http://www.apra.gov.au/GI/PrudentialFramework/Documents/Prudential-Practice-Guide-GPG-230-Operational-Risk.pdf>

²⁶ APRA, “Prudential Practice Guide LPG 230 – Operational Risk”, March 2007: s. 1.

<http://www.apra.gov.au/lifs/PrudentialFramework/Documents/Prudential-Practice-Guide-LPG-230-Operational-Risk.pdf>

²⁷ <http://www.bma.bm/AboutUs/SitePages/Introduction%20to%20the%20BMA.aspx>, accessed January 10, 2014.

²⁸ Later sections of this research paper describe the regulatory and classification system for insurers operating in Bermuda.

Prudential Standards: ‘Operational risk’ means the risk of loss resulting from inadequate or failed internal processes, people and systems or from external events, including legal risk.²⁹

CIRA Guidance Note: The risk of loss arising from inadequate and/or failed internal processes, people, systems and/or external events. Operational risk also includes legal risks. Reputation risks arising from strategic decisions do not count as operational risks.³⁰

It is interesting to note that strategic, reputational, and legal/litigation risks are all identified separately from operational risk by the BMA in its *Insurance Code of Conduct*. Where strategic and reputational risks are excluded from operational risk in most other regulatory regimes, legal risk is typically included with operational risk.

South Africa – Financial Services Board

The Financial Services Board (FSB) was established in 1991 as an independent body to “oversee the South African Non-Banking Financial Services Industry.”³¹ The mission of FSB includes promotion of the financial soundness of financial institutions as well as the systemic stability of financial services industries. In FSB’s *Solvency and Assessment Management – Third South African Quantitative Impact Study (SA QIS3) – Technical Specifications*, the FSB describes operational risk in precisely the same manner as Basel II.

U.S. – National Association of Insurance Commissioners

The National Association of Insurance Commissions (NAIC) “is the U.S. standard-setting and regulatory support organization created and governed by the chief insurance regulators from the 50 states, the District of Columbia and five U.S. territories.”³² In *The Increasing Importance of Sound Operational Risk Management*, Felice and Hall describe operational risk as follows:

It refers to risk that result from shortfalls or inadequacies in the management of otherwise quantifiable risk, and from unforeseen external events that can impact an insurer. Operational risk potentially exists in all business activities; it encompasses a wide range of events and actions or inactions, such as fraud, human error, accounting errors, legal actions and system failures. Many of these problems arise during the course of conducting day-to-day business operations and are typically managed with little or no incident.³³

²⁹ BMA, “Insurance (Prudential Standards) (Class C, Class D and Class E Solvency Requirement) Rules 2011”: 4. [http://www.bma.bm/legislation/Insurance/Insurance%20\(Prudential%20Standards\)%20\(Class%20C%20Class%20D%20and%20Class%20E%20Solvency%20Requirement\)%20Rules%202011.pdf](http://www.bma.bm/legislation/Insurance/Insurance%20(Prudential%20Standards)%20(Class%20C%20Class%20D%20and%20Class%20E%20Solvency%20Requirement)%20Rules%202011.pdf)

³⁰ BMA, “Guidance Note #17 Commercial Insurer Risk Assessment”, November 2008: s.7. <http://www.bma.bm/document-centre/policy-and-guidance/INSURANCE%20II/Guidance%20Note%20No.%2017%20-%20Commercial%20Insurer%20Risk%20Assessment.pdf>.

There is a footnote link for definition of OR in Guidance Note to CEIOPS-DOC-23/01:QIS4 Technical Specifications.

³¹ <https://www.fsb.co.za/aboutUs/Pages/default.aspx>, accessed January 18, 2014.

³² http://www.naic.org/index_about.htm, accessed January 6, 2014.

³³ L. Felice and S. Hall, “The Increasing Importance of Sound Operational Risk Management”, *CIPR newsletter*, National Association of Insurance Commissioners and the Center for Insurance Policy and Research, October 2013: 3. http://www.naic.org/cipr_newsletter_archive/vol9_op_risk_management.pdf.

Felice and Hall state that the definition of operational risk used for banks by the Basel Committee is inappropriate for insurers due to the differences between the business models for banking and insurance. They believe that the characteristics and sources of operational risk differ:

Banks are in the borrowing and lending business, while insurers act as risk-takers and managers of insurable risks. Banking/investment banking is a transactional business, supported by short-term funding in the capital markets, whereas insurers' business is not transactional. Insurers cover risk exposures through reinsurance.³⁴

Boundary between Operational and Other Risk Categories

In *Operational Risk Reporting Standards 2011*, the Operational Riskdata eXchange Association (ORX)³⁵ notes that the definition of operational risk is broadly worded and could lead to an interpretation that is too far-reaching. An overly broad interpretation could be problematic for events that have aspects of operational risk and are already included in the capital requirements associated with other risk types (e.g., credit, market, or insurance risk). For general insurers, an example of potential double counting of risk could arise with insurance risks that may include an element of claim fraud (detected or undetected); fraud may be embedded in the claim ratios used to quantify underwriting risk and/or the historical claims development patterns that are used to quantify reserve risk. Operational risk solvency capital requirements generally focus on low frequency-high severity claim fraud events. It is important, nevertheless, to recognize that a certain amount of double counting may exist, reflecting a conservative approach to the overall quantification of capital requirements. The focus would be directed at adequate management actions to reduce the exposure to these types of boundary risk events.

An important objective in quantifying a capital charge associated with operational risk is to avoid double counting with other risk categories. To assist in differentiating operational risk from other risks, this section of the research paper sets out definitions for the following major risk categories:

- Credit risk;
- Market risk;
- Liquidity risk;
- Technical risk (insurance risk);
- Strategic risk;
- Business risk;
- Project risk; and
- Reputational risk.

³⁴ Ibid.: 4, with reference to M. Acharyya, "Why the current practice of operational risk management in insurance is fundamentally flawed – evidence from the field", *The Business School, Bournemouth University, United Kingdom*.

³⁵ ORX is described in the next section of this research paper.

The abstract to the discussion paper *A Common risk classification system for the actuarial profession – A discussion paper* by Kelliher et al. prepared for the Institute and Faculty of Actuaries (IFoA) states:

Risk terminology varies from organisation to organisation, and actuaries working in different organisations may use different terms to refer to the same risk, or use the same nomenclature for completely different risks. This paper sets out a classification system developed by the Risk Classification Working Party for the Profession that can be used as a common reference point for discussing risk. Actuaries would not be required to use this system, but it is hoped that common terminology would reduce the possibility of confusion in discussing risks.³⁶

In this research paper, the definitions for credit, market, liquidity, and technical risks are from the IAIS Glossary of Insurance Terms and the discussion paper of the Risk Classification Working Party (also referred to as the IFoA Working Party). The definitions for strategic, business, project, and reputational risks are from ORX's *Operational Risk Reporting Standards 2011*. The IFoA Working Party also set forth a definition for strategy risk that is included in the following discussion. Finally, the IFoA Working Party's descriptions of frictional risk aggregation and diversification risk are also presented.

Credit, Market, Liquidity, and Technical Risks

Credit Risk

The IAIS Glossary defines credit risk as:

The risk of financial loss resulting from default or movements in the credit rating assignment of issuers of securities (in the insurer's investment portfolio), debtors (e.g. mortgagors), or counterparties (e.g. on reinsurance contracts, derivative contracts or deposits) and intermediaries, to whom the company has an exposure. Credit risk includes default risk, downgrade or migration risk, indirect credit or spread risk, concentration risk and correlation risk. Sources of credit risk include investment counterparties, policyholders (through outstanding premiums), reinsurers, intermediaries and derivative counterparties.³⁷

Credit risk can also be described as:

The risk of loss a firm is exposed to if a counterparty fails to perform its contractual obligations (including failure to perform them in a timely manner) including losses from downgrades and other adverse changes to the likelihood of counterparty failure.³⁸

³⁶ P.O.J. Kelliher, D. Wilmot, J. Vij, and P.J.M. Klumpes, "A common risk classification system for the actuarial profession – a discussion paper", prepared for *The Institute and Faculty of Actuaries*, January 2011: 1.

<http://www.actuaries.org.uk/research-and-resources/documents/discussion-paper-common-risk-classification-system-actuarial-profes>

³⁷ IAIS Glossary, accessed January 6, 2014, <http://www.iaisweb.org/index.cfm?pageID=47&vSearchLetter=c##>.

³⁸ P.O.J. Kelliher, D. Wilmot, J. Vij, and P.J.M. Klumpes, "A common risk classification system for the actuarial profession – a discussion paper", prepared for *The Institute and Faculty of Actuaries*, January 2011: 4.

<http://www.actuaries.org.uk/research-and-resources/documents/discussion-paper-common-risk-classification-system-actuarial-profes>

Market Risk

The IAIS Glossary defines market risk as:

The risk to an insurer's financial condition arising from movements in the level or volatility of market prices of assets, liabilities and financial instruments, whether on all investments as a whole (general market risk) or on an individual investment (specific market risk).³⁹

Liquidity Risk

The IAIS Glossary defines liquidity risk as:

The risk that an insurer is unable to realise its investments and other assets in a timely manner in order to settle its financial obligations as they fall due.⁴⁰

Liquidity risk can also be described as:

The risk that a firm, although solvent, either does not have available sufficient financial resources to enable it to meet its obligations as they fall due, or can secure such resources only at excessive cost.⁴¹

Technical Risks (Insurance Risk)

Technical risks, as described by the IAIS Glossary:

Represent the various kinds of risk that are directly or indirectly associated with the technical or actuarial bases of calculation for premiums and technical provisions in both life and non-life insurance, as well as risks associated with operating expenses and excessive or uncoordinated growth. Technical risks result directly from the type of insurance business transacted. They differ depending on the class of insurance. Technical risks exist partly due to factors outside the company's area of business activities, and the company often may have little influence over these factors. The effect of such risks - if they materialise - is that the company may no longer be able to fully meet the guaranteed obligations using the funds established for this purpose, because either the claims frequency, the claims amounts, or the expenses for administration and settlement are higher than expected. [Equivalent term: Insurance risk]⁴²

Technical risks may also be referred to as insurance and demographic risks.⁴³

³⁹ IAIS Glossary, accessed January 6, 2014, <http://www.iaisweb.org/index.cfm?pageID=47&vSearchLetter=m##>.

⁴⁰ IAIS Glossary, accessed January 6, 2014, <http://www.iaisweb.org/index.cfm?pageID=47&vSearchLetter=l##>.

⁴¹ P.O.J. Kelliher, D. Wilmot, J. Vij, and P.J.M. Klumpes, "A common risk classification system for the actuarial profession – a discussion paper", prepared for *The Institute and Faculty of Actuaries*, January 2011: 5. <http://www.actuaries.org.uk/research-and-resources/documents/discussion-paper-common-risk-classification-system-actuarial-profes>.

⁴² IAIS Glossary, accessed January 6, 2014, <http://www.iaisweb.org/index.cfm?pageID=47&vSearchLetter=t##>.

⁴³ P.O.J. Kelliher, D. Wilmot, J. Vij, and P.J.M. Klumpes, "A common risk classification system for the actuarial profession – a discussion paper", prepared for *The Institute and Faculty of Actuaries*, January 2011: 4.

Strategic, Business, Project, and Reputational Risks

ORX Definitions

ORX sets out the following definitions of strategic, business, project, and reputational risks.

Strategic risk is defined as negative effects on capital and earnings due to business policy decisions, changes in the economic environment, deficient or insufficient implementation of decisions, or a failure to adapt to changes in the economic environment.

Business risk is defined as the risk that volumes may decline or margins may shrink, with no opportunity to offset the revenue declines with a reduction in costs. Business Risk captures the risk to the firm's future earnings, dividend distributions and equity price.

Project Risk is the risk that a project does not provide the agreed functionality, and/or complete within the Budget, and/or complete on time.

Reputational Risk is defined as the damage to the firm's reputation with relevant external parties, such as counterparts, clients, the shareholder community, governments, regulators etc.⁴⁴

Risk Classification (IFoA) Working Party Definitions

The IFoA Working Party identified a separate strategy risk category to address "threats to the realisation of the goodwill of a firm in relation to future new business as well as future projects/initiatives."⁴⁵ Strategy risk is broadly described by the IFoA Working Party and includes strategic, business, project, and reputational risk.

The IFoA Working Party identified two additional risk categories: (1) frictional risk and (2) aggregation and diversification risk. Frictional capital represents the excess amount over economic capital due to regulatory, accounting, and/or rating agency requirements. This category covers:

- Problems related to a firm's operating structure such as the fungibility of capital tied up in subsidiaries;
- Tax risks (e.g., changes in the corporation tax regime); and
- Any increase in economic capital requirements arising in the absence of a change in the economic risk profile of the firm (e.g., increase in the confidence level required).⁴⁶

<http://www.actuaries.org.uk/research-and-resources/documents/discussion-paper-common-risk-classification-system-actuarial-profes>.

⁴⁴ Project is defined by ORX as "a temporary endeavour undertaken to create a unique product, service or result. A project has a definite beginning and end. The end of the project is reached when the project's objectives have been achieved or when the project is terminated because it will not or cannot achieve its objectives, or the need for the project no longer exists." Source: ORX Association, "Operational Risk Reporting Standards (ORRS) – Edition 2011", Revised 12 July 2012: s.3.4.3, s.3.4.5, s.3.4.4, and s. 3.4.6.

⁴⁵ P.O.J. Kelliher, D. Wilmot, J. Vij, and P.J.M. Klumpes, "A common risk classification system for the actuarial profession – a discussion paper", prepared for *The Institute and Faculty of Actuaries*, January 2011: 5.

<http://www.actuaries.org.uk/research-and-resources/documents/discussion-paper-common-risk-classification-system-actuarial-profes>.

Aggregation and diversification risk is defined as:

The risk that the aggregate of risks across individual categories is greater than the sum of the individual parts and/or that anticipated diversification benefits are not fully realised.⁴⁷

The IFoA Working Party noted that:

... aggregation and diversification is also considered as a sub-set of each high-level category e.g. Market Risk will include an Aggregation and Diversification Risk category to address the combined impact of individual market risks such as equities and property. However this high-level category will consider impact across the other high-level categories e.g. between Market and Operational Risks.⁴⁸

⁴⁶ P.O.J. Kelliher, D. Wilmot, J. Vij, and P.J.M. Klumpes, "A common risk classification system for the actuarial profession – a discussion paper", prepared for *The Institute and Faculty of Actuaries*, January 2011: 6.

<http://www.actuaries.org.uk/research-and-resources/documents/discussion-paper-common-risk-classification-system-actuarial-profes>.

⁴⁷ Ibid.

⁴⁸ Ibid.

CATEGORIZATION OF OPERATIONAL RISKS

The CORS requested a comprehensive and mutually exclusive list of operational risks. This section provides lists of operational risk categories (ORCs) established by the following:

- Basel II;
- IFoA and the Risk Classification Working Party;
- APRA PPGs;
- BMA and the *Insurance Code of Conduct*;
- Operational Risk Consortium; and
- ORX.

Basel II

For banks following the Standardized Approach of Basel II, activities are divided into eight business lines:

- Corporate finance;
- Trading and sales;
- Retail banking;
- Commercial banking;
- Payment and settlement;
- Agency services;
- Asset management; and
- Retail brokerage.

The business lines are described in detail in Annex 9 of Basel II and reproduced as Appendix A of this research paper. Basel II further differentiates operational risk by seven event types:

- Internal fraud;
- External fraud;
- Employment practices and workplace safety;
- Clients, products and business practices;
- Damage to physical assets;
- Business disruption and system failures; and
- Execution, delivery and process management.

The event types are described in detail in Annex 10 of Basel II and reproduced as Appendix B of this research paper. Each of the Basel II event types is also applicable to insurers as evident in the following examples:

- Internal fraud – misappropriation of assets, tax evasion, insider trading, and bribery;
- External fraud – theft of customer data, hacking damage, third-party theft, and forgery;
- Employment practices and workplace safety – poor customer service, discrimination, workers compensation, health, and safety;
- Clients, products and business practices – mis-selling, mis-pricing, legal, and regulatory;
- Damage to physical assets – natural disasters, terrorism, and vandalism;
- Business disruption and system failures – utility disruptions, software failures, and hardware failures; and
- Execution, delivery and process management – poor change management, transaction errors, accounting errors, and bonus calculation.

IFoA and the Risk Classification Working Party

A Common risk classification system for the actuarial profession – A discussion paper contains the most detailed and comprehensive list of operational risks facing insurers. In deriving the common risk classification system, the IFoA Working Party applied the following key principles:

- Event-based rather than cause-based classification;
- Focus on gross risk, generally excluding control failures; and
- No distinction in the classification of risk for the entity level at which the risk occurs.⁴⁹

While the IFoA Working Party selected an event-based classification system, they noted that causal analysis is essential to understanding risk. However, a risk classification system based on cause can be challenging as multiple causes may lead to a specific event; a problem arises in determining how far back to go in causal analysis. The IFoA Working Party stated:

Because of such complications, the Working Party opted for event-based classification. However we would stress that our purpose is limited to creating a common risk “language” for use between actuaries, and that risk management requires that the causes of events be rigorously analysed and understood.⁵⁰

With respect to ignoring the entity level, the IFoA Working Party stated:

⁴⁹ P.O.J. Kelliher, D. Wilmot, J. Vij, and P.J.M. Klumpes, “A common risk classification system for the actuarial profession – a discussion paper”, prepared for *The Institute and Faculty of Actuaries*, January 2011: 7.

<http://www.actuaries.org.uk/research-and-resources/documents/discussion-paper-common-risk-classification-system-actuarial-profes>.

Other key principles are set out on page 7 of the discussion paper.

⁵⁰ Ibid.: 8.

No distinction is made in the classification for the entity level at which the risk arises i.e. an interest rate swap exposure in an insurance sub-fund is not classed any differently from say a similar swap at holding company level or an exposure to interest rate movements in a firm's defined benefit pension scheme. Similarly it does not distinguish between the level at which a risk may be managed (e.g. as "business as usual" or warranting Board consideration). This will vary from firm to firm depending on their circumstances. The only explicit account taken of corporate structure in the classification relates to fungibility of capital issues covered under Frictional Risk, and this would be more of an issue for a holding company than a particular subsidiary.

However, the Working Party would note that corporate structure is an important consideration in ERM [enterprise risk management] and risk governance arrangements.⁵¹

The IFoA Working Party identified 23 ORCs based to a large extent on the categories used by Operational Risk Consortium (ORIC), which in turn are based on categories set out in Basel II.⁵² The 23 ORCs identified in Appendix G of the IFoA's discussion paper are:

- Internal Fraud, split
 - Unauthorised Activity e.g. rogue trading;
 - Theft and Fraud;
- External Fraud, split
 - Theft and Fraud;
 - Systems Security e.g. "phishing";
- Employment Practices and Workplace Safety, split
 - Employee Relations e.g. strikes; constructive dismissal claims;
 - Health and Safety;
 - Diversity and Discrimination;
- Clients, Products & Business Practices, split
 - Suitability, Disclosure & Fiduciary e.g. breach of faith;
 - Improper Business or Market Practices e.g. bribery; money-laundering;
 - Product Flaws;
 - Selection, Sponsorship & Exposure e.g. failure to vet client status;
 - Advisory Activities & Misselling;

⁵¹ P.O.J. Kelliher, D. Wilmot, J. Vij, and P.J.M. Klumpes, "A common risk classification system for the actuarial profession – a discussion paper", prepared for *The Institute and Faculty of Actuaries*, January 2011: 8.

<http://www.actuaries.org.uk/research-and-resources/documents/discussion-paper-common-risk-classification-system-actuarial-profes>.

⁵² *Ibid.*: Appendix G.

- Damage to Physical Assets
- Business disruption and system failures e.g. computer crashes
- Execution, Delivery & Process Management, split
 - Customer Intake and Documentation – errors in setting up contracts;
 - Transaction Capture, Execution & Maintenance – errors in servicing of contracts as well as general transactions such as supplier payment;
 - Customer / Client Account Management – errors in claims etc.;
 - Monitoring and Reporting e.g. account misstatements;
 - Trade Counterparties e.g. asset managers; reinsurers;
 - Vendors & Suppliers e.g. outsourcers;
- Legal and Regulatory Risk relating to costs incurred from complying with changes in regulations; from new laws impacting on embedded value (including the seizure of assets); and from adverse variations in regulatory levies such as those for the Financial Services Compensation Scheme (FSCS).
- Operational Risk Capital – not covered in ABI [Association of British Insurers] ORIC but emerging loss experience can have a “knock on” impact on OR [operational risk] capital requirements, as may scenario analysis and model changes.
- Aggregation and Diversification e.g. weak corporate governance leading to multiple losses across categories.

Like Market Risk, this last category relates only to anticipated diversification benefits between Operational Risks not being realised.⁵³

Within the 23 ORCs, more than 340 sub-categories were identified reflecting the wide range of operational risks that confront insurers. The IFoA Working Party produced an MS Excel spreadsheet that includes detailed classification with Stage 2 and Stage 3 classifications (i.e., further categorization that is more finely refined by “stages”). For both stages, the following are included in the MS Excel file:

- Operational risk type;
- Description;
- Comment; and
- Demarcation notes.

⁵³ P.O.J. Kelliher, D. Wilmot, J. Vij, and P.J.M. Klumpes, “A common risk classification system for the actuarial profession – a discussion paper”, prepared for *The Institute and Faculty of Actuaries*, January 2011: 32. <http://www.actuaries.org.uk/research-and-resources/documents/discussion-paper-common-risk-classification-system-actuarial-profes>.

The work of the IFoA Working Party on operational risk is available on the IFoA website by using the following link: <http://www.actuaries.org.uk/research-and-resources/documents/underlying-spreadsheet-discussion-paper-common-risk-classification->.

Finally, in concluding the operational risk section of the discussion paper, the IFoA Working Party addressed the topics of:

- Risk and reward; and
- Risk and uncertainty.

The IFoA Working Party commented that the classification of risks is typically viewed in terms of the adverse effect of risk to economic value and does not recognize the possible reward to accepting a risk. “However the Working Party would note that for wider ERM purposes, risks cannot be considered in isolation to reward.”⁵⁴

Uncertainty is described by the IFoA Working Party as follows:

Uncertainty is a shortfall of knowledge or information about what kinds of outcome may occur, the factors which may influence future outcomes, and the likelihood or impact of various outcomes. These possible outcomes can be divided into unfavourable, expected or favourable, according to present perceptions (which may change in future). Risk in the context of this paper is exposure to unfavourable outcomes, but it worth noting there may be upside risk in terms of exposure to favourable outcomes e.g. better than expected lapse rates.⁵⁵

APRA Prudential Practice Guides (PPGs)

In Australia, PPGs provide guidance on APRA’s view of sound practice in specific areas. PPGs frequently address legal requirements that arise from legislation, regulations, or APRA’s prudential standards; PPGs do not in themselves create enforceable standards. *Prudential Practice Guide GPG 230 Operational Risk* (February 2006) (PPG GPG 230) addresses operational risk for general insurers; and *Prudential Practice Guide LPG 230 Operational Risk* (March 2007) (PPG LPG 230) addresses operational risk for life insurers.

General Insurers

For general insurers, APRA states that the management of operational risk would typically include (but is not limited to) the risks associated with:

- Outsourcing;
- Business continuity;

⁵⁴ P.O.J. Kelliher, D. Wilmot, J. Vij, and P.J.M. Klumpes, “A common risk classification system for the actuarial profession – a discussion paper”, prepared for *The Institute and Faculty of Actuaries*, January 2011: 9.

<http://www.actuaries.org.uk/research-and-resources/documents/discussion-paper-common-risk-classification-system-actuarial-profes>.

⁵⁵ Ibid.

- Inadequate human resources;
- Internal and external fraud;
- Project management;
- Underwriting and claims;
- Business processes; and
- Introduction of new products.⁵⁶

PPG GPG 230 provides further details for the risks associated with human resources, fraud, and project management.

Life Insurers

For life insurers, APRA states that the management of operational risk would include consideration of a broad range of risks for current and legacy operations including:

- Information technology;
- Human resources;
- Internal and external fraud;
- Project management;
- Information systems;
- Outsourcing;
- Product administration (including processing, transactions, production of documentation; underwriting and claims);
- Unit pricing;
- Business processes including non-outsourced third party arrangements; and
- Introducing new products.⁵⁷

PPG LPG 230 provides further details for the risks associated with information technology, human resources, fraud, and information systems.

⁵⁶ APRA, "Prudential Practice Guide GPG 230 – Operational Risk", February 2006: s.2.

<http://www.apra.gov.au/GI/PrudentialFramework/Documents/Prudential-Practice-Guide-GPG-230-Operational-Risk.pdf>

⁵⁷ APRA, "Prudential Practice Guide LPG 230 – Operational Risk", March 2007: s.2.

<http://www.apra.gov.au/lifs/PrudentialFramework/Documents/Prudential-Practice-Guide-LPG-230-Operational-Risk.pdf>.

BMA and the *Insurance Code of Conduct*

In Bermuda, the *Insurance Code of Conduct*, which came into effect on July 1, 2010 with compliance required by July 1, 2011, establishes duties, requirements, and standards for Bermuda insurers (including captive insurers). The *Insurance Code of Conduct* categorizes “material risks” in the following categories:

- Insurance underwriting risk;
- Investment, liquidity, and concentration risk;
- Market risk;
- Credit risk;
- Systems and operations risk (operational risk);
- Group risk;
- Strategic risk;
- Reputational risk; and
- Legal / litigation risk.

The *Insurance Code of Conduct* specifically identifies eight possible examples of operational risk; each of these risks is defined in the *CIRA Guidance Note*, which is applicable to class 4 insurers.⁵⁸ The eight examples of operational risk include:

- a. Business Process Risks which includes data entry and data processing errors arising from application design misspecifications.
- b. Business Continuity Risks which includes risks that threaten or disrupt an insurer’s continuous operations such as risks arising from natural and man-made hazards.
- c. Compliance Risks which includes legal and regulatory breaches.
- d. Information Systems Risks which includes unauthorized access to systems and data, data loss, utility disruptions, software and hardware failures, and inability to access information systems.
- e. Distribution Channels Risks which includes inexperienced or incapable brokers/agents.
- f. Fraud Risks which includes intentional misconduct or unauthorized activities such as misappropriation of assets, information theft, forgery, and fraudulent claims.
- g. Human Resources Risks which includes key person risk, unethical staff (not including fraud), inexperienced or incapable staff, training, retention, and communication failures.
- h. Outsourcing Risks which includes communication failures, and incapable outsourcing partners.⁵⁹

⁵⁸ Further information about Bermuda insurance regulation and the classification of insurers is provided in the Regulatory Regime section of this research paper.

2011 Presentation to Actuarial Society of South Africa

At the Actuarial Society of South Africa's 2011 Convention, R. den Heever and J. Slawski discussed ORCs for insurers in their presentation titled *Operational Risk Management*. They identified the following ORCs:

- Financial reporting;
- Taxation;
- Internal fraud;
- External fraud;
- Premises;
- Data and records;
- Transactions;
- Product development;
- Payments;
- Third-party suppliers;
- Technology;
- People;
- Legal;
- Regulatory; and
- Compliance.

ORIC

ORIC was founded in 2005 by the Association of British Insurers (ABI) and 16 insurers in part as a response to new solvency regulations for insurers in the United Kingdom, as set out by the UK Financial Services Authority (FSA), and Solvency II. The FSA and Solvency II both consider operational risk in the determination of an insurer's solvency requirements. The purpose of ORIC is to provide thought leadership about operational risk and to enhance the quantitative and qualitative understanding of operational risk. ORIC maintains an operational risk loss database that currently includes more than 4,000 loss events from the past six years.

⁵⁹ BMA, "Guidance Note #17 Commercial Insurer Risk Assessment", November 2008: pp 4 and 5.
<http://www.bma.bm/document-centre/policy-and-guidance/INSURANCE%20II/Guidance%20Note%20No.%2017%20-%20Commercial%20Insurer%20Risk%20Assessment.pdf>.

The loss events recorded by ORIC include information on losses due to failed people, processes, systems or external events. ORIC relies on the Level 1 and 2 categories set out by Basel II and has developed a further Level 3 categorization to increase the granularity of the database.

ORX

ORX, founded in 2002, created “a platform for the secure and anonymised exchange of high-quality operational risk loss data. The ORX Global Loss Database contains 327,465 operational risk loss events, each event over €20,000 in value, to a total value of €166 billion.”⁶⁰ ORX is owned and controlled by its 67 members, which include leading banks from 21 countries. Confidential data are only available to contributing members, but high-level data abstracts are available to the general public. The latest report available, *ORX Operational Risk Loss Report 2014*,⁶¹ includes operational risk loss data from events occurring in 2008 through 2013.

The information included in the ORX database consists of:

- Business line – representing “profit centres where the revenues are generated from third-parties, not allocations from other parts of the firm”⁶²;
- Event type – a description of what happened;
- Product (including services) – representing the sources of revenue for a bank through direct or indirect fees;
- Bundled products – a package of products or services with a single fee charged for the package or “a product which is offered on a standalone basis by one bank is provided as an adjunct or incidental service in association with a ‘primary’ product by another bank”;⁶³
- Process – defined as “a set of coordinated tasks and activities that will lead to accomplishing a specific organisational goal”;⁶⁴ and
- Large loss attributes – including:
 - Alleged causes;
 - Jurisdiction / choice of law;
 - Counterparty / claimant type;
 - Role of the firm; and
 - Environmental volatility.

⁶⁰ <http://www.orx.org/pages/AboutORX.aspx>, accessed January 6, 2014.

⁶¹ <http://www.orx.org/Pages/ORXData.aspx>, accessed October 10, 2014.

⁶² ORX Association, “Operational Risk Reporting Standards (ORRS) – Edition 2011”, Revised July 12, 2012: s.5.1.

⁶³ *Ibid.*: s.5.3.1.

⁶⁴ *Ibid.*: s.5.4.

Business lines and event types are generally similar to the descriptions set out in Basel II. Large losses are defined as a single or group of associated losses with gross loss amount equal to or greater than 10 million Euros.⁶⁵

ORCs that are Quantifiable and Those Requiring Alternative Treatment

As the banks have been modeling operational risk for a longer period of time and have dedicated significant resources to this modeling, the Basel Committee will continue to be an important source of information for the insurance community. While there are differences in the exact ORCs facing insurers and those facing banking institutions, there is tremendous value for actuaries in reviewing the papers of the Basel Committee. There are important lessons to be learned and good practice to borrow from.

As part of the first research area of concentration, the CIA specifically requested the segmentation of ORCs into those that are quantifiable from a capital context and those that require alternative treatment. The extensive research conducted in preparation for this research paper did not uncover any papers that differentiated in any substantive way between those ORCs that can be readily quantifiable and those requiring alternative treatment. In fact, in the insurance literature, there are repeated references to the significant challenges in the quantification of operational risk in general. In *ICPs-October 2011*, the IAIS comments twice on the difficulty in quantifying some operational risks.⁶⁶ Section 17.7.5 of *ICPs-October 2011* states:

Treatment of risks which are difficult to quantify

17.7.5 The IAIS recognises that some risks, such as strategic risk, reputational risk, liquidity risk and operational risk, are less readily quantifiable than the other main categories of risks. Operational risk, for example, is diverse in its composition and depends on the quality of systems and controls in place. The measurement of operational risk, in particular, may suffer from a lack of sufficiently uniform and robust data and well developed valuation methods.⁶⁷

The Basel Committee addresses ORCs at length in the following publications:

- The *Basel Guidelines for the AMA*, “Modeling” section; and
- *Observed range of practice in key elements of Advanced Measurement Approaches (AMA)* (July 2009), “Section V – Modeling / quantification issues”.

Two types of operational risk that were specifically noted as particularly difficult to quantify were legal risk⁶⁸ and incompetence that is associated with people risk.⁶⁹

⁶⁵ ORX Association, “Operational Risk Reporting Standards (ORRS) – Edition 2011”, Revised 12 July 2012: s.5.5.

⁶⁶ IAIS, “Insurance Core Principles, Standards, Guidance and Assessment Methodology”, (1 October 2011, including amendments 12 October 2012 and 19 October 2013): s.16.1.13 and 17.7.5, accessed February 27, 2014, <http://www.iaisweb.org/Insurance-Core-Principles-material-adopted-in-2011-795>.

⁶⁷ *Ibid.*: 17.7.5.

⁶⁸ V. Chavez-Demoulin, P. Embrechts, and J. Nešlehová, “Quantitative Models for Operational Risk: Extremes, Dependence and Aggregation”, presented to the *Federal Reserve Bank of Boston*, May 18-20, 2005: 2. http://www.math.ethz.ch/~embrecht/ftp/manuscript_cen.pdf.

⁶⁹ P. Embrechts, H. Furrer, and R. Kaufmann, “Quantifying Regulatory Capital for Operational Risk”, Research supported by *Credit Suisse Group, Swiss Re* and *UBS AG* through *RiskLab*, Switzerland, 2003: pp 10 and 11. <http://www.math.ethz.ch/~embrecht/ftp/OPRiskWeb.pdf>

ORCs and the Necessity for Capital

In *Quantifying Operational Risk in Life Insurance Companies*, Dexter et al. report that once ORCs are identified and understood, the next step is to determine if capital is necessary for each risk. Possible reasons to not require capital include:

- The risk does not impact the solvency balance sheet; or
- There are more appropriate mitigating actions in response to the risk; or
- The impact is covered elsewhere in the ICA [individual capital assessment]; or
- The impact is not material for ICA purposes.⁷⁰

Dexter et al, provide a description for each of these categories and examples of risk types that are not reproduced in this research paper.

⁷⁰ N. Dexter, C. Ford, P. Jakahria, P. Kelliher, D. McCall, et al., "Quantifying Operational Risk in Life Insurance Companies", Developed by the Life Operational Risk working Party, 2006: 11.
<http://www.actuaries.org.uk/system/files/documents/pdf/opriskcapital.pdf>

QUANTIFICATION METHODS

Introduction

Literature Primarily Focused on Banks

There are countless papers on the topic of operational risk management and measurement, particularly directed at banks. These papers provide detailed theoretical presentations of various methods used to quantify operational risk. They also present the results of comprehensive case studies, some based on the historical experience of individual banks and others based on aggregated data for multiple institutions. One of the greatest challenges in preparing this research paper was culling through the multitude of papers with the goal to meet the objectives of the CIA. Finding up-to-date literature specifically applicable to insurers was also a challenge. While there are papers directed at insurers, they are far fewer than those directed at banks. Furthermore, some of the papers for insurers are now dated given the continued advancements in economic capital modeling, Solvency II, and the activities of the IAIS.

One of the reasons explaining the relatively limited number of papers focusing on operational risk for insurers is that many insurers currently rely on standard formulae developed by regulatory authorities to calculate operational risk capital instead of quantifying operational risk using internal models. Those insurers who do rely on models to quantify operational risk tend to be part of large insurance groups with a head office located in certain countries, such as the U.K. and Germany. Moreover, even when an insurer develops and uses an internal model to estimate capital requirements, it seldom models all risk categories with the internal model and instead relies on a standard formula approach for quantifying its operational risk. Key reasons why many insurers are not yet modeling operational risk include:

- The lack of credible data due to the relatively short time span for which historical operational risk loss data have been collected;
- The role of the internal control environment and its ever-changing nature, which makes historical operational risk loss data somewhat irrelevant;
- The important role of infrequent but very large operational risk loss events;
- The continued state of development for insurers' internal models and the rigorous governance framework surrounding the use of such models; and
- Cost-benefit issues that result in questions about the value of internal models given their significant implementation costs.

IAIS' Requirements for Internal Models

The *ICPs-October 2013* set out the requirements that insurers are required to meet in order to rely on internal models for the determination of regulatory capital. Specifically, the IAIS requires:

- Prior supervisory approval for the insurer's use of an internal model for the purpose of calculating regulatory capital requirements;

- The insurer to adopt risk modelling techniques and approaches appropriate to the nature, scale and complexity of its current risks and those incorporated within its risk strategy and business objectives in constructing its internal model for regulatory capital purposes;
- The insurer to validate an internal model to be used for regulatory capital purposes by subjecting it, as a minimum, to three tests: “statistical quality test”, “calibration test” and “use test”; and
- The insurer to demonstrate that the model is appropriate for regulatory capital purposes and to demonstrate the results of each of the three tests.⁷¹

The *ICP-October 2013* provides supplementary general discussion of the three required tests:

The “statistical quality test” and the “use test” are envisaged to be more insurer-specific measures which should allow the supervisor to gain an understanding of how a particular insurer has embedded its internal model within its business. The “calibration test” would be used by the supervisor to assess the results from the internal model in comparison to the insurer’s regulatory capital requirements and to those of other insurers.⁷²

The statistical quality test for internal models is addressed in Section 17.14 of *ICP-October 2013*:

17.14 Where a supervisor allows the use of internal models to determine regulatory capital requirements, the supervisor requires:

- the insurer to conduct a “statistical quality test” which assesses the base quantitative methodology of the internal model, to demonstrate the appropriateness of this methodology, including the choice of model inputs and parameters, and to justify the assumptions underlying the model; and
- that the determination of the regulatory capital requirement using an internal model addresses the overall risk position of the insurer and that the underlying data used in the model is accurate and complete.⁷³

Section 17.15 of *ICP-October 2013* addresses the calibration test for internal models:

17.15 Where a supervisor allows the use of internal models to determine regulatory capital requirements, the supervisor requires the insurer to conduct a “calibration test” to demonstrate that the regulatory capital requirement determined by the internal model satisfies the specified modelling criteria.⁷⁴

Finally, the use test and governance for internal models is described in Section 17.16 of *ICP-October 2013*.

17.16 Where a supervisor allows the use of internal models to determine regulatory capital requirements, the supervisor requires:

⁷¹ IAIS, “Insurance Core Principles, Standards, Guidance and Assessment Methodology”, (1 October 2011, including amendments 12 October 2012 and 19 October 2013): s.17.13, accessed on February 27, 2014, <http://www.iaisweb.org/Insurance-Core-Principles-material-adopted-in-2011-795>.

⁷² Ibid.: s.17.13.5.

⁷³ Ibid.: s.17.14.

⁷⁴ Ibid.: s.17.15.

- the insurer to fully embed the internal model, its methodologies and results, into the insurer's risk strategy and operational processes (the "use test");
- the insurer's Board and Senior Management to have overall control of and responsibility for the construction and use of the internal model for risk management purposes, and ensure sufficient understanding of the model's construction at appropriate levels within the insurer's organisational structure. In particular, the supervisor requires the insurer's Board and Senior Management to understand the consequences of the internal model's outputs and limitations for risk and capital management decisions; and
- the insurer to have adequate governance and internal controls in place with respect to the internal model.⁷⁵

To receive approval for the use of an internal model to determine operational risk capital requirements, an insurer would have to meet each of these three tests for that part of the internal model used to quantify operational risk. In practice, these three tests have presented significant challenges that many insurers are not yet prepared to meet.

Papers on Operational Risk Specifically for Insurers

As noted previously, a literature search for papers discussing the topic of operational risk and particularly quantification methods for this type of risk results in a much larger number of papers focused on the banking industry than on the insurance industry. Three papers specifically addressing the quantification of operational risk for insurers are:

- General Insurance Research Organisation (GIRO) Working Party, including M.H. Tripp, H.L. Bradley, R. Devitt, G.C. Orros, G.L. Overton, et al., *Quantifying Operational Risk in General Insurance Companies*, March 22, 2004;
- Life Operational Risk Working Party, including N. Dexter, C. Ford, P. Jakahria, P. Kelliher, D. McCall, et al., *Quantifying Operational Risk in Life Insurance Companies*, May 26, 2006; and
- J. Corrigan and P. Luraschi, *Operational risk modelling framework*, Milliman Research Report, February 13, 2013.

The first paper, by Tripp et al., groups assessment and quantification methods for operational risk into families under the following broad headings:

- Statistical/curve fitting including empirical studies, maximum loss approach, theoretical probability distribution functions, and regression analysis;
- Frequency-severity analysis including extreme value theory and stochastic differential equations;
- Statistical (Bayesian) including systems (dynamic) models, influence diagrams, Bayesian belief networks and Bayesian causal models, process maps and assessments, and neural networks;

⁷⁵ IAIS, "Insurance Core Principles, Standards, Guidance and Assessment Methodology", (1 October 2011, including amendments 12 October 2012 and 19 October 2013): s.17.16, accessed on February 27, 2014, <http://www.iaisweb.org/Insurance-Core-Principles-material-adopted-in-2011-795>.

- Expert including fuzzy logic, direct assessment of likelihood/preference among bets, the Delphi method, capital asset pricing models (CAPM), and risk analysis and mitigation process (RAMP); and
- Practical including stress testing and scenario analysis, business/industry scenarios, dynamic financial analysis, and market beta comparison for individual companies within market sectors.⁷⁶

With respect to this long list of methods, Tripp et al. state: “It is still early days in investigating which are likely to be most useful. We have set out ... a list of those which we feel represent emerging best practice, and which we believe may have increased applicability in the future.”⁷⁷ Section 8 – “Pitfalls and Considerations of Soft Issues” is a valuable section of the paper by Tripp et al. and contains information about practical implications beyond the aspects included in this research paper.

The second paper, by Dexter et al., focuses on two methods that can be used for life insurers: frequency-severity model and risk event scenarios. Dexter et al. refer to the work of Tripp et al., specifically the Bayesian networks and causal risk maps, and recommend that some of the methods cited by Tripp et al. be fully explored as future development in operational risk assessment. Dexter et al. also include a discussion about quantifying and parameterizing key operational risks through the use of internal and external loss data as well as a discussion of quantifying operational risk without historic loss data. They also report on four practical issues related to setting parameters, namely: subjectivity, misunderstanding of the methodology, getting buy-in, and the governance and sign-off process.

This research paper does not address all of the methods identified by Tripp et al.; the complete listing is specifically included to provide readers with sources for information on approaches not included in the research paper. Similarly, this research paper does not repeat the information that can be found in the paper by Dexter et al.

The third paper, by Corrigan and Luraschi, addresses many of the objectives set out by the CIA for this research paper and includes the following major sections:

- Nature of operational risk events;
- Basic indicators and standard formula approaches;
- Quantitative risk assessment or scenario analysis;
- Statistical models: loss distribution approach;
- Structural or causal approaches;
- Regulatory requirements;
- Emerging operational risk assessment and black swans;
- Loss data collection; and
- Case studies.

⁷⁶ M.H. Tripp, H.L. Bradley, R. Devitt, G.C. Orros, G.L. Overton, et al., “Quantifying Operational Risk in General Insurance Companies”, developed by a *GIRO Working Party*, March 22, 2004: s.1.3.

<http://www.actuaries.org.uk/system/files/documents/pdf/33784baj105919-10262004tripp.pdf>.

⁷⁷ Ibid.

Corrigan and Luraschi incorporate more in-depth theoretical discussion of the various quantitative methods than what is included in this research paper. This paper represents an up-to-date and valuable resource for insurers modeling operational risk.

Given the limited practical experience related to operational risk modeling for insurers, one turns to the vast body of literature and guidance that have been developed on modeling for the banking sector as a result of the AMA option of Basel II. Publications of the Basel Committee can be constructive even if such papers contain less practical experience and application to modeling operational risk for insurers. While significant differences exist in the details of the operational risks faced by banks and those faced by insurers, lessons can be learned from the banking industry's solutions to many issues related to the overall approach used to model operational risk.

Organization

A review of the published literature on operational risk reveals a distinction between models that are used for (a) quantifying operational risk and calculating economic or regulatory capital and (b) managing operational risk. Such a differentiation can present challenges as those models used to quantify operational risk can also be used for management and vice versa. This research paper focuses on models used to quantify operational risk rather than models used for operational risk management. The frequency-severity approach can be classified as a model that is used to quantify operational risk; whereas, key risk indicators (KRIs) and causal models (such as multi-factor models and Bayesian networks) are typically used to manage operational risk. As described later in this section, many believe that Bayesian networks are also valuable for the measurement of operational risk. Scenario analysis can be used to both quantify and manage operational risk.

This section of the research paper focuses on the three primary methods that are found in the literature for both banks and insurers:

- Frequency-severity approach (known by banks as the loss distribution approach, or LDA);
- Causal modeling and Bayesian estimation techniques (including the use of key risk indicators); and
- Scenario analysis.

This research paper does not present the theoretical background for any of these methods. Numerous papers containing comprehensive theoretical discussions are herein mentioned for further reference.

In selecting a method to quantify operational risk, it is critical to carefully consider the definition of operational risk and any potential overlap with other risk categories. Many operational risks may already be considered implicitly as part of other risk event types. It is essential that boundary conditions be clearly articulated so that risks are neither double-counted nor overlooked. This topic is addressed in a presentation document titled *Operational Risk Management* prepared by van den Heever and Slawski for the Actuarial Society of South Africa's 2011 Convention. They state: "A detailed taxonomy is required to obtain approximately consistent interpretations of risk event types and to ensure complete risk universe assessments."⁷⁸ They note that

⁷⁸ R. van den Heever and J. Slawski, "Operational risk management", presented at the 2011 convention of the Actuarial Society of South Africa, 8-9 November, 2011. <http://www.actuarialsociety.org.za/Portals/2/Documents/Convention-OperationalRiskManagement-RH-JS-2011.pdf>.

operational risks arising from shared services are often double counted leading to duplication of risk management and capital. Another frequently cited example is the treatment of outsourcing risks.

The Quantification Methods section of the research paper begins with the identification and description of key issues affecting the quantification of operational risks regardless of the method selected, followed by a description of the three primary methods in use today (i.e., frequency-severity approach, Bayesian methods, and scenario analysis). The section concludes with a summary of current practice based on KPMG global studies conducted in 2012 and 2013 on the topics of economic capital modeling and operational risk in particular.

Key Issues Affecting the Use of Any Method (other than a Standard Formula) to Quantify Operational Risk Capital

Data

In *Regulatory Capital for Operational Risk*, Embrechts et al. state: “The accuracy in predicting future loss values depends on the volume and quality of the observed historical data.”⁷⁹ The reliability of any operational risk modeling exercise is strictly connected with the actual quality of the overall data (internal or external data), which is generally an unknown. As a result, the appropriate model calibration in the data-poor environment of operational risk is one of the most significant and persistent challenges for insurers. Without sufficient data, models to quantify operational risk cannot be calibrated adequately.

Basel II requires banks to use a minimum of five years of internal loss data when using the AMA.⁸⁰ Internal data represent the actual operational risk losses incurred by the financial institution and can be used for all three quantification methods described in this research paper. One of the reasons that internal loss data are often used as a foundation for AMA is that internal data are considered to be the most objective risk indicator currently available reflecting the unique risk profile of the specific financial institution.⁸¹ The challenges in securing sufficient internal data and the need to evaluate the exposure to potentially severe tail events are among the reasons why Basel II requires banks to supplement their own data with further sources (including both external data and scenario analysis) to determine their operational risk capital charge.

In *LDA at Work*, Aue and Kalkbrener discuss two inherent weaknesses of internal loss data when used as a foundation for operational risk exposure measurement:

1. Loss data is a “backward-looking” measure, which means it will not immediately capture changes to the risk and control environment.

⁷⁹ P. Embrechts, H. Furrer, and R. Kaufmann, “Quantifying Regulatory Capital for Operational Risk”, Research supported by *Credit Suisse Group, Swiss Re and UBS AG* through *RiskLab*, Switzerland, 2003: 4.
<http://www.math.ethz.ch/~embrecht/ftp/OPRiskWeb.pdf>.

⁸⁰ When first moving from the BIA or SA to the AMA, a bank is allowed to use three years of internal loss data.

⁸¹ F. Aue and M. Kalkbrener, “LDA at Work”, Deutsche Bank AG, February 2007: 8.
http://kalkbrener.at/Selected_publications_files/AueKalkbrener06.pdf.

2. Loss data is not available in sufficient quantities in any financial institution to permit a reasonable assessment of exposure, particularly in terms of assessing the risk of extreme losses.⁸²

Aue and Kalkbrener point out a variety of approaches to address these weaknesses, including “the use of statistical modelling techniques, as well as the integration of the other AMA elements, i.e. external data, scenario analysis and factors reflective of the external risk and internal control environments.”⁸³

External data refer to operational risk losses that have occurred in other organizations. External data may be obtained from a third-party vendor or from a data consortium such as ORIC for insurers or ORX for banks. Aue and Kalkbrener explain that “external loss data can be used to supplement an internal loss data set, to modify parameters derived from the internal loss data, and to improve the quality and credibility of scenarios. External data can also be used to validate the results obtained from internal data or for benchmarking.”⁸⁴

One of the greatest impediments to modeling operational risk is the lack of a sufficient volume of high quality, accurate data – both internal and external data. There are numerous factors contributing to the challenges with data. First, for insurers, historical operational risk loss data have only been routinely recorded and aggregated for a relatively short period of time. Historically, data on losses arising from events that are categorized as operational risk loss events were not required. Furthermore, the costs of collecting such data were deemed to outweigh the benefits.

In *Operational risks in banks: an analysis of empirical data from an Australian bank*, Evans et al. state:

Even if the data had been collected, accuracy would have been an issue as indirect losses such as systems errors, which cause delays in transactions, may produce losses which are not readily quantifiable and the duration of operational loss events can vary significantly.⁸⁵

Evans et al. also comment on the problem of truncation, which refers to the minimum loss value used for reporting operational risk loss events. The truncation point frequently changes over time and may vary between organizations, thus making comparisons between organizations difficult.

In *Loss Distribution Approach for Operational Risk*, Frachot et al. comment on biases in the available data. They state:

- Internal data are biased toward low-severity losses. For obvious reasons, extreme events may be hardly represented in internal databases.
- Only significant losses are reported, meaning that the recorded losses are, by definition, greater than some specific threshold. In statistical terms, this bias is referred as a truncation bias and leads to an overestimation of the severity. As a matter of fact, one has to find a balance between the cost of recording very low severity data and the truncation bias or accuracy loss resulting from too high thresholds.

⁸² F. Aue and M. Kalkbrener, “LDA at Work”, Deutsche Bank AG, February 2007: 8.
http://kalkbrener.at/Selected_publications_files/AueKalkbrener06.pdf.

⁸³ Ibid.: 8.

⁸⁴ Ibid.: 12.

⁸⁵ J. Evans, R. Womersley, and D. Wong, “Operational risks in banks: an analysis of empirical data from an Australian bank”, the *Institute of Actuaries of Australia*, 2007: 2.
http://www.actuaries.asn.au/Library/Events/Conventions/2007/8.d_Conv07_Paper_Evans%20Womersley%20Wong_An%20Empirical%20Analysis%20of%20Operational%20Risk%20in%20Banks.pdf.

- Sy[m]metrically to internal data, external data are biased toward high-severity losses since only they are publicly released. Practically, it means that an appropriate mix between internal and external data must be imposed, in order to enhance statistical efficiency.⁸⁶

Other issues related to data include:

- Low-frequency, high-volatility of loss occurrences;
- Treatment of near-misses and whether they are aggregated with events that resulted in losses; and
- Implications of reporting bias and changes in bias level over time.

“In general, operational risks are characterised by underlying drivers, which tend to adapt and change over time. This makes it problematic to use a classical statistical approach, as data can rapidly cease to relate to the risk.”⁸⁷ Changes in processes may reduce or even eliminate the possibility that particular past losses would occur in the future, or that losses that happened in the past would recur in the future but with a significantly different severity.

While some insurers lack a sufficient volume of operational risk loss data, others face challenges with the inconsistency in the collection of operational risk loss data. Because operational risk spreads over different activities of an insurer, any loss analysis would be exposed to the potential for inconsistencies in the identification, categorization, and reporting of losses. Inconsistencies may exist from department to department or business line to business line within an insurer as well as from one insurer to another. Inconsistencies present challenges when the internal data are aggregated within an insurer or when internal data are combined with external data. Such inconsistencies could influence the statistical analysis of operational risk losses, particularly given the limited volume of data possessed by most insurers.

Moscadelli discusses the inconsistencies in data for operational risk losses in banks in *The modelling of operational risk: experience with the analysis of the data collected by the Basel Committee*. He states:

Sound practices require banks to conduct a rigorous and detailed classification of their products, functions and processes and to adopt a clear and widespread definition of operational risk in their organisational units before any loss event identification and mapping is conducted and a statistical analysis of losses is made.⁸⁸

To use external data, an insurer would decide whether scaling is required and, if necessary, the method for scaling. In reporting on the experience of banks, Moscadelli states:

As a general rule, if substantial differences in terms of the behaviour of the losses were detected for some banks, suitable statistical treatments (so-called “scaling methodologies”) would be required to make data comparable and to ensure that merging all the individual

⁸⁶ A. Frachot, P. Georges and T. Roncalli, “Loss Distribution Approach for Operational Risk”, *Groupe de Recherche Opérationnelle, Crédit Lyonnais*, April 25, 2001.

⁸⁷ N. Cantele, D. Clark, J. Kent, and H. Verheugen, “A brief overview of current approaches to operational risk under Solvency II”, *Milliman White Paper*, July 2012: 2. <http://uk.milliman.com/uploadedFiles/insight/life-published/pdfs/current-approaches-operational-risk.pdf>.

⁸⁸ M. Moscadelli, “The modelling of operational risk: experience with the analysis of the data collected by the Basel Committee”, *Banca D'Italia*, July 2004: 15.

http://www.bancaditalia.it/pubblicazioni/econo/temidi/td04/td517_04/td517en/en_tema_517.pdf.

databases leads to unbiased estimates (for a recent scaling proposal, see Frachot and Roncalli, 2002, who address the problem of mixing banks internal and external data).⁸⁹

When using external data, it is also important to assess its relevance. In *A brief overview of current approaches to operational risk under Solvency II*, Cantele et al. describe challenges with external insurance data as follows:

However, the ORIC database has proved difficult to standardize, and is sometimes seen as subject to mislabelling and uncertainty over the homogeneity of the data. There is also uncertainty over what credibility factor to give industry data when blending with own company data.⁹⁰

Tripp et al. discuss the collection of both loss and exposure data. They note two opposing views. The first emphasizes model design; and data collection is then driven by the requirements of the model. The second approach purports model selection based on the availability of the data. They also comment that “it is much more difficult to collect exposure data, as often there are no commonly agreed measures of exposure.”⁹¹ For their case study, they describe a conceptually simple operational risk loss database that is very similar to an insurance claim database and consists of:

- Date loss incurred;
- Date loss reported;
- Initial estimate of loss and loss development;
- Cause of loss reported in a manner that is consistent with the insurer’s risk categorization; and
- Consequence of the loss (i.e., how the loss manifested itself).

Tripp et al. comment that in creating an operational risk loss database, the following issues need to be addressed:

- How are losses that arise from more than one cause tested? Should the loss amount be split between causes, or should the whole amount be allowed to appear under each cause?
- Should data on near misses—incidents that did not in the end result in any monetary loss—be collected?

⁸⁹ I. M. Moscadelli, “The modelling of operational risk: experience with the analysis of the data collected by the Basel Committee”, *Banca D’Italia*, July 2004: 18.

http://www.bancaditalia.it/pubblicazioni/econo/temidi/td04/td517_04/td517en/en_tema_517.pdf.

⁹⁰ N. Cantele, D. Clark, J. Kent, and H. Verheugen, “A brief overview of current approaches to operational risk under Solvency II”, *Milliman White Paper*, July 2012: 2. <http://uk.milliman.com/uploadedFiles/insight/life-published/pdfs/current-approaches-operational-risk.pdf>.

⁹¹ M.H. Tripp, H.L. Bradley, R. Devitt, G.C. Orros, G.L. Overton, et al., “Quantifying Operational Risk in General Insurance Companies”, developed by a *GIRO Working Party*, March 22, 2004: s.3.8.7.

<http://www.actuaries.org.uk/system/files/documents/pdf/33784bai105919-10262004tripp.pdf>.

- How should a blame-free procedure for reporting both actual losses and near misses, and avoid under-reporting be set up?⁹²

Other practical considerations related to data include but are not limited to:

- The rigour around internal data collection processes and the procedures to record incidences of operational risk losses;
- The selection of data points to be used as input to scenario workshops (e.g., 1-in-20, 1-in-50, or other data points) or for the estimation of parameters for frequency-severity models or Bayesian networks; and
- The robustness of the quantification around all data points.

In their concluding remarks to *Scenario Analysis in the Measurement of Operational Risk Capital: A Change of Measure Approach*, Dutta and Babbel state:

If we can draw any inference from the experiences reported in other disciplines that use scenarios as a cornerstone for measuring and managing uncertainty, we can say that in due course the data will become slightly (but not a whole lot) better. We should search for a method to compensate for the inherent problem of data quality.⁹³

For actuaries involved in the modeling of operational risk, it is important to adhere to applicable actuarial standards of practice that address the sufficiency and reliability of data, reliance on the work of others, and documentation and reporting obligations.

Use of Expert Judgment

In light of the challenges related to data, many organizations incorporate the use of experts to supplement historical operational risk loss events. Where used, it would be important that expert judgment be robustly applied, well documented, and supported by data wherever possible.

In the *Guidelines on Pre-Application of Internal Models*, the EIOPA sets requirements related to the validation, documentation, consistency, and fit of expert judgment in internal models. Guideline 19 states:

1.55. Through the pre-application process national competent authorities should form a view on how the insurance or reinsurance undertaking ensures that all assumption setting, and the use of expert judgement in particular, follows a validated and documented process.

1.56. National competent authorities should form a view on how the insurance or reinsurance undertaking ensures that the assumptions are derived and used consistently over time and across the insurance or reinsurance undertaking and that they are fit for their intended use.⁹⁴

⁹² M.H. Tripp, H.L. Bradley, R. Devitt, G.C. Orros, G.L. Overton, et al., “Quantifying Operational Risk in General Insurance Companies”, developed by a *GIRO Working Party*, March 22, 2004: s.3.8.6.

<http://www.actuaries.org.uk/system/files/documents/pdf/33784baj105919-10262004tripp.pdf>.

⁹³ K.K. Dutta and D.F. Babbel, “Scenario Analysis in the Measurement of Operational Risk Capital: A Change of Measure Approach”, *Wharton School of the University of Pennsylvania*, July 5, 2012: 22.

<http://fic.wharton.upenn.edu/fic/papers/12/12-15.pdf>.

⁹⁴ EIOPA, “EIOPA Guidelines on Pre-Application of Internal Models”, EIOPA-CP-13/011: 12-13.

https://eiopa.europa.eu/fileadmin/tx_dam/files/publications/guidelines/Pre_Application_of_Internal_Models/Final_EN_IntMod_Clean.pdf.

One of the challenges cited in the literature is the absence of methods for combining expert opinion with relevant internal and external data. Two papers that address approaches for the integration of expert opinion are:

- D.D. Lambrigger, P.V. Shevchenko, and M.V. Wüthrich, *The Quantification of Operational Risk using Internal Data, Relevant External Data and Expert Opinions*, July 4, 2007; and
- P.V. Shevchenko and M.V. Wüthrich, *The structural modeling of operational risk via Bayesian inference: combining loss data with expert opinions*, *Journal of Operational Risk*, August 2006.

Lambrigger et al. develop a Bayesian inference model that allows for combining three sources (i.e., internal data, external data, and expert opinions). This three-way approach is then contrasted with Shevchenko and Wüthrich's method:

... described the use of the Bayesian inference approach, in the context of operational risk, for estimation of frequency/severity distributions in a risk cell, where expert opinion or external data are used to estimate prior distributions. This allows the combining of two data sources: either expert opinion and internal data or external data and internal data.⁹⁵

Unit of Measure / Granularity

The unit of measure refers to the level or degree of granularity used for analyzing an insurer's operational risk capital. Insurers may determine operational risk capital for several units of measure (e.g., by line of business or type of operational risk loss event) and then aggregate the estimates of capital. "Smaller business lines and/or less common types of loss events are frequently combined to create one unit of measure."⁹⁶ Enterprise is the least granular unit of measure.

In *Observed range of practice in key elements of Advanced Measurement Approaches (AMA)*, the Basel Committee states that the granularity "reflects the degree to which the framework separately models individual operational risk exposures."⁹⁷ In the banking sector, considerable diversity has been observed in the level of granularity of the operational risk models. This varying level of granularity may be driven by modeller's preferences or by actual differences in operational risk profiles. The Basel Committee further comments on the diversity in approaches:

The least granular approach uses a single ORC (or unit of measure) for all of a bank's operational risk exposures. An advantage of this approach is that only a single distribution of operational risk losses is estimated, allowing operational risk loss data to be pooled. Pooling helps to address issues related to data paucity. However, this approach may not reflect the true nature of the underlying losses, as losses may arise from different operational risk sources and often are not independent.

⁹⁵ D.D. Lambrigger, P.V. Shevchenko, and M.V. Wüthrich, "The Quantification of Operational Risk using Internal Data, Relevant External Data and Expert Opinions", July 4, 2007: 3. [http://www.ressources-actuarielles.net/EXT/ISFA/1226.nsf/0/dfdd987956704deac1257840002b6931/\\$FILE/CombiningDataSourcesOpRisk.pdf](http://www.ressources-actuarielles.net/EXT/ISFA/1226.nsf/0/dfdd987956704deac1257840002b6931/$FILE/CombiningDataSourcesOpRisk.pdf).

⁹⁶ K.K. Dutta and D.F. Babbel, "Scenario Analysis in the Measurement of Operational Risk Capital: A Change of Measure Approach", *Wharton School of the University of Pennsylvania*, July 5, 2012: 3. <http://fic.wharton.upenn.edu/fic/papers/12/12-15.pdf>.

⁹⁷ Basel Committee on Banking Supervision, "Observed range of practice in key elements of Advanced Measurement Approaches (AMA)", Bank for International Settlements, July 2009: 6. <https://www.bis.org/publ/bcbs160b.pdf>.

More granular approaches estimate potential operational risk losses by business line and/or operational risk event type. These approaches provide an ability to capture differences in operational risk exposures across business lines or event types.⁹⁸

In a prior version of *Scenario Analysis in the Measurement of Operational Risk Capital: A Change of Measure Approach*, Dutta and Babbel (2010) address the unit of measure in the context of scenario analysis for banks. They state:

A unit of measure gets predetermined based on risk management decisions before the scenario data generation happens ... The issue of the selection of a unit of measure is as important as finding a distribution that will fit a set of data ... we strongly advocate that the risk management requirements should be the primary criteria for the selection of units of measure.⁹⁹

One of the most important aspects in selecting a unit of measure for modeling operational risk is related to the aggregation for all ORCs modeled. In *A Tale of tails: an empirical analysis of loss distribution models for estimating operational risk capital*, Dutta and Perry address the question of whether the measurement of operational risk capital at the enterprise level is different from that derived by aggregating operational risk capital measured for each business line or event type under any dependence structure. They analyze this question under two extreme conditions, independence (i.e., zero correlation) and comonotonicity (i.e., simple addition of unit level risk measures), and compare the results to the measurement of operational risk capital at the enterprise level.¹⁰⁰

Dependence

Exposure to common processes or structural factors (such as those related to human resources or IT systems) as well as environmental factors (such as a change in legal risk associated with a particular business process) has the potential to affect multiple areas within an insurer thus leading to dependency in ORCs. These types of factors can influence the observed frequency and/or severity of losses and the modeled results for operational risk using a frequency-severity approach. Dependency between ORCs is also important when quantifying operational risk capital using Bayesian networks or scenario analysis.

Basel II allows for recognition of the dependence among ORCs for banks using the AMA to quantify operational risk. Section 669, which addresses the detailed criteria for use of AMA, states:

Risk measures for different operational risk estimates must be added for purposes of calculating the regulatory minimum capital requirement. However, the bank may be permitted to use internally determined correlations in operational risk losses across individual operational risk estimates, provided it can demonstrate to the satisfaction of the national

⁹⁸ Basel Committee on Banking Supervision, "Observed range of practice in key elements of Advanced Measurement Approaches (AMA)", Bank for International Settlements, July 2009: 46. <https://www.bis.org/publ/bcbbs160b.pdf>.

⁹⁹ K.K. Dutta and D.F. Babbel, "Scenario Analysis in the Measurement of Operational Risk Capital: A Change of Measure Approach", *Wharton School of the University of Pennsylvania*, September 24, 2010: 7. <http://fic.wharton.upenn.edu/fic/papers/10/10-10.pdf>.

¹⁰⁰ K.K. Dutta and J. Perry, "A tale of tails: An empirical analysis of loss distribution models for estimating operational risk capital", Working paper series, *Federal Reserve Bank of Boston*, No. 06-13, July 2006. <https://www.econstor.eu/dspace/bitstream/10419/55646/1/514906588.pdf>.

supervisor that its systems for determining correlations are sound, implemented with integrity, and take into account the uncertainty surrounding any such correlation estimates (particularly in periods of stress). The bank must validate its correlation assumptions using appropriate quantitative and qualitative techniques.¹⁰¹

In *Operational risk quantification using extreme value theory and copulas: from theory to practice*, Gourier et al. discuss the issue of dependency and the challenge in combining VaR for different business lines (for banks) for the purpose of determining required capital. They state:

Calculating the minimum capital requirements as the sum of the VaR over the different business lines assumes a perfect dependence between them. However, Frachot *et al* (2004b) argue on the one hand that operational risk models cannot, by construction, show high levels of correlation between losses from different business lines, suggesting that the capital charges are highly overestimated. On the other hand, Embrechts and Puccetti (2006) point out that, when VaR is not subadditive, dependence can lead to an underestimation of the capital requirements.¹⁰²

Just as the quantification of operational risk is an evolving area for insurers, so is the modeling of dependencies. The choice of approach for recognizing dependency can have a significant influence on the estimated required capital. Among the most common approaches used by insurers to reflect dependencies are copulas and correlation matrices. A discussion of the theory behind these approaches is beyond the scope of this research paper. Interested readers are directed to the referenced papers for further information.

Three papers that are focused on dependency and the quantification of operational risk for banks are:

- L. Dalla Valle, D. Fantazzini, and P. Giudici, *Copulae and Operational Risks*, International Journal of Risk Assessment and Management, Vol. 9, No. 3, 2008;
- A. Frachot, T. Roncalli, and E. Salomon, *The Correlation Problem in Operational Risk*, Groupe de Recherche Opérationnelle, Group Risk Management, Crédit Agricole SA, France, January 23, 2004; and
- E. Gourier, W. Farkas, and D. Abbate, *Operational risk quantification using extreme value theory and copulas: from theory to practice*, The Journal of Operational Risk (3-26), Volume 4/Number 3, Fall 2009.

The first two papers conclude that there are significant capital savings that can result from the appropriate reflection of dependency in the quantification of operational risk. In the third paper, the authors report on the result of an empirical study with heavy-tailed data. Gourier et al. state: "We show that standard economic thinking about risk diversification may be inappropriate when infinite-mean distributions are involved, as is standard in operational risk."¹⁰³

¹⁰¹ Basel Committee on Banking Supervision, "International Convergence of Capital Measurement and Capital Standards – A Revised Approach – Comprehensive Version", *Bank for International Settlements*, June 2006: s.669 (d).
<https://www.bis.org/publ/bcbs128.pdf>.

¹⁰² E. Gourier, W. Farkas, and D. Abbate, "Operational risk quantification using extreme value theory and copulas: from theory to practice", *The Journal of Operational Risk (3-26)*, Volume 4/Number 3, Fall 2009: 19.
http://www.risk.net/digital_assets/4682/jop_v4n3a1.pdf.

¹⁰³ E. Gourier, W. Farkas, and D. Abbate, "Operational risk quantification using extreme value theory and copulas: from theory to practice", *The Journal of Operational Risk (3-26)*, Volume 4/Number 3, Fall 2009: 3.
http://www.risk.net/digital_assets/4682/jop_v4n3a1.pdf.

In *Practical methods for measuring and managing operational risk in the financial sector: A clinical study*, Chapelle et al. model the dependence of aggregate losses (for banks) using copulas in order to combine the marginal distributions of different ORCs into a single joint distribution. They comment that copulas possess “more attractive theoretical properties than traditional linear correlation when dealing with non-elliptical distributions, such as those encountered in operational risk modelling.”¹⁰⁴

Correlation and dependence are among the topics discussed in the *Basel Guidelines for the AMA*. In reporting on current practices (as of June 2011), the Basel Committee states:

- There are significant differences in banks’ approaches to modelling dependence with 29% of banks reporting that they do not model dependence or correlation estimates in their AMA;
- When incorporating dependence in the AMA, banks primarily rely on expert judgment (40%), followed by internal loss data by 36% of respondents and external data by 17%;
- Copulas are the most common approach (43%) when dependence is used in the modelling process, and Gaussian copulas are the most frequently used copulas;
- Less than 20% of AMA banks (17%) reported using a correlation matrix to model dependence;
- Many banks (31%) use methods other than a copula or correlation matrix; and
- Finally, most respondents that incorporate dependence in the modelling process use the dependence as an input in the model through aggregate losses.¹⁰⁵

The *Basel Guidelines for the AMA* related to correlation and dependence address practical considerations. The considerations are also relevant for insurers when modeling operational risk. These guidelines state:

228. Dependence assumptions should be supported to the greatest extent possible by an appropriate combination of empirical data analysis and expert judgment. It is important to recognise that using internal and external data to model dependence presents challenges, as data limitations observed in the univariate context (modelling loss distributions for single ORCs) are likely to be more significant in the multivariate context (modelling multiple ORCs). Using judgment to model dependence presents its own challenges, as eliciting accurate but subjective estimates is more difficult in the multivariate context than in the univariate context. As such, the specification of dependence structures represents one of the most significant challenges in AMA modelling.

229. Assumptions regarding dependence should be conservative given the uncertainties surrounding dependence modelling for operational risk. Consequently, the dependence structures considered should not be limited to those based on Normal or Normal-like (eg T-

¹⁰⁴ A. Chapelle, Y. Crama, G. Hübner, and J.-P. Peters, “Practical methods for measuring and managing operational risk in the financial sector: A clinical study”, *ScienceDirect, Journal of Banking & Finance* 32 (2008) 1049-1061, October 1, 2007: s.2.4. <http://finance.flemingeurope.com/webdata/3118/JBF-Chapelle-et-al2008.pdf>.

¹⁰⁵ Basel Committee on Banking Supervision, “Operational Risk – Supervisory Guidelines for the Advanced Measurement Approaches”, *Bank for International Settlements*, June 2011: 44. <http://www.bis.org/publ/bcbs196.pdf>.

Student distributions with many degrees of freedom) distributions, as normality may underestimate the amount of dependence between tail events.

230. The degree of conservatism should increase as the rigor of the dependence model and the reliability of the resulting capital requirements estimates decrease. Accordingly, models assuming statistical independence across all loss events would require a very high degree of rigour. Such rigor may be difficult to attain given the evolving nature of dependence modelling for operational risk. It is important to note that the trade-off between rigor and conservatism will function only within certain bounds; supervisors would not accept a high degree of conservatism to compensate for an approach to dependence that suffered from fundamental deficiencies.

231. Losses within each ORC should be independent of each other.¹⁰⁶ If this is not the case, either within-ORC dependence should be modelled explicitly or the input data should be modified to achieve independence across individual losses.¹⁰⁷

232. Dependence should not be inappropriately affected by the choice of granularity. For example, many operational risk management frameworks assume statistical independence between losses within the same ORC. To the extent that a bank's framework has only a few ORCs, the impact of dependence may be inappropriately minimised. In such a situation, it may be preferable to simply add capital estimates across ORCs.

233. A bank should perform sensitivity analyses and stress testing (eg different parameter values and different correlation models) on the effect of alternative dependence assumptions on its operational risk capital charge estimate. A bank should have a rigorous process in place specifying the conditions under which the results based on alternative dependence assumptions would lead to a revision of the operational risk capital requirements estimate.

234. Given the evolving nature of dependence modelling for operational risk, it may be difficult to meaningfully differentiate the impact of dependence at one bank versus another. One would thus expect some degree of cross-bank consistency in the overall impact of dependence.¹⁰⁸

Papers on operational risk directed at insurers repeatedly warn of the challenges in modeling dependence. Dexter et al. comment on correlation between ORCs for insurers and note that even when data are available, it is difficult to determine reliable correlations between ORCs. Given the scarcity of data, Dexter et al. recommend a pragmatic approach for setting correlation assumptions. They suggest that a base assumption of zero correlation between ORCs is reasonable where there is no clear common driver. They also suggest grouping ORCs prior to modeling to reduce the number of correlation estimates that are required, particularly if strong correlation is suspected between a few ORCs. Risks may be allocated into one or more functional,

¹⁰⁶ Given that it could be challenging to prove statistically the independence of losses within an ORC, sound logical arguments may be used to evaluate the independence of such losses. For example, losses arising from the same root cause would not generally be considered independent.

¹⁰⁷ This can be achieved, for example, by integrating data which show strong cross dependence into a single data point.

¹⁰⁸ Basel Committee on Banking Supervision, "Operational Risk – Supervisory Guidelines for the Advanced Measurement Approaches", Bank for International Settlements, June 2011: 44-45. <http://www.bis.org/publ/bcbs196.pdf>.

geographic, or Basel categories with an assumed standard correlation, such as 1.0, assumed within the group.¹⁰⁹

One of the key research findings by Corrigan and Luraschi is that:

Abstract statistical methods such as correlations and copulas mean that modelled outcomes can be difficult to calibrate and explain, and lack robustness for high severity loss estimates given the paucity of historical loss data and difficulties people have in estimating 1-in-200 or -1,000-year event.¹¹⁰

Their paper contains brief descriptions of four types of copulas: Gaussian, Student's t, Archimedean, and Gumbel. They conclude the section on copulas by noting that "the main challenge with using a copula is that a very large amount of data is required in order to determine a robust calibration. This can be orders of magnitude larger than the datasets currently available for operational risk."¹¹¹

Dexter et al. also comment on correlation between operational risk and other risk categories. They discuss a correlation matrix approach, describe the process for setting correlation assumptions, and conclude with an example for a life insurer.

Iterative Nature of Model-Building

The process of building effective models (i.e., approaches to the quantification of operational risk) is best thought of as an iterative process. According to Tripp et al., "the models and data requirements will be refined in the light of experience and lessons learned."¹¹² This statement is true for any type of model used to quantify operational risk including the three approaches described in depth in this research paper.

Cost-Benefit Analysis of Advanced Modeling for Operational Risk

Chapelle et al. address the issue of cost versus benefit in the concluding remarks of their paper. They state:

As for the next research question, namely the cost-benefit analysis of adopting the AMA instead of a less sophisticated method, two major conclusions can be drawn. First, the behaviour of extremely large losses collected in external databases, as well as the dependence structure of operational losses among business lines and/or event types, are both likely to affect the cost-saving properties of the AMA choice in a significant way. A proper treatment of external data allows refining the analysis of the tail of the aggregate loss distribution. Furthermore, since the AMA aims at capturing rare events, it tends to be overly conservative when the basic assumption of additive capital charges (perfect correlation) is

¹⁰⁹ N. Dexter, C. Ford, P. Jakahria, P. Kelliher, D. McCall, et al., "Quantifying Operational Risk in Life Insurance Companies", Developed by the Life Operational Risk working Party, 2006: 30.
www.actuaries.org.uk/system/files/documents/pdf/opriskcapital.pdf.

¹¹⁰ J. Corrigan and P. Luraschi, "Operational risk modelling framework", *Milliman Research Report*, February 13, 2013: 6.
<http://www.milliman.com/uploadedFiles/insight/life-published/operational-risk-modelling-framework.pdf>.

¹¹¹ *Ibid.*: 31.

¹¹² M.H. Tripp, H.L. Bradley, R. Devitt, G.C. Orros, G.L. Overton, et al., "Quantifying Operational Risk in General Insurance Companies", developed by a *GIRO Working Party*, March 22, 2004: s.3.8.4.
<http://www.actuaries.org.uk/system/files/documents/pdf/33784baj105919-10262004tripp.pdf>.

adopted. The estimation of risk exposure is significantly reduced when dependence is taken into account in a reasonable way.

Second, the differential capital charge between the Standardized Approach and the AMA, and thus the opportunity cost of adopting (or not) a complex operational risk management system, significantly hinges on the discretionary weight assigned to the business lines. Banks should not take capital reduction for granted when adopting well-calibrated AMA, as the choice of the SA may be attractive to some banks whose risk is greater than average, and unattractive to others. With this respect, our cost-benefit trade-off analysis of adopting a full-fledged operational risk management system has less normative content than methodological substance. On the basis of controlled scenarios, we document that managerial actions are likely to bring significant improvements on the risk-adjusted profitability of the institution. The arbitrage between different managerial actions is mostly tied to the distributional behavior of the aggregate loss for each business line and event type. This kind of analysis of the profit side of operational risk management should be matched with a more industrial view on the cost-side of these types of actions, which is beyond the scope of the study.¹¹³

Business Environment and Strength of Existing Management Programs

Aue and Kalkbrener discuss the issue of a changing environment in the context of the models used to quantify operational risk. Although their paper focuses on the frequency-severity approach, the general message is also applicable to the other two approaches used to quantify operational risk described in depth in this research paper. They state:

Apart from generated loss scenarios LDA models mainly rely on loss data and are inherently backward looking. It is therefore important to incorporate a component that reflects changes in the business and control environment in a timely manner ... The ways that adjustments are performed vary in form and complexity and the processes for collecting relevant information differ across financial institutions. Common industry practice is to compile the data into a scoring mechanism which translates qualitative information into numerical values. The most prevalent forms of qualitative adjustment utilize data from key risk indicators (KRIs) and risk self-assessment.¹¹⁴

Qualitative adjustments might be incorporated in different components of a quantification model, and expert judgment continues to play an important role in this regard. Aue and Kalkbrener also mention the importance of transparency in the use of qualitative adjustments to improve the acceptance of the methodology by the business.

This issue remains an area requiring further research as the direct application of qualitative adjustments to the operational risk economic capital is difficult to justify from a statistical perspective. Aue and Kalkbrener

¹¹³ A. Chapelle, Y. Crama, G. Hübner, and J.-P. Peters, "Practical methods for measuring and managing operational risk in the financial sector: A clinical study", *ScienceDirect, Journal of Banking & Finance* 32 (2008) 1049-1061, October 1, 2007: s.5. <http://finance.flemingeurope.com/webdata/3118/JSF-Chapelle-et-al2008.pdf>.

¹¹⁴ F. Aue and M. Kalkbrener, "LDA at Work", Deutsche Bank AG, February 2007: 38. http://kalkbrener.at/Selected_publications_files/AueKalkbrener06.pdf.

state that it is “one of the main challenges for the development of the next generation of LDA models.”¹¹⁵ This is also true for other types of models used to quantify operational risk.

Validating the Soundness of the Capital Management Process

In *Observed range of practice in key elements of Advanced Measurement Approaches (AMA)*, the Basel Committee describes a number of processes and activities that may be used to assess and validate the soundness of the capital measurement process and its results. These activities include:

- Internal validation of model inputs, methodology, and model outputs on an ongoing basis to assess whether the models work as predicted and whether the results are suitable to the various internal and supervisory purposes;
- Review of the operational risk measurement process and systems by the internal audit function;
- In-depth sensitivity analysis of each material model assumption to ensure a clear understanding of the resulting variation in capital. This type of analysis is particularly important for assumptions and modeling decisions that have a high degree of subjectivity;
- Uncertainty analysis or evaluation of the accuracy of the operational risk capital figure. For this purpose, the capital figure would be supplemented by appropriate computed confidence bands identifying the potential variability of the point estimate;
- Back-testing the capital estimates to measure how well the selected models have performed against actual loss experience; and
- Benchmarking the capital estimates generated through modeling with other indicators of operational risk exposure (e.g., financial or operational risk management indicators).

Aue and Kalkbrener also discuss back-testing and benchmarking. They describe back-testing as “the sequential testing of a model against reality to check the accuracy of the predictions.”¹¹⁶ In practice, back-testing can be conducted by comparing the outputs of the model against the actual results experienced over a given period. Such a validation approach, which is often used in the development of risk models, is challenging to implement for operational risk models due to the inherent limitations associated with loss data. Specific approaches to perform back-testing are beyond the scope of this research paper.

The literature for operational risk also refers to comparisons against relevant benchmarks as another model validation technique. Benchmark comparisons may indicate consistency with other similar organizations. Some benchmarks that are suggested include comparison of:

- An insurer’s or bank’s operational risk capital charge against the operational risk capital of close peers;
- The modeled operational risk capital charge against the standard regulatory capital charge; and
- The model outputs against adverse extreme but realistic scenarios.

¹¹⁵ F. Aue and M. Kalkbrener, “LDA at Work”, Deutsche Bank AG, February 2007: 39. http://kalkbrener.at/Selected_publications_files/AueKalkbrener06.pdf.

¹¹⁶ Ibid.: 45.

Aue and Kalkbrener note limitations related to the use of benchmarks. Although benchmarks may provide some guidance as to the appropriateness of the level of an insurer's operational risk capital derived using an internal model, significant limitations still remain. Comparisons with peers do not necessarily indicate that the calculated level of capital is appropriate for the specific risks facing a particular insurer. Given that standard formulae used to calculate regulatory capital in many countries are non-risk sensitive methodologies and that the quantification approaches based on modelling are risk-sensitive, the value of comparisons to regulatory capital charges could be questionable. Validation through the use of scenarios "is highly subjective and requires substantial resources for specifying a comprehensive operational risk profile"¹¹⁷ of an organization.

Frequency-Severity Approach

Organization, Introduction, and Sources

Organization

The description of the frequency-severity approach is organized as follows:

- Organization, introduction, and sources;
- Characteristics of operational risk loss and implications on the frequency-severity approach;
- Extreme value theory (including introduction, key assumptions of EVT related to data, fitting the severity generalized Pareto distribution (GPD), and testing the goodness of fit of the severity GPD);
- The frequency distribution;
- Aggregated losses;
- Challenges of frequency-severity analysis and EVT methods; and
- Practical considerations.

Introduction

The use of frequency-severity analysis is well documented in actuarial literature for general insurance. Within the context of Basel II, frequency-severity analysis is referred to as the loss distribution approach (LDA). Dutta and Babbel note that "given the similarity of operational losses to property/casualty losses, the measurement approach predominantly follows the loss distribution approach (LDA), which actuaries use for pricing property/casualty insurance."¹¹⁸

¹¹⁷ F. Aue and M. Kalkbrener, "LDA at Work", Deutsche Bank AG, February 2007: 48.

http://kalkbrener.at/Selected_publications_files/AueKalkbrener06.pdf.

¹¹⁸ K.K. Dutta and D.F. Babbel, "Scenario Analysis in the Measurement of Operational Risk Capital: A Change of Measure Approach", *Wharton School of the University of Pennsylvania*, July 5, 2012: 3.

<http://fic.wharton.upenn.edu/fic/papers/12/12-15.pdf>.

The LDA is described by Chapelle et al. as follows:

... a parametric technique that consists in separately estimating a frequency distribution for the occurrence of operational losses and a severity distribution for the economic impact of individual losses. In order to obtain the total distribution of operational losses, these two distributions are then combined through n -convolution of the severity distribution with itself, where n is a random variable that follows the frequency distribution.¹¹⁹

For banks complying with the requirements of the AMA under Basel II, the LDA would include:

- Homogeneous categories of internal observations to derive univariate distributions of operational losses for each type of loss event;
- Integration of external loss data to refine the shape of the distribution tail at its extreme; and
- Joint analysis of loss event categories to reflect possible dependence between univariate distributions.

The basic principle of a frequency-severity analysis is to generate the number of losses and the average value (i.e., severity) of each loss using separate and distinct statistical models. Model parameters are derived by fitting historical data to a variety of distributions using the input of experts or a combination of data and expert input.

Sources

The primary sources for this part of the research paper are:

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- Basel Committee on Banking Supervision, *Operational Risk – Supervisory Guidelines for the Advanced Measurement Approaches*, Bank for International Settlements, June 2011;
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- K.K. Dutta and D.F. Babbel, *Scenario Analysis in the Measurement of Operational Risk Capital: A Change of Measure Approach*, Wharton School of the University of Pennsylvania, July 5, 2012;
- P. Embrechts, H. Furrer, and R. Kaufmann, *Quantifying Regulatory Capital for Operational Risk*, *Credit Suisse Group, Swiss Re and UBS AG through RiskLab*, Switzerland, 2003;

¹¹⁹ A. Chapelle, Y. Crama, G. Hübner, and J.-P. Peters, "Practical methods for measuring and managing operational risk in the financial sector: A clinical study", *ScienceDirect, Journal of Banking & Finance* 32 (2008) 1049-1061, October 1, 2007: s.2.1. <http://finance.flemingeurope.com/webdata/3118/JBF-Chapelle-et-al2008.pdf>.

- A. Frachot, P. Georges, and T. Roncalli, *Loss Distribution Approach for Operational Risk*, Groupe de Recherche Opérationelle, Crédit Lyonnais, April 25, 2001;
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- Joint Risk Management Section of the Society of Actuaries, the Canadian Institute of Actuaries, and the Casualty Actuarial Society, *A New Approach for Managing Operational Risk*, July 2010;
- D.D. Lambrigger, P.V. Shevchenko, and M.V. Wüthrich, *The Quantification of Operational Risk using Internal Data, Relevant External Data and Expert Opinions*, July 4, 2007;
- M. Moscadelli, *The modelling of operational risk: experience with the analysis of the data collected by the Basel Committee*, Banca D'Italia, July 2004; and
- M. Neil, D. Marquez, and N. Fenton, *Using Bayesian networks to model the operational risk to information technology infrastructure in financial institutions*, The Capco Institute – Journal for Financial Transformation.

Characteristics of Operational Risk Loss Data and the Implications on the Frequency-Severity Approach

The *Basel Guidelines for the AMA* offers valuable guidance for using a frequency-severity approach. In the section titled “Identification of the probability distributions,” the Basel Committee states:

Severity distributions play a crucial role in AMA models. That the models are often medium/heavy tailed implies that the final outcome is significantly impacted by the chosen distribution. The choice of frequency distributions has a lesser impact on the final outcome.¹²⁰

Moscadelli describes operational risk loss data as follows:

In fact, operational risk data appear to be characterised by two “souls”: the first one, driven by high-frequency low-impact events, constitutes the body of the distribution and refers to expected losses; the second one, driven by low-frequency high-impact events, constitutes the tail of the distribution and refers to unexpected losses. In practice, the body and the tail of data do not necessarily belong to the same, underlying, distribution or even to distributions belonging to the same family. More often their behaviour is so different that it is hard to identify a unique traditional model that can at the same time describe, in an accurate way, the two “souls” of data.¹²¹

As a result, operational risk loss data tend to be very skewed and kurtotic. The kurtosis stems from a concentration of data points with lower values of loss, and the skewness is due to the presence of extreme data points with the largest data points often many multiples of the mean value.

¹²⁰ Basel Committee on Banking Supervision, “Operational Risk – Supervisory Guidelines for the Advanced Measurement Approaches”, *Bank for International Settlements*, June 2011: 39. <http://www.bis.org/publ/bcbs196.pdf>.

¹²¹ M. Moscadelli, “The modelling of operational risk: experience with the analysis of the data collected by the Basel Committee”, *Banca D'Italia*, July 2004: 27.

http://www.bancaditalia.it/pubblicazioni/econo/temidi/td04/td517_04/td517en/en_tema_517.pdf

One issue that arises in the analysis of severities associated with operational risk events is that traditionally-used distributions do not provide a reasonable fit for the entire range of observations. Thus, severities are typically modeled separately for high frequency-low severity events (also referred to as ordinary events) and low frequency-high severity events. For modeling the severity of ordinary events, commonly used distributions include:

- Lognormal;
- Pareto;
- Gamma;
- Weibull;
- Exponential; and
- Beta.

Corrigan and Luraschi report that empirical distributions and splines are also sometimes used.¹²² Embrechts et al. briefly describe four approaches for determining the compound distribution function for losses: approximation, inversion methods, recursive methods (Panjer recursion), and simulation. Monte Carlo simulation is the approach most frequently referred to in other sources.

Moscadelli articulates several weaknesses of mixture distributions including greater complexity and thus less ease in handling. He states that robust theory does not support the arbitrary choice involved in selecting a mixture distribution. Finally, he believes that there is less confidence in extrapolating the outcomes beyond the empirical data.¹²³

The preferred approach repeatedly found in the literature for modeling the low-frequency-high severity operational risk loss events is extreme value theory (EVT). EVT focuses on extreme values rather than measures of central tendency (i.e., mean). In *A New Approach for Managing Operational Risk*, the Joint Risk Management Section of the Society of Actuaries (SOA), the CIA, and the Casualty Actuarial Society (CAS) contrasts the relevance of measures of central tendency (such as the mean, the mode or the median) to the extreme values (i.e., outliers) when fitting frequency-severity distributions as part of the approach used for operational risk quantification. They mention:

In most statistical analysis, where the goal is to understand central tendency, the mean is not a reliable measure, because the mean is affected by outliers. Therefore, most statisticians prefer using the median (the middle value) or the mode (the most common observation). However, because the mean has many useful properties, many statisticians still use this metric. But to make the mean a better representation of central tendency, it has become acceptable to throw out the outliers.

¹²² J. Corrigan and P. Luraschi, "Operational risk modelling framework", *Milliman Research Report*, February 13, 2013: 22. <http://www.milliman.com/uploadedFiles/insight/life-published/operational-risk-modelling-framework.pdf>.

¹²³ M. Moscadelli, "The modelling of operational risk: experience with the analysis of the data collected by the Basel Committee", *Banca D'Italia*, July 2004: 27. http://www.bancaditalia.it/pubblicazioni/econo/temidi/td04/td517_04/td517en/en_tema_517.pdf.

In risk analysis the opposite is true, particularly in ORM [Operational Risk Management] where the major risks are characterized by large rare events. In operational risk modeling it is the outliers that are most relevant.¹²⁴

Whereas traditional statistical techniques focus on the mean and fail at estimating the values of larger losses, EVT ignores the majority of the underlying loss data and concentrates on the distribution tail. EVT is valuable for analysing rare events, and several of the ORCs exhibit properties that call for an EVT analysis. “The key attraction of EVT is that it offers a set of ready-made approaches to a challenging problem of quantitative (AMA) operational risk analysis, that is, how can risks that are both extreme and rare be modelled appropriately?”¹²⁵

In discussing EVT, Moscadelli quotes from Diebold et al. (1998) and Smith (1987), respectively:

EVT helps the analyst to draw smooth curves through the extreme tails of empirical survival functions in a way that is guided by powerful theory and hence provides a rigorous complement to alternatives such as graphical analysis or empirical survival functions.

There is always going to be an element of doubt, as one is extrapolating into areas one doesn't know about. But what EVT is doing is making the best use of whatever data you have about extreme phenomenon.¹²⁶

Extreme Value Theory

Introduction

Basic frequency-severity techniques are not typically designed for the analysis of the tail area of a distribution. However, the quantification of operational risk for the purpose of determining capital (regulatory or economic capital) requires an analysis of the distribution's tail. EVT can be used to fit a model to the tail of a loss distribution using only the extreme events.

The critical aspect of EVT is the selection of the threshold for large losses. A peak over threshold (POT) approach is used to determine a cut-off threshold and to calibrate a distribution for extreme operational risk losses using all the observations above the selected threshold. In discussing the severity distribution for large losses, Chapelle et al. remark:

The procedure builds upon results of Balkema and de Haan (1974) and Pickands (1975) which state that, for a broad class of distributions, the values of the random variables above a sufficiently high threshold U follow a generalized Pareto distribution (GPD) with parameters ξ

¹²⁴ Joint Risk Management Section of the Society of Actuaries, the Canadian Institute of Actuaries, and the Casualty Actuarial Society, “A New Approach for Managing Operational Risk”, July 2010: 48.

<http://www.soa.org/Files/Research/Projects/research-new-approach.pdf>.

¹²⁵ V. Chavez-Demoulin, P. Embrechts, and J. Nešlehová, “Quantitative Models for Operational Risk: Extremes, Dependence and Aggregation”, presented to the *Federal Reserve Bank of Boston*, May 18-20, 2005: 3.

http://www.math.ethz.ch/~embrecht/ftp/manuscript_cen.pdf.

¹²⁶ M. Moscadelli, “The modelling of operational risk: experience with the analysis of the data collected by the Basel Committee”, *Banca D'Italia*, July 2004: 27.

http://www.bancaditalia.it/pubblicazioni/econo/temidi/td04/td517_04/td517en/en_tema_517.pdf.

(the shape index, or tail parameter), β (the scale index) and U (the location index). The GPD can thus be thought of as the conditional distribution of X given $X > U$.¹²⁷

An EVT approach supports the high quantile level requirements of Basel II for banks and Solvency II for insurers. "In risk management applications, it is the tail area $x > u$ (for large u) that matters and that is the region where EVT enters."¹²⁸ Using the GPD, measures of extreme risk (e.g., VaR for high confidence levels) can be derived through simple parametric formulae.

This research paper focuses on key assumptions and practical implications of using a frequency-severity method and EVT in particular. The research paper does not repeat the theory or justification for the use of EVT nor does it describe the steps involved in the application of EVT. Instead it refers the reader to many other papers that address these topics. Each of the papers cited contains multiple references to other papers for additional information.

Key Assumptions of EVT Related to Data

Key assumptions underlying EVT analyses include:

- The observations are independent and identically distributed (iid) random variables; and
- The data are stationary.¹²⁹

The iid assumption implies that "the time aspect beyond correction for inflation is negligible and that there are no significant structural changes in the observed data as time evolves."¹³⁰ The challenges with assuming stationarity of data are discussed in many papers including Embrechts *et al.* Non-stationarity may arise due to:

- Survival bias, which refers to the fact that data for operational risk loss events that occurred in the past may not have survived in the current database;
- Reporting bias in which severity and frequency increase over time due to increased awareness and reporting of operational risk losses; and
- Changes in the external environment (e.g., economic, regulatory, and legal) or internal environment (e.g., the volume of business, organizational characteristics, and internal control systems).

Moscadelli, Embrechts *et al.* stress that non-stationarities have to be modelled before EVT analysis is conducted. Moscadelli states:

¹²⁷ A. Chapelle, Y. Crama, G. Hübner, and J.-P. Peters, "Practical methods for measuring and managing operational risk in the financial sector: A clinical study", *ScienceDirect, Journal of Banking & Finance* 32 (2008) 1049-1061, October 1, 2007: s.2.2.2. <http://finance.flemingeurope.com/webdata/3118/JBF-Chapelle-et-al2008.pdf>.

¹²⁸ P. Embrechts, H. Furrer, and R. Kaufmann, "Quantifying Regulatory Capital for Operational Risk", Research supported by *Credit Suisse Group, Swiss Re* and *UBS AG* through *RiskLab*, Switzerland, 2003: 8. <http://www.math.ethz.ch/~embrecht/ftp/OPRiskWeb.pdf>.

¹²⁹ *Stationarity*, is defined as a quality of a process in which the statistical parameters (mean and standard deviation) of the process do not change with time (Challis and Kitney November 1991).

<http://etclab.mie.utoronto.ca/people/moman/Stationarity/stationarity.html>, accessed January 20, 2014.

¹³⁰ P. Embrechts, H. Furrer, and R. Kaufmann, "Quantifying Regulatory Capital for Operational Risk", Research supported by *Credit Suisse Group, Swiss Re* and *UBS AG* through *RiskLab*, Switzerland, 2003: 9. <http://www.math.ethz.ch/~embrecht/ftp/OPRiskWeb.pdf>.

... the non-stationarity condition can distort the results of the applied statistical models, which are mainly based on the i.i.d. assumption: the authors therefore stress the importance of modelling the non-stationarities of data before a statistical analysis can be made.¹³¹

Moscadelli also comments that if losses are based on a moderately short time horizon, such as one to two years, the risk of non-stationarity due to either survival bias or changes in the environment should be reduced.¹³² However, a time frame longer than two years is typically required for the collection of data needed to comply with regulatory requirements and to ensure a sufficient volume of loss data.

Fitting the Severity GPD

The primary goal in EVT analysis is to determine the curve that best explains the behaviour of the loss severity in the tail area of the distribution. Parametric distributions are fit to data sets to obtain parameter estimates; parameter estimates may be derived using maximum likelihood estimation or probability-weighted moments.¹³³ Fitting the GPD is dependent on the threshold value (u) and the excess data (i.e., original loss data minus the selected threshold). Two parameters (ξ and β) are estimated from the excess data, where ξ represents the shape, i.e., the thickness of the tail of the distribution, and β represents scale.

The key to EVT analysis is the selection of a threshold value (u). To obtain a reliable empirical estimate of the distribution function, the threshold would be set at a level where there are enough observations that are greater than u .

In discussing the selection of the threshold, Moscadelli states:

A key modeling aspect with the GPD is the selection of the threshold, that is the point where the tail starts. The choice of u should be large enough to satisfy the limit law condition (theoretical condition: u should tend to the right-end point x_F), while at the same time leaving sufficient observations for the estimation (practical condition). Furthermore, any inference conclusion on the shape parameter – which, as noted, governs the heaviness of the tail – should be insensitive to increases in the threshold above this suitable level.¹³⁴

Moscadelli also discussed the minimum number of data points and exceedances required for analysis:

... the results of a simulation study conducted by McNeil and Saladin, 1997, aimed to detect the minimal number of data and exceedances to work with in order to obtain reliable estimates of high quantiles of given distributions. In particular, the exercise showed that, when the data presented a Pareto heavy tail with shape parameter $\alpha = 1/\xi = 1$, a minimum

¹³¹ M. Moscadelli, "The modelling of operational risk: experience with the analysis of the data collected by the Basel Committee", *Banca D'Italia*, July 2004: 17.

http://www.bancaditalia.it/pubblicazioni/econo/temidi/td04/td517_04/td517en/en_tema_517.pdf.

¹³² Ibid.

¹³³ J. Evans, R. Womersley, D. Wong, "Operational risks in banks: an analysis of empirical data from an Australian bank", *Institute of Actuaries of Australia*, September 2007: 6.

http://www.actuaries.asn.au/Library/Events/Conventions/2007/8.d_Conv07_Paper_Evans%20Womersley%20Wong_An%20Empirical%20Analysis%20of%20Operational%20Risk%20in%20Banks.pdf.

¹³⁴ M. Moscadelli, "The modelling of operational risk: experience with the analysis of the data collected by the Basel Committee", *Banca D'Italia*, July 2004: 34.

http://www.bancaditalia.it/pubblicazioni/econo/temidi/td04/td517_04/td517en/en_tema_517.pdf.

number of 1,000 (2,000) data and 100 (200) exceedances was required to have a reliable GPD estimate of the 99th (99.9th) percentile.¹³⁵

Testing the Goodness of Fit of the Severity GPD

The *Basel Guidelines for the AMA* address the need to apply “appropriate diagnostic tools for evaluating the quality of the fit of the distributions to the data, giving preference to those most sensitive to the tail.”¹³⁶ Section 197 states:

In order to examine the statistical properties of each ORC (ie homogeneity, independence, stationarity¹³⁷), a bank should make use of statistical tools which include, but are not limited to, scatter plots, time series autocorrelation plots, empirical distribution plots, histograms and regression analysis. Other tools, such as p-p plots, q-q plots and mean excess plots provide preliminary evidence on the type and shape of the probability distributions which better represent the data.¹³⁸

Sections 206 through 208 of the *Basel Guidelines for the AMA* also address evaluating the quality of the fit:

206. A bank should assess the quality of fit between the data and the selected distribution. The tools typically adopted for this purpose are graphical methods (which visualise the difference between the empirical and theoretical functions) and quantitative methods, based on goodness-of-fit tests. In selecting these tools, a bank should give preference to graphical methods and goodness-of-fit tests that are more sensitive to the tail than to the body of the data (eg the Anderson Darling upper tail test).

207. While diagnostic tools provide information on the quality of fit between the data and each distribution, they do not always lead to a clear choice of the best-fitting distribution. Moreover, the results of the goodness-of-fit tests are usually sensitive to the sample size and the number of parameters estimated. In such cases, a bank should consider selection methods that use the relative performance of the distributions at different confidence levels. Examples of selection methods may include the Likelihood Ratio, the Schwarz Bayesian Criterion and the Violation Ratio.

208. A bank should have a regular cycle to verify assumptions underlying the probability distributions they have selected. These verifications may follow the criteria and tests a bank’s use in the selection of the probability distribution. If assumptions are invalidated, alternative

¹³⁵ M. Moscadelli, “The modelling of operational risk: experience with the analysis of the data collected by the Basel Committee”, *Banca D’Italia*, July 2004: 37.

http://www.bancaditalia.it/pubblicazioni/econo/temidi/td04/td517_04/td517en/en_tema_517.pdf.

Footnote based on: A.J. McNeil and T. Saladin, “The Peaks over Thresholds Method for Estimating High Quantiles of Loss Distributions”, April 24, 2007. <http://www.macs.hw.ac.uk/~mcneil/ftp/cairns.pdf>.

¹³⁶ Basel Committee on Banking Supervision, “Operational Risk – Supervisory Guidelines for the Advanced Measurement Approaches”, *Bank for International Settlements*, June 2011: s.196 (c). <http://www.bis.org/publ/bcbs196.pdf>.

¹³⁷ “An ORC is *homogeneous* when the data of the ORC are of the same or similar nature under the operational risk profile, *independent* when no form of dependence or correlation is identifiable across them, *stationary* when the characteristics of the data do not change when shifted in time or space.”

¹³⁸ Basel Committee on Banking Supervision, “Operational Risk – Supervisory Guidelines for the Advanced Measurement Approaches”, *Bank for International Settlements*, June 2011: s.197. <http://www.bis.org/publ/bcbs196.pdf>.

methods should be tested and implemented. However, any change should be properly justified. In particular, after suffering one or more significant losses in an ORC, a bank should not decide to replace the probability distributions used in that ORC with lighter-tailed curves.¹³⁹

Moscadelli also describes back-testing with a severity value at risk (VaR_{sev}) performance analysis. He states:

The relative VaR_{sev} performance of each model ... is backtested by comparing the estimated and the expected number of violations: a violation occurs when the actual loss exceeds the VaR_{sev} value. A number of violations higher than the expected one indicates that the model consistently underestimates the risk at the tail.

In practice, the expected number of violations in each BL [business line] is obtained by comparing the total number of observations with the desired percentile. For instance, if a BL contains 1,000 data overall, the expected number of violations at the 99th percentile is equal to $0.01 * 1,000 = 10$. Therefore, if the parametric model were correct, one would expect only 10 observations to be greater than the 99th percentile singled out by the model. If the violations are more than 10, the 99th parametric percentile lies at a lower level and hence underestimates the actual tail of data.¹⁴⁰

The Frequency Distribution

For frequency, common distributions include the Poisson, negative binomial, and binomial. Dexter et al. also list the Bernoulli as a possible frequency distribution for modelling operational risk. Chapelle et al. comment that “the choice between these distributions is important as the intensity parameter is deterministic in the first case and stochastic in the second.”¹⁴¹

In Embrechts et al. address the frequency distribution:

The most prominent example of a counting process is the homogeneous Poisson process with intensity λ . It is well-known that the mean value and the variance of a Poisson (λ)-distributed random variable are both equal to λ . If the number of claims exhibits a larger spread around the mean, one may use the negative binomial distribution instead. The negative binomial distribution arises naturally by assuming that the intensity λ of a Poisson process follows a gamma distribution; moving from a deterministic λ to a random intensity is referred to as mixing.¹⁴²

¹³⁹ Basel Committee on Banking Supervision, “Operational Risk – Supervisory Guidelines for the Advanced Measurement Approaches”, *Bank for International Settlements*, June 2011: s.206-208. <http://www.bis.org/publ/bcbs196.pdf>.

¹⁴⁰ M. Moscadelli, “The modelling of operational risk: experience with the analysis of the data collected by the Basel Committee”, *Banca D'Italia*, July 2004: 46.

http://www.bancaditalia.it/pubblicazioni/econo/temidi/td04/td517_04/td517en/en_tema_517.pdf.

¹⁴¹ A. Chapelle, Y. Crama, G. Hübner, and J.-P. Peters, “Practical methods for measuring and managing operational risk in the financial sector: A clinical study”, *ScienceDirect, Journal of Banking & Finance* 32 (2008) 1049-1061, October 1, 2007: s.2.2. <http://finance.flemingeurope.com/webdata/3118/JBF-Chapelle-et-al2008.pdf>.

¹⁴² P. Embrechts, H. Furrer, and R. Kaufmann, “Quantifying Regulatory Capital for Operational Risk”, Research supported by *Credit Suisse Group, Swiss Re* and *UBS AG* through *RiskLab*, Switzerland, 2003: 6. <http://www.math.ethz.ch/~embrecht/ftp/OPRiskWeb.pdf>.

EVT can be used to estimate and measure the frequency of the large losses. The peak over threshold approach that is used is referred to as the point process representation of the exceedances (POT-PP). In describing this approach, Moscadelli states:

The basic assumption of this method - developed as a probabilistic technique by Leadbetter *et al.*, 1983, and Resnick, 1987, and as a statistical tool by Smith, 1989 - is to view the number of exceedances and the excesses as a marked point process with a proper intensity, that, in its basic representation, converges to a two-dimensional Poisson process. In practice:

- a) the exceedances (x) over a threshold u occur at the times of a Poisson process with intensity λ ;
- b) the corresponding excesses ($y=x-u$) are independent and have a GPD distribution;
- c) the number of exceedances and the excesses are independent of each other.

The parameter λ measures the intensity of the exceedances at u per unit of time, that is if the number of large losses is stable over time or if it becomes more or less frequent.¹⁴³

In practice, the choice of a frequency distribution is often regarded as a relatively minor issue as the results of the frequency-severity approach in the context of operational risk tend to be driven by the choice of severity distributions. Aue and Kalkbrener explain that “the impact of the shape of frequency distributions on capital requirements is rather limited ... This is a consequence of: for subexponential severities, the tail of the aggregate loss distribution is determined by the tail of the severity distribution and the expected frequency (but not its precise shape).”¹⁴⁴ As a result, the Poisson distribution appears to be the most commonly used frequency distribution.

Aggregated Losses

Corrigan and Luraschi describe the aggregation process and include detailed steps for simulation analysis. They also discuss alternative risk statistics that can be used from the cumulative distribution function for the purpose of capital assessment. These descriptions are not repeated in this research paper.

According to Basel II, the final operational risk capital for a bank would be equal to the sum of the risk measures (i.e., VaR) for each ORC modeled if the model cannot accurately account for correlation between ORCs. The sum of individual VaRs to determine the VaR of the total distribution is sometimes too conservative and is equivalent to the assumption of perfect dependence between risks.

Lambrigger et al. also comment on aggregation of modeled ORCs. They state:

However, reasonable aggregation is still an open challenging problem that needs further investigation. The choice of appropriate dependence structures is crucial and determines the amount of diversification. In the general case, when no information about the dependence

¹⁴³ M. Moscadelli, “The modelling of operational risk: experience with the analysis of the data collected by the Basel Committee”, *Banca D'Italia*, July 2004: pp 53-54.

http://www.bancaditalia.it/pubblicazioni/econo/temidi/td04/td517_04/td517en/en_tema_517.pdf.

¹⁴⁴ F. Aue and M. Kalkbrener, “LDA at Work”, Deutsche Bank AG, February 2007: 43.

http://kalkbrener.at/Selected_publications_files/AueKalkbrener06.pdf.

structure is available, Embrechts and Puccetti¹⁴⁵ work out bounds for aggregated operational risk capital; for further issues regarding aggregation we would like to refer to Embrechts et al.^{146 147}

Moscadelli compares the aggregation approach using EVT to traditional actuarial models:

This approach [EVT] differs sharply from the conventional actuarial approach, where – except for the rare case in which the expression for the compound distribution of the aggregated losses is analytically derivable from the distributions of its components of frequency and severity – the computation of a (high) percentile of the aggregated losses is obtained by treating the estimate of the severity and the frequency components as a separate, disjointed, problem and, afterwards, aggregating the corresponding outcomes using numerical, approximation or simulation methods (i.e. the MonteCarlo procedure). Owing to the absence of an analytical basis, these methods require many steps to be generated to calculate the highest percentiles of the aggregated distribution of losses.¹⁴⁸

Moscadelli notes that the advantages of the POT approach in estimating the tail of the aggregated losses arise from two properties:

Property 1: the POT method takes into consideration the (unknown) relationship between the frequency and the severity of large losses up to the end of the distribution;

Property 2: the POT method makes it possible to employ a semiparametric approach to compute the highest percentiles of the aggregated losses, hence reducing the computational cost and the estimate error related to a not analytical representation of the aggregated losses themselves. In the POT model, it suffices to select a suitable (high) threshold, on which basis the model can be built and the relevant parameters estimated. Once the model is correctly calibrated, the total losses (and their percentiles) are easily obtainable by proper analytical expressions.¹⁴⁹

Challenges of Frequency-Severity Analyses and EVT Methods

Some of the most significant challenges with frequency-severity analyses are related to data. Neil et al. discuss some of these issues in *Using Bayesian networks to model the operational risk to information technology infrastructure in financial institutions*. They state:

¹⁴⁵ P. Embrechts and G. Puccetti, “Aggregating Risk Capital, with an Application to Operational Risk”, *The Geneva Risk and Insurance Review*, 2006, vol. 31, issue 2, pp 71–90.

¹⁴⁶ P. Embrechts, J. Nešlehová, and M. V. Wüthrich, “Additivity properties for Value-at-Risk under Archimedean dependence and heavy-tailedness”, *ETH Zurich*, 2007.
http://www.math.ethz.ch/~embrecht/ftp/Emb_Nes_Wu_VaR_V4.pdf.

¹⁴⁷ D.D. Lambrigger, P.V. Shevchenko, and M.V. Wüthrich, “The Quantification of Operational Risk using Internal Data, Relevant External Data and Expert Opinions”, July 4, 2007: 24. [http://www.ressources-actuarielles.net/EXT/ISFA/1226.nsf/0/dfdd987956704deac1257840002b6931/\\$FILE/CombiningDataSourcesOpRisk.pdf](http://www.ressources-actuarielles.net/EXT/ISFA/1226.nsf/0/dfdd987956704deac1257840002b6931/$FILE/CombiningDataSourcesOpRisk.pdf).

¹⁴⁸ M. Moscadelli, “The modelling of operational risk: experience with the analysis of the data collected by the Basel Committee”, *Banca D’Italia*, July 2004: pp 60-61.

http://www.bancaditalia.it/pubblicazioni/econo/temidi/td04/td517_04/td517en/en_tema_517.pdf.

¹⁴⁹ *Ibid.*: pp 61-62.

The traditional statistical approach to these kinds of problems is to rely purely on historical data to find the inherent distribution of losses. However, in the case of operational loss data, even when a large loss dataset is available, it is unlikely that there will be enough data on the large unexpected losses for us to be able to estimate the tail of the distribution properly — usually we end up with tails that are too thin or indeed too fat if the loss data are not relevant for the domain in question. Even when modeling the expected losses (the bulk of the distribution), the data-oriented approach suffers from the following limitations: (1) loss data will be gathered over a period of time that may represent varying levels of operational effectiveness and risk/threat (we cannot expect that losses are generated from one single distribution with a small number of known parameters); (2) losses experienced are simply a sample of possible events (they may not be representative of changing operational processes. As the underlying operational process degrades or improves the value of such historical data wanes); and (3) the reported loss data might be wrong (under-reporting and data ambiguity can lead to significant errors in estimation). Any attempt to bolster loss data with data gathered from other organizations is subject to the same problems and more because very often the provenance of the data is unknown or in doubt.¹⁵⁰

Chavez-Demoulin et al. express similar reservations about the use of EVT and the need for sufficient data:

Whereas EVT is the natural set of statistical techniques for estimating high quantiles of a loss distribution, this can be done with sufficient accuracy only when the data satisfy specific conditions; we further need sufficient data to calibrate the models.¹⁵¹

Two issues related to operational risk loss data that were previously discussed include reporting bias and the effect of changes over time. Embrechts et al. conclude that “for repetitive and stationary losses the standard actuarial methods and their refinements can be employed to derive capital charges.”¹⁵² However, issues arise when the stationary or survival conditions are breached.

Sample size presents a significant challenge when using EVT for modeling operational risk. Embrechts et al. present the sample size required for the reliable estimation of certain high quantiles under ideal¹⁵³ data structure assumptions. Throughout the literature on operational risk modeling, it is noted that the existing data available and data structure of operational risk losses makes “a straightforward EVT application somewhat

¹⁵⁰ M. Neil, D. Marquez, and N. Fenton, “Using Bayesian networks to model the operational risk to information technology infrastructure in financial institutions”, *The Capco Institute – Journal for Financial Transformation*: pp 133-134, http://www.eecs.gmul.ac.uk/~martin/index_files/capco%20paper.pdf.

¹⁵¹ V. Chavez-Demoulin, P. Embrechts, and J. Nešlehová, “Quantitative Models for Operational Risk: Extremes, Dependence and Aggregation”, presented to the *Federal Reserve Bank of Boston*, May 18-20, 2005: 3. http://www.math.ethz.ch/~embrecht/ftp/manuscript_cen.pdf.

Referenced to P. Embrechts, H. Furrer, and R. Kaufmann, “Quantifying Regulatory Capital for Operational Risk”, Research supported by *Credit Suisse Group, Swiss Re* and *UBS AG* through *RiskLab*, Switzerland, 2003. <http://www.math.ethz.ch/~embrecht/ftp/OPRiskWeb.pdf>.

and P. Embrechts, R. Kaufmann, and G. Samorodnitsky, “Ruin Theory Revisited: Stochastic Models for Operational Risk”, 2004.

¹⁵² P. Embrechts, H. Furrer, and R. Kaufmann, “Quantifying Regulatory Capital for Operational Risk”, Research supported by *Credit Suisse Group, Swiss Re* and *UBS AG* through *RiskLab*, Switzerland, 2003: 15. <http://www.math.ethz.ch/~embrecht/ftp/OPRiskWeb.pdf>.

¹⁵³ Referred to as iid, independent and identically distributed.

questionable.”¹⁵⁴ One outcome of relying on insufficient data is that the estimation procedures at the high quantiles (e.g., 99.9% confidence level) result in very wide confidence intervals for the resulting risk capital.¹⁵⁵ Nevertheless, there are subclasses of operational risk (for banks) for which EVT is believed to be an effective approach.

As stated earlier, one of the most significant challenges in the application of EVT is the choice of a suitable threshold value. Chapelle et al. comment that “while several authors ... have suggested methods to identify the cut-off threshold, no single approach has become widely accepted yet.”¹⁵⁶ This is true even with standard, repetitive iid data. The key issue related to this challenge is the number of exceedances required (i.e., how many observations are needed in the tail) for modeling purposes. Embrechts et al. reproduce tables from McNeil and Saladin (1997) (which are copied below). They summarize the minimum number of exceedances and the corresponding number of observations required for three distributions: a lognormal distribution and two Pareto distributions with shape parameters equal to 2 and 1. These distributions were selected to respectively represent the following three types of loss distributions, which occur in operational risk literature:

- Medium-tailed (lognormal);
- Heavy-tailed with infinite moments of order greater than or equal to two; and
- Heavy-tailed with infinite moments of order greater than or equal to one.

Table 1 – Lognormally distributed claims

Accuracy of estimating high quantiles by means of the POT method¹⁵⁷

$u = F^{\leftarrow}(q)$	α	Goodness of $\widehat{\text{VaR}}_{\alpha}$
$q = 0.7$	0.99	A minimum number of 50 exceedances (corresponding to 167 observations) is required to ensure accuracy wrt bias <i>and</i> standard error.
	0.999	A minimum number of 100 exceedances (corresponding to 333 observations) is required to ensure accuracy wrt bias <i>and</i> standard error.
$q = 0.9$	0.99	Full accuracy can be achieved with the minimum number 25 of exceedances (corresponding to 250 observations).
	0.999	Full accuracy can be achieved with the minimum number 25 of exceedances (corresponding to 250 observations).

¹⁵⁴ V. Chavez-Demoulin, P. Embrechts, and J. Nešlehová, “Quantitative Models for Operational Risk: Extremes, Dependence and Aggregation”, presented to the *Federal Reserve Bank of Boston*, May 18-20, 2005: 4. http://www.math.ethz.ch/~embrecht/ftp/manuscript_cen.pdf.

¹⁵⁵ *Ibid.*: 11.

¹⁵⁶ A. Chapelle, Y. Crama, G. Hübner, and J.-P. Peters, “Practical methods for measuring and managing operational risk in the financial sector: A clinical study”, *ScienceDirect, Journal of Banking & Finance* 32 (2008) 1049-1061, October 1, 2007: s.2.2.2. <http://finance.flemingeurope.com/webdata/3118/JBF-Chapelle-et-al2008.pdf>.

¹⁵⁷ P. Embrechts, H. Furrer, and R. Kaufmann, “Quantifying Regulatory Capital for Operational Risk”, Research supported by *Credit Suisse Group, Swiss Re* and *UBS AG* through *RiskLab*, Switzerland, 2003: 13. <http://www.math.ethz.ch/~embrecht/ftp/OPRiskWeb.pdf>.

Table 2 – Pareto distributed claims with shape parameter $\theta = 2$
Accuracy of estimating high quantiles by means of the POT method¹⁵⁸

$u = F^{-1}(q)$	α	Goodness of $\widehat{\text{VaR}}_{\alpha}$
$q = 0.7$	0.99	A minimum number of 100 exceedances (corresponding to 333 observations) is required to ensure accuracy wrt bias <i>and</i> standard error.
	0.999	A minimum number of 200 exceedances (corresponding to 667 observations) is required to ensure accuracy wrt bias <i>and</i> standard error.
$q = 0.9$	0.99	Full accuracy can be achieved with the minimum number 25 of exceedances (corresponding to 250 observations).
	0.999	A minimum number of 100 exceedances (corresponding to 1000 observations) is required to ensure accuracy wrt bias <i>and</i> standard error.

Table 3 – Pareto distributed claims with shape parameter $\theta = 1$
Accuracy of estimating high quantiles by means of the POT method¹⁵⁹

$u = F^{-1}(q)$	α	Goodness of $\widehat{\text{VaR}}_{\alpha}$
$q = 0.7$	0.99	For all number of exceedances up to 200 (corresponding to a minimum of 667 observations) the VaR estimates fail to meet the accuracy criteria.
	0.999	For all number of exceedances up to 200 (corresponding to a minimum of 667 observations) the VaR estimates fail to meet the accuracy criteria.
$q = 0.9$	0.99	A minimum number of 100 exceedances (corresponding to 1000 observations) is required to ensure accuracy wrt bias <i>and</i> standard error.
	0.999	A minimum number of 200 exceedances (corresponding to 2000 observations) is required to ensure accuracy wrt bias <i>and</i> standard error.

Larger sample sizes are required for the heavier tails in order to obtain the desired accuracy. Furthermore, it is valuable to have sufficient data far in the tail.¹⁶⁰

¹⁵⁸ P. Embrechts, H. Furrer, and R. Kaufmann, "Quantifying Regulatory Capital for Operational Risk", Research supported by *Credit Suisse Group, Swiss Re* and *UBS AG* through *RiskLab*, Switzerland, 2003: 13.
<http://www.math.ethz.ch/~embrecht/ftp/OPRiskWeb.pdf>.

¹⁵⁹ *Ibid.*: 14.

Gourier et al. discuss the challenges in applying a frequency-severity analysis to real heavy-tailed data:

Finally, we think that the key message of this study is that heavy-tailed distributions with shape parameters bigger than one are the source of many theoretical problems including a high impact on the overall capital charges, instability and high uncertainty of the results, and incoherence of the VaR leading to a possible misestimation of the capital charges. Therefore, the shortfalls of the current modeling techniques need to be kept in mind. However, this is not a lost cause, and the studies on operational risk keep uncovering parts of the iceberg.¹⁶¹

Challenges exist in understanding the effect of diversification in operational risk modeling using frequency-severity analysis as well as in the modeling of dependent risk processes. There are also unresolved issues in the quantification of operational risk related to risk aggregation. Chavez-Demoulin et al. state:

The loss characteristics of operational loss data, as summarized by heavy-tailedness, skewness and unknown interdependence between the various loss rvs [random variables], imply that the Value-at-Risk measure for risk capital may not be subadditive. Due to a lack of publicly available data, it is not yet clear to what extent [extent] correlation issues can be taken into account which may lead to a reduction of the calculated risk capital based on $\sum_{k=1}^d VaR_{99,9\%}(L_k)$.¹⁶²

Gourier et al. report on the result of an empirical study with heavy-tailed data. In their concluding remarks on the modeling of dependencies using copulas, they state:

Using copulas to model the dependence structure allows for better realism but does not provide a solution to the calculation of capital charges when the model involves GPDs [generalized Pareto distributions] with ξ [shaper parameter] > 1 . Indeed, the superadditivity of VaR prevents capital charges from decreasing as would be expected when the correlation between business lines in the model is decreased. Our results are in line with the existing literature and show that the standard copula approach yields results that contradict standard economic thinking about diversification.¹⁶³

Practical Considerations

There are numerous issues for consideration when conducting frequency-severity analysis. The following discussion is not presented in any particular order and is also not exhaustive.

Dutta and Babel state the following with respect to frequency-severity models:

¹⁶⁰ P. Embrechts, H. Furrer, and R. Kaufmann, "Quantifying Regulatory Capital for Operational Risk", Research supported by *Credit Suisse Group, Swiss Re* and *UBS AG* through *RiskLab*, Switzerland, 2003: 14.

<http://www.math.ethz.ch/~embrecht/ftp/OPRiskWeb.pdf>.

¹⁶¹ E. Gourier, W. Farkas, and D. Abbate, "Operational risk quantification using extreme value theory and copulas: from theory to practice", *The Journal of Operational Risk* (3-26), Volume 4/Number 3, Fall 2009: 24.

http://www.risk.net/digital_assets/4682/jop_v4n3a1.pdf.

¹⁶² V. Chavez-Demoulin, P. Embrechts, and J. Nešlehová, "Quantitative Models for Operational Risk: Extremes, Dependence and Aggregation", presented to the *Federal Reserve Bank of Boston*, May 18-20, 2005: 15.

http://www.math.ethz.ch/~embrecht/ftp/manuscript_cen.pdf.

¹⁶³ E. Gourier, W. Farkas, and D. Abbate, "Operational risk quantification using extreme value theory and copulas: from theory to practice", *The Journal of Operational Risk* (3-26), Volume 4/Number 3, Fall 2009: 23.

http://www.risk.net/digital_assets/4682/jop_v4n3a1.pdf.

If the historical-loss-data-based model for either severity or frequency is not estimated correctly, then these methods will suffer from instability and inaccuracy. For evaluation of severity and frequency models, we strongly suggest that, along with goodness-of-fit tests for each model, one should judge performance by the following criteria, used in Dutta and Perry (2007).

1. Realistic - If a method fits well in a statistical sense, does it generate a loss distribution with a realistic capital estimate?
2. Well-Specified - Are the characteristics of the fitted data similar to the loss data and logically consistent?
3. Flexible - How well is the method able to reasonably accommodate a wide variety of empirical loss data?
4. Simple - Is the method easy to apply in practice, and is it easy to generate random numbers for the purposes of loss simulation?

In addition, one should stress-test each distribution in terms of coherence, consistency, and robustness. A log-log plot may be a useful tool to ascertain the threshold of a Pareto tail if the Pareto family of distributions is used to fit the tail of the distribution. It could reduce the number of simulations.¹⁶⁴

Frequency-severity analysis requires deciding whether to model the number of incidents or true frequency (i.e., the number of incidents relative to an exposure measurement). This decision depends on the availability of reasonable exposure measures. As noted previously, there are currently no commonly agreed measures of exposure for operational risk, and reliable exposure data are difficult to access.

Another consideration related to frequency-severity analysis is whether to include or exclude data points at both extremes (i.e., low severity and extremely high severity events). To the extent that the historical data does not contain any extreme events, or only includes a limited number of such events, the insurer could seek the advice of experts (internal or external to the insurer) with respect to quantifying the potential exposure to such losses. The tails of the severity and frequency distributions could be modified, based on the experts' advice, to ensure that the cumulative distribution passed through certain points specified by these experts.

In practice, the availability or lack thereof of statistical software will likely influence the types of curves that can be readily fit to the data as well as the types of goodness of fit tests that can be employed.

Due to the considerable judgment necessary in conducting frequency-severity analysis, great care is necessary when evaluating model results. The wide array of distributions as well as the parameter uncertainty for a given distribution could result in substantial variability in operational risk estimates. Thus, it is important to recognize the potential for error. Tripp et al. state:

It will be instructive to look at the standard error for the parameter and consider the impact of changing the parameters by, say, one standard error, on the outcome. Where capital requirements are set to reflect a relatively high level of risk aversion, this could make a very

¹⁶⁴ K.K. Dutta and D.F. Babbel, "Scenario Analysis in the Measurement of Operational Risk Capital: A Change of Measure Approach", *Wharton School of the University of Pennsylvania*, July 5, 2012: 18. <http://fic.wharton.upenn.edu/fic/papers/12/12-15.pdf>.

significant difference to the amount of capital that a model might suggest should be set aside in respect of operational risk.¹⁶⁵

Similarly, the choice of distributions is typically not a clear cut decision. Thus, testing the effects of changing the distributions could prove valuable.

Dexter et al. discuss the need for sensitivity testing given the subjective nature of the input parameters. They provide the following examples of tests that could be used:

- Test 1: Investigating the effect of a small change in the pessimistic values for the frequencies and severities. This test considers the effect of increasing the pessimistic values of the frequencies and severities by 10%, while keeping the median values constant.
- Test 2: Investigating the impact of a small change in the percentiles for the pessimistic severities. This test considers the effect of incorrectly estimating the pessimistic percentiles of the frequencies. For example, suppose one had estimated the 'pessimistic' severity to be 1 in 100 event, when it was actually a 1 in 50 event.
- Test 3: Given the subjective nature of the distributions, it is important [to] test the impact on the results of fitting a number of different distributions for frequency and severity. The sensitivity is taken to be the maximum capital given by the various combinations of distributions.
- Other tests would be specific to a certain model and may involve changing the values of parameters concerning insurance, threshold values, truncation values, etc. ...

Note it is important to test the sensitivities of the tail values of the inputs, as those are much harder to estimate correctly compared to the medians, and should have a larger impact on the stand-alone capital for each scenario.¹⁶⁶

Another practical consideration previously identified is the systematic integration of external operational risk events loss data with internal loss data, particularly for the analysis of the severity distribution. One of the most important issues is how to scale the relevant, available, external data to reflect differences in the size and characteristics of organizations.

Another issue that requires consideration in the quantification process is the dependence between operational risk categories and sub-categories. In frequency-severity analysis, "dependence between risks can be modelled either between frequencies of loss events, or between their severities, or between aggregate annual losses."¹⁶⁷

¹⁶⁵ M.H. Tripp, H.L. Bradley, R. Devitt, G.C. Orros, G.L. Overton, et al., "Quantifying Operational Risk in General Insurance Companies", developed by a *GIRO Working Party*, March 22, 2004: s.5.5.11.

<http://www.actuaries.org.uk/system/files/documents/pdf/33784baj105919-10262004tripp.pdf>.

¹⁶⁶ N. Dexter, C. Ford, P. Jakahria, P. Kelliher, D. McCall, et al., "Quantifying Operational Risk in Life Insurance Companies", Developed by the Life Operational Risk Working Party, 2006: 31.

www.actuaries.org.uk/system/files/documents/pdf/opriskcapital.pdf.

¹⁶⁷ A. Chapelle, Y. Crama, G. Hübner, and J.-P. Peters, "Practical methods for measuring and managing operational risk in the financial sector: A clinical study", *ScienceDirect, Journal of Banking & Finance* 32 (2008) 1049-1061, October 1, 2007: s.2.4. <http://finance.flemingeurope.com/webdata/3118/JBF-Chapelle-et-al2008.pdf>.

Causal Modeling and Bayesian Estimation Techniques

Organization, Introduction, and Sources

Organization

This section of the research paper is organized as follows:

- Organization, introduction, and sources;
- General description of a Bayesian network (BN);
- Applications of a BN including scenario analysis, key risk indicators, and estimating capital;
- Bayesian decision networks;
- Advancements in BN including hybrid dynamic BNs, using BNs to capture correlation, and credal networks;
- Practical considerations in using BNs; and
- Strengths and weaknesses of BNs.

Introduction

Bayesian networks (BNs) are described by Alexander, a prominent author on the topic, as “a statistical model that relates the marginal distributions of ‘causal’ factors, or ‘attributes’ of a risk, to its multivariate distribution.”¹⁶⁸ BNs have been used for decades in numerous applications including medical expert systems, transportation, failure diagnosis, pattern matching, chemical processing, speech recognition, infrastructure, environmental modeling, and legal and evidential reasoning. The use of BNs within financial institutions, and insurance in particular, has not been as pervasive as in other industries.

BNs, also referred to as Bayesian belief networks (BBNs), are described as an elegant solution to the modeling of operational risk that combines both qualitative and quantitative information to arrive at a loss estimate.¹⁶⁹ BNs can be particularly useful for modeling ORCs with little or no loss data (internal or external). Unlike the frequency-severity approach, BNs are causal networks and thus valuable for analyzing the causes that contribute to operational risk.

¹⁶⁸ C. Alexander, “Chapter 14 Managing Operational Risks with Bayesian Networks”, *Operational Risk: Regulation, analysis, and Management*, 2003: S.14.2.

http://www.carolalexander.org/publish/download/JournalArticles/PDFs/Chapter_Alexander_Bayesian_2003.pdf.

¹⁶⁹ S. Ramamurthy, H. Arora, and A. Ghosh, “Operational Risk Probabilistic Networks – An Application to Corporate Actions Processing”, *Infosys*, White Paper, November 2005: 2. <http://www.infosys.com/industries/financial-services/white-papers/documents/operational-risk-probabilistic-networks.pdf>.

Sources

There are many papers on the topic of BNs and operational risk. This section of the research paper is based on descriptions of BNs from the following sources:

- K. Adusei-Poku, *Operational Risk Management – Implementing a Bayesian Network for Foreign Exchange and Money Market Settlement*, University of Gottingen, 2005;
- C. Alexander, *Bayesian Methods for Measuring Operational Risk*, ISMA Centre, The Business School for Financial Markets, University of Reading, 2000;
- C. Alexander, *Chapter 14 – Managing Operational Risks with Bayesian Networks*, *Operational Risk: Regulation, Analysis, and Management*, 2003;¹⁷⁰
- A. Antonucci, A. Piatti, and M. Zaffalon, *Credal Networks for Operational Risk Measurement and Management*, Istituto “Dalle Molle” di Studi sull’Intelligenza Artificiale, Switzerland, 2007;
- V. Aquaro, M. Bardoscia, R. Bellotti, A. Consiglio, F. De Carlo, et al., *A Bayesian Networks Approach to Operational Risk*, Preprint submitted to Physica A, February 14, 2012;
- J. Corrigan and P. Luraschi, *Operational risk modeling framework*, Milliman Research Report, February 13, 2013;
- GIRO Working Party, including M.H. Tripp, H.L. Bradley, R. Devitt, G.C. Orros, G.L. Overton, et al., *Quantifying Operational Risk in General Insurance Companies*, March 22, 2004;
- M. Neil, D. Häger, and L.B. Andersen, *Modeling operational risk in financial institutions using hybrid dynamic Bayesian networks*, *The Journal of Operational Risk* (3-33), Volume 4/Number 1, Spring 2009;
- M. Neil, D. Marquez, and N. Fenton, *Using Bayesian network to model the operational risk to information technology infrastructure in financial institutions*, The Capco Institute – Journal for Financial Transformation;
- S. Ramamurthy, H. Arora, and A. Ghosh, *Operational Risk Probabilistic Networks – An Application to Corporate Actions Processing*, Infosys, White Paper, November 2005;
- A.D. Sanford and I.A. Moosa, *A Bayesian network structure for operation risk modelling in structured finance operations*, Department of Accounting and Finance, Monash University, Australia, Draft Working Paper, 2008;¹⁷¹ and
- Y.K. Yoon, *Modelling Operational Risk in Financial Institutions Using Bayesian Networks*, Faculty of Actuarial Science and Statistics, Cass Business School, May 1, 2003.

Similar to the frequency-severity approach, this research paper does not include a detailed theoretical discussion of BNs. Instead readers are directed to the numerous papers on the topic.

¹⁷⁰ In Section 14.1 of this paper is a valuable list of references and web links to literature on BNs.

¹⁷¹ Of particular value in Sanford and Moosa is a detailed literature review of the use of BNs in a wide range of industries including financial institutions. Furthermore, the paper consists of numerous references to other papers on the topic.

General Description of a BN

A BN¹⁷² is a graphical model in which probability theory is combined with graph theory. Yoon states that BNs are “the result of converging developments in statistical modelling, engineering and artificial intelligence that began in the 1980’s.”¹⁷³ In general, a graphical model consists of a network of nodes and edges connecting variables that have some form of relationship, whether of correlation or causation. A directed acyclic graph (DAG), which is the basic building block of a BN, consists almost entirely of causal relationships and thus involves nodes connected by directed edges. Given initial node probability distributions and the conditional probabilities for all nodes, a BN uses Bayes’ Theorem to propagate through the entire network quantifying the distributions of all nodes.

In *A Bayesian network structure for operational risk modelling in structured finance operations*, Sanford and Moosa provide the following general description of a BN:

A Bayesian network consists of nodes and directional arcs or arrows. Each node may be either discrete, having at least two states, or continuous, with a Gaussian distribution over the real line. Within the Bayesian network, each node represents some variable of interest within the domain being modelled. Behind each node is a function that represents the probability distribution of the states of that node. Often that function is represented as a table, which is called the conditional probability table (or CPT), or node probability table (NPT). Given the semantics of the nodes and states, we see that in modelling an environment, the modeller must decide on what variables are of interest to the user or decision maker. They must also decide on what measures are used to determine the state of these variables and what state descriptors provide the most value to the user or decision maker. In determining the number of states for a discrete node, the modeller should be aware that increasing the states will improve the granularity of the measure, but will make probability elicitation potentially more complex. A trade off therefore, between the number of states, and the additional complexity needs to be considered when developing the network.¹⁷⁴

The probabilities used in a BN can be based on experts’ judgment, a scorecard approach, statistical analysis of historical data, or determined by the BN. BNs offer tremendous flexibility to the modeler. Discrete random variables with many states can be modeled. Alternatively, a BN can be developed using “discrete or continuous random variables from some family of distributions where parameter values themselves have distributions that are conditional on the states of the parent nodes.”¹⁷⁵

¹⁷² BNs are also referred to as belief networks, causal probabilistic networks, directed graphical models, or generative models.

¹⁷³ Y.K. Yoon, “Modelling Operational Risk in Financial Institutions Using Bayesian Networks”, *Faculty of Actuarial Science and Statistics, Cass Business School, City of London*, 1 May 2003: 15.

http://www.scor.com/images/stories/pdf/library/actuarial-prize/2004_UK_YewKhuenYoon.pdf.

¹⁷⁴ A.D. Sanford and I.A. Moosa, “A Bayesian network structure for operation risk modelling in structured finance operations”, *Department of Accounting and Finance, Monash University, Australia*, Draft Working Paper, 2008: 7.

http://www.melbournecentre.com.au/WorkingPaper_part1_Sanford_Moosa2008.pdf.

¹⁷⁵ C. Alexander, “Chapter 14 Managing Operational Risk with Bayesian Networks”, *Operational Risk: Regulation, Analysis, and Management*, 2003: S.14.2.

http://www.carolalexander.org/publish/download/JournalArticles/PDFs/Chapter_Alexander_Bayesian_2003.pdf.

Application of BNs

Alexander discusses the use of BNs with scenario analysis, key risk indicators, and linkage to the economic capital of an organization.

Scenario Analysis

BNs are typically used for causal analysis and scenario analysis. As the name implies, causal analysis is used to examine the causes influencing operational losses. In causal analysis, updated probabilities for all the causal risk factors are determined using new evidence of operational losses. In scenario analysis, one or more of the causal risk factors are calibrated and the influence on the loss estimate is analyzed.

Alexander comments on the use of BNs for scenario analysis:

... if the states of any nodes are fixed, the network can use Bayes' rule to propagate backwards through the network and hence calculate the posterior probabilities of every node in the network. This is the basis of scenario analysis in Bayesian networks, and it is one of the most attractive features of Bayesian networks. The ability to perform scenario analysis in this rigorous, but also tractable and visual manner should be viewed as the over-riding reason for their use.¹⁷⁶

Key Risk Indicators and BNs

Tripp et al. state that BNs are most valuable when used in conjunction with key risk indicators (KRIs). KRIs can be used to help calibrate the model, which is then used to gain a deeper understanding of the operational risks. In turn, the model can help suggest effective KRIs for ongoing risk monitoring.

Tripp et al. provide a description of KRIs for general insurers that are equally applicable to life and health insurers. KRIs are used to provide an early warning of high or increased risk. Ideally, KRIs are easy to calculate and predictive; they should be based on underlying causes or intended to expose poor processes.¹⁷⁷

According to Tripp et al., KRIs can be an extremely valuable component of an overall risk management process for four reasons:

- They can help with a qualitative assessment of operational risk even when an organization cannot yet quantitatively measure operational risk;
- They can be used for all types of risks not only those that have experienced past losses;
- They can be used to gauge the effectiveness of systems and controls; and

¹⁷⁶ C. Alexander, "Chapter 14 Managing Operational Risks with Bayesian Networks", *Operational Risk: Regulation, Analysis, and Management*, 2003: S.14.2.

http://www.carolalexander.org/publish/download/JournalArticles/PDFs/Chapter_Alexander_Bayesian_2003.pdf.

¹⁷⁷ M.H. Tripp, H.L. Bradley, R. Devitt, G.C. Orros, G.L. Overton, et al., "Quantifying Operational Risk in General Insurance Companies", developed by a *GIRO Working Party*, March 22, 2004: s.3.9.2 and s.3.10.2.

<http://www.actuaries.org.uk/system/files/documents/pdf/33784baj105919-10262004tripp.pdf>.

- They can be the basis for penalties and positive incentives to encourage behaviour that contributes to the reduction of enterprise wide operational risk exposures.¹⁷⁸

Tripp et al. classify KRIs for operational risk in three categories: exposure-related KRIs, loss-related KRIs, and cause-related KRIs. Exposure-related KRIs are volume-based indicators used to measure the throughput of processes that have the potential to result in operational failures. Loss-related KRIs are lagging indicators, as they measure events that have already resulted in an operational loss. Finally, cause-related KRIs are leading indicators, as they measure drivers for operational losses. Cause-related indicators are the most difficult to identify, more complex than the other indicators, and the most valuable indicators in use.

Tripp et al. provide the following illustrative examples of KRIs:¹⁷⁹

¹⁷⁸ M.H. Tripp, H.L. Bradley, R. Devitt, G.C. Orros, G.L. Overton, et al., "Quantifying Operational Risk in General Insurance Companies", developed by a *GIRO Working Party*, March 22, 2004: s.3.9.3.
<http://www.actuaries.org.uk/system/files/documents/pdf/33784baj105919-10262004tripp.pdf>.

¹⁷⁹ Ibid.: Table 3.11.1.

KRI	Category	Comments
Number of unresolved internal audit issues rated 'severe'	Cause	Requires a tracking system for internal audit. Also consider using the number of internal audit issues unresolved after two years.
Staff turnover	Cause	May be a lagging indicator, as it may be symptomatic of other problems as well as leading to problems itself.
Training hours (or pounds spent) per staff member	Cause	Low numbers are bad here.
Number of staff members who require training	Cause	Measure separately for each staff category and type of training. Consider using ratio of untrained to trained staff.
Number of different desktop computer configurations in use	Cause	Inconsistencies can lead to problems, especially for inadequately trained staff.
Hours of paid overtime per staff member	Cause	May indicate that resources are stretched.
Number of claims processed	Exposure	May be a leading indicator, as it may indicate increased pressure on claims handlers. Consider using claims processed per claims handler.
Number of complaints	Loss	A lagging indicator, but nonetheless useful. Consider using ratio of complaints to claims processed.
Growth in sales	Exposure	Can be used to detect anomalies. May be a leading indicator for some risks.
Budget overruns	Loss	Consistent overruns may indicate failures in the budgeting process.
Number of large claims	Exposure	Indicator for possible reinsurance problems.
Sizes of outsourcing contract	Exposure	If significant, may need more indicators from the outsourcing supplier.
Numbers of IT projects under way	Exposure	Potential integration problems and over-stretch of resource.
Percentage of business given to each supplier by volume and pound amount	Exposure	Calculated separately for each category of supplier. Can be used detect anomalies and measure exposure to supplier failure.

In developing a BN, terminal nodes can be set as the KRIs selected by the insurer to manage operational risk. In describing the use of a BN with KRIs, Alexander states:

Bayesian networks can also be used to determine the “trigger levels” associated with a key risk indicator. The trigger levels are bounds that determine various actions, that must be

taken by management, if the risk indicator crosses that level. All nodes in a Bayesian network (with more than one state) are random variables. So when a key risk indicator is used as a target node in a Bayesian network, the network will determine its distribution, under any given scenario. This includes the mean, the standard deviation and the upper percentiles of the key risk indicator. From the initial state of the network, trigger levels can be set at either some multiples of the standard deviation or, if the distribution is skewed or fat-tailed, the upper percentiles. The precise levels at which trigger level are set will, of course, depend on the risk aversion (the more risk averse, the lower the percentile). A variety of trigger levels may be set, for example at increasing percentiles, and the trigger levels at higher percentiles should prompt more drastic actions than those at lower percentiles.¹⁸⁰

Through the analysis of scenarios, a BN can be used to evaluate the influence of alternative risk controls on the distribution of KRIs.

Estimating Capital with BNs

With respect to the application of a BN to estimate capital, Alexander states:

For a fully integrated view of management and capital allocation, a Bayesian network could have terminal nodes corresponding to the number of loss events and the loss given event. Thus the Bayesian network will model the frequency and severity distributions, and therefore their composite (the annual loss distribution) as functions of the key risk drivers in the firm. In this way, the management and control of operational risks can be linked to the economic capital of a firm, or the regulatory capital of a bank. Furthermore, the Bayesian network will allow management decisions to be supported by scenario analysis, and to be integrated with the risk capital and budgeting of the firm.¹⁸¹

Corrigan and Luraschi address the use of BNs for estimating operational risk capital. They state:

A Bayesian framework also has the ability to encompass the full range of data, distributions, and simulations that are required to undertake operational risk capital assessments. Where available, both internal and external data can be used to not only calibrate the end loss distribution (or likelihood and severity equivalents), but it can also be used to calibrate the distributions of the underlying drivers. Many companies are collecting large databases of such information, and analytic and predictive modelling techniques are being used successfully to define these distributions.¹⁸²

¹⁸⁰ C. Alexander, "Chapter 14 Managing Operational Risks with Bayesian Networks", *Operational Risk: Regulation, Analysis, and Management*, 2003: s.14.3.

http://www.carolalexander.org/publish/download/JournalArticles/PDFs/Chapter_Alexander_Bayesian_2003.pdf.

¹⁸¹ *Ibid.*: S.14.3.

¹⁸² J. Corrigan and P. Luraschi, "Operational risk modelling framework", *Milliman Research Report*, February 13, 2013: 45. <http://www.milliman.com/uploadedFiles/insight/life-published/operational-risk-modelling-framework.pdf>.

Corrigan and Luraschi comment further that BNs are ideally suited for determining capital as they “can simultaneously account for the full range of operational outcomes, both positive and negative, and common and extreme.”¹⁸³ Their paper provides examples of this application.

Bayesian Decision Networks

Through the addition of decision nodes and utility nodes, a BN can be used to develop a special type of influence diagram known as a Bayesian decision network, or simply decision network. A decision node represents a variable controlled by a risk manager in order to manage operational risk; and a utility node represents the expected utility from the decision.¹⁸⁴

A decision network can be used to evaluate the cost-benefit relationship of risk controls. Thus, influence diagrams are valuable in the management of operational risk to highlight decisions that maximize expected utility. The decision network can employ utility functions that reflect the risk aversion of the organization. Augmenting a BN with decision and utility nodes provides for an important management tool with increased transparency.

Advancements in BNs

Hybrid Dynamic BNs

In *Modeling operational risk in financial institutions using hybrid dynamic Bayesian networks*, Neil et al., describe the use of generalized hybrid dynamic BNs to model financial institutions' operational risk in terms of economic capital. Neil et al. differentiate between a BN, a hybrid BN, a hybrid dynamic BN (HDBN), and a generalized hybrid dynamic BN. They describe a model for operational risk that is composed of three layers:

- Loss event model;
- Loss severity model; and
- Aggregated loss model.

In the proposed model, each layer is represented by a different BN, dynamic BN, or HDBN with interface links between them comprising common parameters.¹⁸⁵ The “loss event model” is used to model the potential loss events and their evolution path over time. It dynamically takes into account the influences of controls that are embedded within the business processes. The “loss severity model” is based on probabilities generated by the “loss event model” to predict the total losses by severity class given the severity distribution and a measure of volume to scale losses. Finally, the “aggregated loss model” is the aggregated sum based on a

¹⁸³ J. Corrigan and P. Luraschi, “Operational risk modelling framework”, *Milliman Research Report*, February 13, 2013: 49. <http://www.milliman.com/uploadedFiles/insight/life-published/operational-risk-modelling-framework.pdf>.

¹⁸⁴ S. Ramamurthy, H. Arora, and A. Ghosh, “Operational Risk Probabilistic Networks – An Application to Corporate Actions Processing”, *Infosys*, White Paper, November 2005: 5. <http://www.infosys.com/industries/financial-services/white-papers/documents/operational-risk-probabilistic-networks.pdf>.

¹⁸⁵ M. Neil, D. Håger, and L.B. Andersen, “Modeling operational risk in financial institutions using hybrid dynamic Bayesian networks”, *The Journal of Operational Risk* (3-33), Volume 4/Number 1, Spring 2009. http://bayes.customer3.netflexapp.no/media/jop_v4n1a1.pdf.

set of total loss variables for each loss event. The aggregated losses can be solved by convolution, sampling, or the dynamic discretization algorithm, which is presented in an appendix to the paper by Neil et al.¹⁸⁶

Using BNs to Capture Correlation

In *A Bayesian Networks Approach to Operational Risk*, Aquaro et al. present a new approach based on BNs that captures the correlations among different bank processes. They conclude:

... the different-times correlations play a significant role and are in no way negligible with respect to the same-time correlations, but (at least to the best of our knowledge) there is no other approach taking them into account. The need to deal with different-times correlations leads us to propose a solution for the problem of learning a BN using a time ordered set of operational losses.¹⁸⁷

Aquaro et al. identify three principle features of their proposed approach:

- 1) ... the whole topology of the network is derived from data of operational losses; each node in the network corresponds to a bank process and the links between the nodes, which are drawn learning from data, model the causal relationships between the processes ...
- 2) For the first time a Bayesian Network is used to represent the influence between correlated operational losses that take place in different days exploiting a dataset whose records represent losses occurred over T days: using such a dataset the nodes in the network represent the aggregate loss over T and the VaR over a time horizon T can be computed ...
- 3) The proposed approach is tailored for a practical implementation inside a mid or small sized bank: since the network contains only nodes representing the loss distributions over some time horizon, only the losses occurring in the different processes have to be monitored.¹⁸⁸

Credal Networks

In *Credal Networks for Operational Risk Measurement and Management*, Antonucci et al. propose the use of credal networks. They state:

Bayesian networks are graphical models, whose quantification requires a precise elicitation of the probabilistic relations among the different factors. Yet, this requirement clashes with the kind of uncertainty characterizing qualitative expert judgments about operational risk.

¹⁸⁶ M. Neil, D. Häger, and L. B. Andersen, "Modeling operational risk in financial institutions using hybrid dynamic Bayesian networks", *The Journal of Operational Risk* (3-33), Volume 4/Number 1, Spring 2009: Appendix B.

http://bayes.customer3.nefflexapp.no/media/jop_v4n1a1.pdf.

¹⁸⁷ V. Aquaro, M. Bardoscia, R. Bellotti, A. Consiglio, F. De Carlo, et al., "A Bayesian Networks Approach to Operational Risk", *Preprint submitted to Physica A*, February 14, 2012: 15. <http://arxiv.org/pdf/0906.3968.pdf>.

¹⁸⁸ *Ibid.*: 16.

For this reason, we regard *credal networks* (Sect. 3.2), which are a generalization of Bayesian networks to imprecise probabilities, as a more credible model for operational risk. Credal networks allow for the specification of intervals (or, more generally, closed convex sets of mass functions) instead of single values of probability: this appears to be better suited to capture human knowledge. This flexibility regards also the observation of the variables: credal nets can cope with vague observations, where a condition of partial or complete ignorance about the actual state of an observed variable holds.¹⁸⁹

Antonucci et al. conclude that credal networks offer the same advantages as BNs and allow for greater freedom and robustness when incorporating expert evidence in the calibration of underlying probabilities.

Practical Considerations in Using BNs

One of the first practical considerations in using BNs is how to decompose a problem domain into a set of representative and meaningful causal or conditional propositions. Neil et al. state that one does not need to seek the full joint probability distribution from a single expert, but that a “divide and conquer” approach can be used to seek expert advice on partial specifications taking advantage of experts’ knowledge on different issues.¹⁹⁰

Another important consideration is how to appropriately recognize the subjectivity and uncertainty underlying the development of the BN. Corrigan and Luraschi state: “In all cases, the level of quality or uncertainty in the underlying information should be reflected in the distribution parameter estimates, rather than assuming that they are perfect.”¹⁹¹

For the construction of a BN, Sanford and Moosa comment that BNs are more suitable when connections between nodes are sparse rather than saturated.¹⁹² In describing the methodology for constructing a BN, Sanford and Moosa state that the construction and development of BNs remains as much art as it is science. Significant judgment is required with respect to the level of detail that is appropriate, what nodes should be included, and what causal relationships may exist. Sanford and Moosa offer the pragmatic rule: “simple enough to be used and complex enough to be useful.”¹⁹³

Another important practical consideration is that of software. Numerous papers cite the availability of software, much of it available for free from the internet. Web-based sources are identified in various papers by Alexander. There is also a website written by Kevin Murphy and last updated on June 16, 2014 that lists software packages for graphical models; the link is <http://www.cs.ubc.ca/~murphyk/Software/bnsoft.html>

¹⁸⁹ A. Antonucci, A. Piatti, and M. Zaffalon, “Credal Networks for Operational Risk Measurement and Management”, *Istituto “Dalle Molle” di Studi sull’Intelligenza Artificiale*, Switzerland, 2007: 2. <http://www.idsia.ch/~alessandro/papers/antonucci2007c.pdf>.

¹⁹⁰ M. Neil, D. Marquez, and N. Fenton, “Using Bayesian networks to model the operational risk to information technology infrastructure in financial institutions”, *The Capco Institute – Journal for Financial Transformation*: 134, http://www.eecs.qmul.ac.uk/~martin/index_files/capco%20paper.pdf, accessed January 24, 2014.

¹⁹¹ J. Corrigan and P. Luraschi, “Operational risk modelling framework”, *Milliman Research Report*, February 13, 2013: 45. <http://www.milliman.com/uploadedFiles/insight/life-published/operational-risk-modelling-framework.pdf>.

¹⁹² A.D. Sanford and I.A. Moosa, “A Bayesian network structure for operation risk modelling in structured finance operations”, *Department of Accounting and Finance, Monash University, Australia*, Draft Working Paper, 2008: 8. http://www.melbournecentre.com.au/WorkingPaper_part1_Sanford_Moosa2008.pdf.

¹⁹³ *Ibid.*: 12.

Similar to the frequency-severity analysis, issues arise as to how to combine internal and external operational risk loss data with expert opinion.

Strengths and Weaknesses of BNs

Strengths

Researched literature cites numerous advantages for the specific use of BNs for operational risk management and measurement. One of the most comprehensive arguments for the use of BNs is presented by Neil et al.:

BNs have the advantage that they enable us to combine any statistical data that is available with qualitative data and in a way that mirrors the causal structure underlying the process itself, thus making it easy to understand and communicate to business users. Using BNs we can: combine proactive loss indicators, related to the business process, with reactive outcome measures such as near miss and loss data; incorporate expert judgments about the contribution that qualitative estimates can make to the overall risk assessment; enter incomplete evidence and still obtain meaningful predictions; perform powerful ‘what-if?’ analyses to test the sensitivity of conclusions; obtain a visual reasoning tool and a major documentation aid; perform back-to-back comparison of alternative scenarios and sensitivity analyses for the purposes of assessing the impact of design changes to the infrastructure; provide a VaR assessment for each service and in aggregate in order to determine insurance premiums (or indeed decide to self insure) as well as determine levels of and areas for investment in improvements; and obtain outputs in the form of verifiable predictions against actual performance measures and loss event rates.¹⁹⁴

Tripp et al. cite multiple advantages for the use of causal risk maps, which form the basis of BNs. They state that causal risk maps:

- Provide a good structure for analysing known losses;
- Allow for a clear distinction to be made between risk events and risk outcomes;
- Help clarify the management decisions that resulted in operational losses;
- Reveal the complex chain of cause and effect underlying operational risk losses;
- Provide the ability to analyse potential losses; and
- Support the assessment of the effectiveness of controls and mitigation steps.¹⁹⁵

As a forward-looking technique, a BN relates the factors that are thought to influence operational risk (i.e., the key risk drivers) to risk measures (e.g., key risk indicators).¹⁹⁶ Thus, through the development and analysis of

¹⁹⁴ M. Neil, D. Marquez, and N. Fenton, “Using Bayesian networks to model the operational risk to information technology infrastructure in financial institutions”, *The Capco Institute – Journal for Financial Transformation*: 132, http://www.eecs.gmul.ac.uk/~martin/index_files/capco%20paper.pdf, accessed January 24, 2014.

¹⁹⁵ M.H. Tripp, H.L. Bradley, R. Devitt, G.C. Orros, G.L. Overton, et al., “Quantifying Operational Risk in General Insurance Companies”, developed by a *GIRO Working Party*, March 22, 2004: s.6.5.1. <http://www.actuaries.org.uk/system/files/documents/pdf/33784baj105919-10262004tripp.pdf>.

a BN, explicit incentives for behavioural modification can be identified. “Also, when a key risk indicator is the target node, the Bayesian network can be used to set the trigger levels and to evaluate the effectiveness of risk control.”¹⁹⁷ A BN can be used to provide a cost-benefit analysis of risk controls, where the optimal risk controls are determined through scenario analysis. According to Corrigan and Luraschi, the key strength of the BN approach is its ability to have information flow in both directions. This feature enables an insurer to robustly determine operational risk limits that are consistent with its operational risk appetite levels.¹⁹⁸ Corrigan and Luraschi also state that the benefit of using BNs for the determination of capital is the ability “to directly link capital requirements to the observed states of important business drivers, and thus dynamically manage capital in response to the evolving business environment.”¹⁹⁹

As stated by Sanford and Moosa, one of the key advantages of using a BN to model operational risk is its ability to answer queries that are predictive and diagnostic. They differentiate these two types of queries with the following examples:

- A predictive query may ask: “What is the probability of a payment failure given that a loan is being processed?”
- A diagnostic query may ask: “What is the most probably [probable] transaction type processed given that a payment failure occurred?”²⁰⁰

The *Agena White Paper – intelligent solutions for quantifying operational risk* states that there has been a tremendous increase in the interest towards BNs due to the following advantages:

- Best method for reasoning under uncertainty;
- Computational tractability issues have been solved so Bayesian Networks can be used now on real, large-scale problems;
- Can combine diverse data, including subjective beliefs and empirical data;
- Can enter incomplete evidence and still obtain predictions;
- Perform powerful “what-if” analysis to test sensitivity of conclusions;
- Visual reasoning tool and a major documentation aid.²⁰¹

Finally, a BN can be used with a wide range of ORCs including those where historical data (internal or external) are unavailable or insufficient for more traditional frequency-severity modeling. Thus, BNs provide a viable approach for quantifying operational risk when limited or no historical loss data exist. BN’s “have

¹⁹⁶ C. Alexander, “Chapter 14 Managing Operational Risk with Bayesian Networks”, *Operational Risk: Regulation, Analysis, and Management*, 2003: s.14.5.

http://www.carolalexander.org/publish/download/JournalArticles/PDFs/Chapter_Alexander_Bayesian_2003.pdf.

¹⁹⁷ Ibid.: s. 14.5.

¹⁹⁸ J. Corrigan and P. Luraschi, “Operational risk modelling framework”, *Milliman Research Report*, February 13, 2013: 6.

<http://www.milliman.com/uploadedFiles/insight/life-published/operational-risk-modelling-framework.pdf>.

¹⁹⁹ Ibid.: 49.

²⁰⁰ A.D. Sanford and I.A. Moosa, “A Bayesian network structure for operation risk modelling in structured finance operations”, *Department of Accounting and Finance, Monash University, Australia*, Draft Working Paper, 2008: 9.

http://www.melbournecentre.com.au/WorkingPaper_part1_Sanford_Moosa2008.pdf.

²⁰¹ “Intelligent solutions for quantifying Operational Risk”, *Agena White Paper*, *Agena Ltd.*, 2004, pages 2- 3.

http://www.agenarisk.com/resources/technology_articles/Operational_Risk.pdf.

applications to areas where data are more difficult to quantify, such as human risk.²⁰² They are also viewed as valuable when the past is not predictive of the future.

Use of Expert Judgment – a Strength and a Weakness

The use of expert judgment, which is essential for the construction and elicitation phases of a BN, is seen as both an advantage and a weakness of BNs. Sanford and Moosa identify three challenges with the use of experts:

- Available experts may not have sufficient knowledge scope to cover all aspects of the domain;
- Experts may not be able to specify the correct causal orderings of events; and
- Problems arise with the combination of probabilities from different experts.²⁰³

As a result, iterative feedback and re-modeling are important features of using BNs.

Weaknesses

In *Operational Risk Management – Implementing a Bayesian Network for Foreign Exchange and Money Market Settlement*, Adusei-Poku describes the following criticism of BNs in operational risk application:

The initial greatest criticism of BN application in OR [operational risk] was philosophical in nature and concerns the use of subjective data. However, in OR modelling the use of such data in the form of Control Self Assessment is now generally accepted, which thus weakens this criticism. Indeed, it is hardly possible to avoid subjective assessments in the context of OR.

Some Operational Risk practitioners find BNs fairly complex to establish and maintain. Some critics are of the opinion that the networks demand too much effort and give too little in return; still others regard the issue of obtaining the required numerical probabilities as a major obstacle.²⁰⁴

There are several other weaknesses cited repeatedly for the use of BNs to model operational risk. BNs can be very difficult to calibrate and require a significant investment of resources. The construction of a BN is based on tremendous subjectivity. “They are a modeler’s view of reality and hence there can be multiple models representing the same operational loss type.”²⁰⁵ Due to the ever-changing nature of both internal and

²⁰² C. Alexander, “Bayesian Methods for Measuring Operational Risk”, *ISMA Centre, The Business School for Financial Markets, University of Reading*, 2000: 12. <http://www.icmacentre.ac.uk/pdf/discussion/DP2000-02.pdf>.

²⁰³ A.D. Sanford and I.A. Moosa, “A Bayesian network structure for operation risk modelling in structured finance operations”, *Department of Accounting and Finance, Monash University, Australia*, Draft Working Paper, 2008: 13. http://www.melbournecentre.com.au/WorkingPaper_part1_Sanford_Moosa2008.pdf.

²⁰⁴ K. Adusei-Poku, “Operational Risk Management – Implementing a Bayesian Network for Foreign Exchange and Money Market Settlement”, *University of Gottingen*, 2005: 23. <http://ediss.uni-goettingen.de/bitstream/handle/11858/00-1735-0000-0006-AF0F-F/adusei-poku.pdf?sequence=1>.

²⁰⁵ S. Ramamurthy, H. Arora, and A. Ghosh, “Operational Risk Probabilistic Networks – An Application to Corporate Actions Processing”, *Infosys, White Paper*, November 2005: 6. <http://www.infosys.com/industries/financial-services/white-papers/documents/operational-risk-probabilistic-networks.pdf>.

external environments, BNs require regular updating. In reality, these disadvantages are also applicable, potentially to varying degrees, to the frequency-severity approach.

In suggesting that credal networks are preferred to BNs, Antonucci et al. comment on the challenges with BNs:

The most critical and time-consuming task for the realization of a Bayesian net in practical OR [operational risk] measurements is the quantification of the probabilities. This process can be very critical and arbitrary ... The problem is that these kinds of knowledge cannot be modeled by precise probabilistic statements ...

...

For some variables, the specification ... actually reports ranges instead of precise values for the probabilities assessed by the experts. But in the end, a *typical value* in this range has to be adopted for use with Bayesian nets. Thus, the modeling phase requires artificially strong assessments, that can be avoided using credal nets.²⁰⁶

Some European banks have experimented with using BN for operational risk capital quantification without patent success. It is unclear whether the issues encountered by the banking sector will translate to the insurance sector. As such, further research will be required by the insurance industry to determine the applicability of BN for the quantification of operational risk capital.

Scenario Analysis

Organization, Introduction, and Sources

Organization

This section of the research paper is organized as follows:

- Organization, introduction, and sources;
- Basel II and IAIS requirements for scenario analysis;
- Conducting scenario analysis including development of scenarios and using scenarios to determine capital;
- Practical considerations for scenario analysis; and
- Strengths and weaknesses.

²⁰⁶ A. Antonucci, A. Piatti, and M. Zaffalon, "Credal Networks for Operational Risk Measurement and Management", *Istituto "Dalle Molle" di Studi sull'Intelligenza Artificiale*, Switzerland, 2007: pp 5-6.
<http://www.idsia.ch/~alessandro/papers/antonucci2007c.pdf>.

Introduction

Scenario analysis has been used for decades as an important decision-making tool in numerous disciplines including management, engineering, defense, medicine, finance, and economics.²⁰⁷ In *Scenario Analysis in the Measurement of Operational Risk Capital: A Change of Measure Approach*, Dutta and Babbel offer the following introduction to scenario analysis:

When properly and systematically used, scenario analysis can reveal many important aspects of a situation that would otherwise be missed. Given the current state of an entity, it tries to navigate situations and events that could impact important characteristics of the entity in the future. Thus, scenario analysis has two important elements:

1. Evaluation of future possibilities (future states) with respect to a certain characteristic.
2. Present knowledge (current states) of that characteristic for the entity.

Scenarios must pertain to a meaningful duration of time, for the passage of time will make the scenarios obsolete. Also, the current state of an entity and the environment in which it operates give rise to various possibilities in the future.²⁰⁸

According to Dr. Eric Rosengren, scenario analyses are used by banks for three primary purposes: stress testing, creating synthetic losses (when there is insufficient internal loss data), and generating severity functions for the frequency-severity approach.²⁰⁹

In July 2013, the Insurance Regulation Committee of the IAA released a paper titled *Stress Testing and Scenario Analysis*. The Executive Summary states:

A scenario describes a consistent future state of the world over time, resulting from a plausible and possibly adverse set of events or sequences of events. A stress test provides an assessment of an extreme scenario, usually with a severe impact on the firm, reflecting the inter-relations between its significant risks.

Together, they complement the use of economic capital models that apply probabilities to possible future scenarios to determine appropriate capital needs of a firm. In contrast to internal models, scenario analysis and stress testing assess the financial effect of the events or sequence of events that lead to specific scenarios in adequate detail so that their causes can be identified and their effects on the firm can be understood. Thus, they can be used to enhance the understanding of if and why a firm is vulnerable to highly uncertain tail risks.²¹⁰

The output of scenario analysis would be used to inform the risk appetite as well as capital calculations.

²⁰⁷ K.K. Dutta and D.F. Babbel, "Scenario Analysis in the Measurement of Operational Risk Capital: A Change of Measure Approach", *Wharton School of the University of Pennsylvania*, July 5, 2012: 1.

<http://fic.wharton.upenn.edu/fic/papers/12/12-15.pdf>.

²⁰⁸ Ibid.: 1.

²⁰⁹ Dr. Eric Rosengren, Executive Vice President, Federal Reserve Bank of Boston, July 19, 2006 presentation titled "Scenario Analysis and the AMA", July 19, 2006: 3.

http://www.boj.or.jp/en/announcements/release_2006/data/fsc0608be9.pdf.

²¹⁰ Insurance Regulation Committee of the IAA, "Stress Testing and Scenario Analysis", July 2013: 1.

http://www.actuaries.org/CTTEES_SOLV/Documents/StressTestingPaper.pdf.

Sources

Key resources for this section of the research paper include:

- Basel Committee on Banking Supervision, *Operational Risk – Supervisory Guidelines for the Advanced Measurement Approaches*, Bank for International Settlements, June 2011;
- Basel Committee on Banking Supervision, *International Convergence of Capital Measurement and Capital Standards – A Revised Approach – Comprehensive Version*, Bank for International Settlements, June 2006;
- J. Corrigan and P. Luraschi, *Operational risk modelling framework*, Milliman Research Report, February 13, 2013;
- K.K. Dutta and D.F. Babbel, *Scenario Analysis in the Measurement of Operational Risk Capital: A Change of Measure Approach*, Wharton School of the University of Pennsylvania, July 5, 2012;
- IAIS, *Insurance Core Principles, Standards, Guidance and Assessment Methodology*, (1 October 2011, including amendments 12 October 2012 and 19 October 2013);
- Insurance Regulation Committee of the IAA, *Stress Testing and Scenario Analysis*, July 2013;
- Life Operational Risk Working Party, including N. Dexter, C. Ford, P. Jakahria, P. Kelliher, D. McCall, et al., *Quantifying Operational Risk in Life Insurance Companies*, May 26, 2006; and
- Dr. Eric Rosengren, presentation titled *Scenario Analysis and the AMA*, Federal Reserve Bank of Boston, July 19, 2006.

Basel II and IAIS Requirements for Scenario Analysis

Basel II requires banks using the AMA to incorporate scenario analysis. Section 675 of Basel II states:

A bank must use scenario analysis of expert opinion in conjunction with external data to evaluate its exposure to high-severity events. This approach draws on the knowledge of experienced business managers and risk management experts to derive reasoned assessments of plausible severe losses. For instance, these expert assessments could be expressed as parameters of an assumed statistical loss distribution. In addition, scenario analysis should be used to assess the impact of deviations from the correlation assumptions embedded in the bank's operational risk measurement framework, in particular, to evaluate potential losses arising from multiple simultaneous operational risk loss events. Over time, such assessments need to be validated and re-assessed through comparison to actual loss experience to ensure their reasonableness.²¹¹

The IAIS also requires scenario analysis for the identification and measurement of risk. Section 16.1 of the ICPs-October 2013 states:

²¹¹ Basel Committee on Banking Supervision, "International Convergence of Capital Measurement and Capital Standards – A Revised Approach – Comprehensive Version", Bank for International Settlements, June 2006: s.675. <https://www.bis.org/publ/bcbs128.pdf>.

Enterprise risk management framework - risk identification and measurement

16.1 The supervisor requires the insurer's enterprise risk management framework to provide for the identification and quantification of risk under a sufficiently wide range of outcomes using techniques which are appropriate to the nature, scale and complexity of the risks the insurer bears and adequate for risk and capital management and for solvency purposes.²¹²

Section 16.1.6 addresses the requirement to use forward-looking quantitative techniques for the measurement of risk, and sections 16.1.14 through 16.1.16 specifically discuss stress testing and scenario analysis for insurers.

Measuring, analysing and modelling the level of risk

16.1.6 The level of risk is a combination of the impact that the risk will have on the insurer and the probability of that risk materialising. The level of risk borne by the insurer should be assessed regularly using appropriate forward-looking quantitative techniques such as risk modelling ["Modelling" in this context does not necessarily mean complex stochastic modelling. It can also include less sophisticated methods],²⁷ stress testing, including reverse stress testing, and scenario analysis. An appropriate range of adverse circumstances and events should be considered, including those that pose a significant threat to the financial condition of the insurer, and management actions should be identified together with the appropriate timing of those actions. Risk measurement techniques should also be used in developing long-term business and contingency plans, where it is appropriate to the nature, scale and complexity to do so.

...

16.1.14 Stress testing measures the financial impact of stressing one or relatively few factors affecting the insurer. Scenario analysis considers the impact of a combination of circumstances which may reflect extreme historical scenarios which are analysed in the light of current conditions. Scenario analysis may be conducted deterministically using a range of specified scenarios or stochastically, using models to simulate many possible scenarios, to derive statistical distributions of the results.

16.1.15 Stress testing and scenario analysis should be carried out by the insurer to validate and understand the limitations of its models. They may also be used to complement the use of models for risks that are difficult to model, or where the use of a model may not be appropriate from a cost-benefit perspective. This may arise, for example, where a range of calculations is urgently required focusing on specific aspects or going beyond the current parameters of the model to investigate the effect of proposed management actions.

16.1.16 Scenario analysis may be particularly useful as an aid to communication in relation to risk management between the Board and Senior Management and other parts of the

²¹² IAIS, "Insurance Core Principles, Standards, Guidance and Assessment Methodology", (1 October 2011, including amendments 12 October 2012 and 19 October 2013): s.16.1, accessed on February 27, 2014, <http://www.iaisweb.org/Insurance-Core-Principles-material-adopted-in-2011-795>.

organisation thereby facilitating the integration of the insurer's ERM framework with its business operations and culture.²¹³

Conducting Scenario Analysis

Corrigan and Luraschi describe scenario analysis, which they refer to as quantitative risk assessment (QRA), as "a fusion of the expert knowledge of the current and future states of the business and the environment in which it operates, in order to assess operational risk."²¹⁴ They present the QRA framework as comprising six elements:

- Governance – Effective governance is essential to ensure support for the process from participants and stakeholders, such that it has integrity, consistency, and longevity.
- Preparation – A clear understanding of the objectives, framework, and input requirements is needed in order for participants to effectively contribute to the process. Potential areas for scenarios and any relevant data should be sourced and prepared in advance.
- Assessment – This is typically undertaken through a series of workshops, interviews, or questionnaires involving a combination of subject matter experts, executives, risk managers, and group functions. Quantitative input parameters on risk severity and frequency of each scenario are required.
- Validation – Given the biases that may enter into the process, scenarios need to be reviewed holistically and challenged to ensure consistency in their framing, depth, breadth, and calibration.
- Reporting – Scenario results must be reported to a variety of stakeholders across various levels of the business, from business units all the way through to the board.
- Evolution – Scenarios must be updated to reflect the ongoing evolutionary process through which the business dynamically changes to respond to changes in the environment in which it operates.²¹⁵

Development of Scenarios

Dexter et al. describe a three-step process for generating combined scenarios:

- Step 1 – decide on a base risk event;
- Step 2 – brainstorm all potential causes and effects; and
- Step 3 – select plausible adverse scenarios.

²¹³ IAIS, "Insurance Core Principles, Standards, Guidance and Assessment Methodology", (1 October 2011, including amendments 12 October 2012 and 19 October 2013): s.16.1.6 and s.16.1.14 through s.16.1.16, accessed on February 27, 2014, <http://www.iaisweb.org/Insurance-Core-Principles-material-adopted-in-2011-795>.

²¹⁴ J. Corrigan and P. Luraschi, "Operational risk modelling framework", *Milliman Research Report*, February 13, 2013: 17. <http://www.milliman.com/uploadedFiles/insight/life-published/operational-risk-modelling-framework.pdf>.

²¹⁵ *Ibid.*: 17.

Step 1 involves reviewing a risk assessment matrix or similar detailed listing of ORCs to select an appropriate base risk event. Step 2 considers all potential causes of the base risk. Dexter et al. state:

This also allows overlaps between scenarios to be identified so that the final number of scenarios is the optimum number; it is more effective to have a small number of wide-ranging scenarios, than a larger number of scenarios which are not comprehensive.

Similarly, it is then important to identify all of the widest range of potential effects and outcomes of the scenario. Certain of these may seem unrealistic or extremely unlikely, but this again allows the widest possible implications of the scenario to be considered.²¹⁶

For Step 3, it is recommended that a facilitated discussion be used to identify the plausible scenario:

Senior managers with relevant expertise should use their experience and knowledge of systems and controls to consider what is a plausible scenario, given all of the potential causes and effects of the scenario. It is likely that there will be several logical permutations to be extracted from the potential worst case. Following the initial discussion, the plausible scenarios should be agreed by all the senior managers involved in the workshop, and the assessment process can begin to consider the potential financial impact and likelihood of these scenarios.²¹⁷

Organizations frequently use scenario workshops to bring “business line managers, business risk managers, and people with significant knowledge and understanding of their business and the environments in which it operates”²¹⁸ together in a structured environment. The “workshop participants discuss the business environments and current business practices, and take guidance and help from external data” to derive scenarios within each unit of measure.²¹⁹ External consultants often bring additional expertise to the decision-making process during a scenario workshop. In deliberating, the participants would consider both internal and external operational risk event losses. Workshops may be facilitated by an external consultant or by the insurer’s Chief Risk Officer (CRO). If the insurer’s CRO is not involved in the scenario workshop, he/she may have responsibility for validating the decisions arising from the workshop.

Guidelines for AMA set out the following expectations for banks conducting scenario analysis:

Scenario data provides a forward-looking view of potential operational risk exposures. A robust governance framework surrounding the scenario process is essential to ensure the integrity and consistency of the estimates produced. Supervisors will generally observe the following elements in an established scenario framework:

- a) A clearly defined and repeatable process;
- b) Good quality background preparation of the participants in the scenario generation process;

²¹⁶ N. Dexter, C. Ford, P. Jakahria, P. Kelliher, D. McCall, et al., “Quantifying Operational Risk in Life Insurance Companies”, Developed by the Life Operational Risk Working Party, 2006: 28.
<http://www.actuaries.org.uk/system/files/documents/pdf/opriskcapital.pdf>.

²¹⁷ Ibid.: 28.

²¹⁸ K.K. Dutta and D.F. Babbel, “Scenario Analysis in the Measurement of Operational Risk Capital: A Change of Measure Approach”, *Wharton School of the University of Pennsylvania*, July 5, 2012: 6.
<http://fic.wharton.upenn.edu/fic/papers/12/12-15.pdf>.

²¹⁹ Ibid.: 6.

- c) Qualified and experienced facilitators with consistency in the facilitation process;
- d) The appropriate representatives of the business, subject matter experts and the corporate operational risk management function as participants involved in the process;
- e) A structured process for the selection of data used in developing scenario estimates;
- f) High quality documentation which provides clear reasoning and evidence supporting the scenario output;
- g) A robust independent challenge process and oversight by the corporate operational risk management function to ensure the appropriateness of scenario estimates;
- h) A process that is responsive to changes in both the internal and external environment; and
- i) Mechanisms for mitigating biases inherent in scenario processes. Such biases include anchoring, availability and motivational biases.²²⁰

In developing scenarios, an insurer analyzes operational risk event losses (based on both internal and external data) and considers the magnitude and probability of occurrence given the current state of its risk profile. An insurer would also consider other information related to its business environment and internal control system that would influence scenarios. Scenarios are selected as events that are intended to have a defined probability of occurrence (such as a one in 100-year event).²²¹ The IAA notes that scenarios can be complex, involving changes to and interactions among many factors over time, perhaps generated by a set of cascading events.²²² A description of the loss event together with the specified severity and frequency of the event constitute the scenario. The severity may be specified as a value or a range of values.

In conducting scenario analysis, Tripp et al. note that two types of events, historical and hypothetical, may be considered. They state that historical events are often easier to understand and sometimes considered to be less arbitrary, while hypothetical events may provide a more thorough and systematic analysis, but anticipate risk with no historical parallel.²²³ Capturing hypothetical events in scenario analysis is important, as they may capture tail events that are not included in internal or external loss data. With respect to timing and frequency of scenario analysis, Tripp et al. state: "Tests should be carried out at least annually, or more often, depending on the possible impact of the risks."²²⁴

²²⁰ Basel Committee on Banking Supervision, "Operational Risk – Supervisory Guidelines for the Advanced Measurement Approaches", Bank for International Settlements, June 2011: 51. <http://www.bis.org/publ/bcbs196.pdf>.

²²¹ M.H. Tripp, H.L. Bradley, R. Devitt, G.C. Orros, G.L. Overton, et al., "Quantifying Operational Risk in General Insurance Companies", developed by a *GIRO Working Party*, March 22, 2004: s.4.2.2. <http://www.actuaries.org.uk/system/files/documents/pdf/33784baj105919-10262004tripp.pdf>.

²²² Insurance Regulation Committee of the IAA, "Stress Testing and Scenario Analysis", July 2013: 3. http://www.actuaries.org/CTTEES_SOLV/Documents/StressTestingPaper.pdf.

²²³ M.H. Tripp, H.L. Bradley, R. Devitt, G.C. Orros, G.L. Overton, et al., "Quantifying Operational Risk in General Insurance Companies", developed by a *GIRO Working Party*, March 22, 2004: s.4.2.3. <http://www.actuaries.org.uk/system/files/documents/pdf/33784baj105919-10262004tripp.pdf>.

²²⁴ *Ibid.*: 4.2.4.

Using Scenarios to Determine Capital

Dexter et al. describe the process for using the results of scenario analysis directly to set capital. The scenario selected for this purpose would be consistent with the desired confidence level (or other statistical measure) required by the regulatory capital regime.

The capital requirement for that OR [operational risk] is simply the quantified loss in the adverse scenario (for those impacts identified as requiring capital).

Let L_i be the scenario loss for i -th OR \approx required percentile from the tail of $\sum_{j=1}^{N_i} X_{ij}$.

It is then necessary to aggregate across the K scenario losses to estimate the percentile loss from the tail of the aggregate loss distribution.

ORCA = $\text{Agg}(\{L_i\}, \{\rho_{ij}\})$ where $i, j = 1, 2, \dots, K$

and ρ_{ij} is the correlation between OR i and j

This aggregation may be performed using an aggregation formula, such as root sum of squares allowing for correlations. This approach requires a K by K matrix of pair-wise correlation estimates. The correlation estimates must be for the relationship between total losses, rather than the frequency or severity of loss events for each risk.²²⁵

In an early version of *Scenario Analysis in the Measurement of Operational Risk Capital: A Change of Measure Approach*, Dutta and Babbel (2010) discussed the challenges in using scenario analysis to quantify operational risk capital. They reported:

The Bank of Japan hosted a workshop on operational risk scenario analysis in 2006.²²⁶ The presentations of Nagafuji (2006), Oyama (2006), and Rosengren (2006) adequately capture and summarize the problems with and the art of using scenario analysis for operational risk assessment. The issues discussed in those presentations are still very valid, four years later. In fact, we would argue that since then, there has been very little, if any, focus on the development of scenario-based methodology for operational risk assessment. While much research has focused on finding a severity distribution for fitting internal or external loss event severity data, we are aware of no work that has systematically studied the problems related to integrating scenario analysis data into an institution's operational risk capital calculation. Yet scenario data, despite their problems, are the essential elements of information that should be taken seriously in the measurement of operation risk.²²⁷

While the above citation is not included in the latest version of their paper, Dutta and Babbel express a similar view in 2012:

²²⁵ N. Dexter, C. Ford, P. Jakahria, P. Kelliher, D. McCall, et al., "Quantifying Operational Risk in Life Insurance Companies", Developed by the Life Operational Risk Working Party, 2006: pp 18-19.
www.actuaries.org.uk/system/files/documents/pdf/opriskcapital.pdf.

²²⁶ Dutta and Babbel: One can get more information on the presentations and discussions held in that workshop at: http://www.boj.or.jp/en/type/release/zuiji_new/fsc0608a_add.htm. We found it to be a very valuable workshop in addressing the issues related to the use of scenario analysis in measuring and managing operational risk.

²²⁷ K.K. Dutta and D.F. Babbel, "Scenario Analysis in the Measurement of Operational Risk Capital: A Change of Measure Approach", *Wharton School of the University of Pennsylvania*, September 24, 2010: 5.
<http://fic.wharton.upenn.edu/fic/papers/10/10-10.pdf>.

Rosengren (2006) adequately captured and summarized the problems with and the art of using scenario analysis for operational risk assessment. The issues discussed in Rosengren (2006) are still valid. In fact, since then, there has been very little, if any, focus on the development of scenario-based methodology for operational risk assessment. One exception was Lambrigger *et al.* (2007), who made an early attempt to combine expert judgment with internal and external operational loss data. Their informal approach was to make qualitative adjustments in the loss distribution using expert opinion, but they provided no formal model for incorporating scenarios with internal and external loss data. The methods that we found in the literature are very *ad hoc*, and most integrate scenarios and internal or external data without sound justifications.²²⁸

Dutta and Babbel propose a method called the “Change of Measure” approach that combines scenario analysis with historical loss data. This approach evaluates the effect of each scenario on the total estimate of operational risk capital. Dutta and Babbel state:

The major contribution of this work, in our opinion, is in the meaningful interpretation of scenario data, consistent with the loss experience of an institution, with regard to both the frequency and severity of the loss. Using this interpretation, we show how one can effectively use scenario data, together with historical data, to measure operational risk exposure and, using the Change of Measure concept, evaluate each scenario’s effect on operational risk.²²⁹

The theoretical and mathematical details of their approach are not repeated in this research paper.

Practical Considerations for Scenario Analysis

Rosengren speaks of “Things to Consider in Scenarios – Behaviour Economic Lessons” in his presentation *Scenario Analysis and the AMA*. He refers to the extensive writings of Tversky and Kahneman about the psychology of choice. Specifically, he references their 1981 *Science* article in which “they illustrate that answers to decision problems vary by how the question is asked and the frame of reference of the respondent.”²³⁰ Rosengren concludes that behavioural theories are relevant to establishing good scenario analysis. The context, tone, style, position of questions, and the sequencing of decisions can influence the responses. Similarly, discussions of the effects of risk mitigation can be influenced by whether they are framed as gains or losses.²³¹

Similar to the other methods previously described, scenario analysis requires significant judgment and thus is built upon much subjectivity. The Basel Committee recognizes the subjectivity and the resulting uncertainty as reflected in the *Guidelines to AMA*:

²²⁸ K.K. Dutta and D.F. Babbel, “Scenario Analysis in the Measurement of Operational Risk Capital: A Change of Measure Approach”, *Wharton School of the University of Pennsylvania*, July 5, 2012: 4.

<http://fic.wharton.upenn.edu/fic/papers/12/12-15.pdf>.

²²⁹ *Ibid.*: 2.

²³⁰ Dr. Eric Rosengren, Executive Vice President, Federal Reserve Bank of Boston, July 19, 2006 presentation titled “Scenario Analysis and the AMA”, July 19, 2006: 14.

http://www.boj.or.jp/en/announcements/release_2006/data/fsc0608be9.pdf.

²³¹ *Ibid.*: 17.

A robust scenario analysis framework is an important part of the ORMF [operational risk management framework] in order to produce reliable scenario outputs which form part of the input into the AMA model. The Committee acknowledges that the scenario process is qualitative and that the output from a scenario process necessarily contains significant uncertainties. This uncertainty, together with the uncertainty from the other elements, should be reflected in the output of the model producing a range for the capital estimate. The Committee recognises that quantifying the uncertainty arising from scenario biases poses significant challenge and is an area requiring further research.²³²

In the *Guidelines for AMA*, the Basel Committee also offers the following suggestions for consideration in scenario analysis:

Some items are important for risk management although they may be beyond the scope required for quantification. In particular, the items below can be useful for promptly detecting failures and errors in processes or internal control systems. These items may also be useful inputs for scenario analysis.

- a) “Near-miss events”: operational risk events that do not lead to a loss. For example, an IT disruption in the trading room just outside trading hours.
- b) “Operational risk gain events”: operational risk events that generate a gain.
- c) “Opportunity costs/lost revenues”: operational risk events that prevent undetermined future business from being conducted (eg unbudgeted staff costs, forgone revenue and project costs related to improving processes).²³³

Other important considerations for the execution of scenario analysis include but are not limited to:

- Defining the criteria for determining subject matter experts for scenario workshops;
- Developing the briefing and training materials to be delivered to subject matter experts in preparation for scenario workshops;
- During the scenario selection process, ensuring that the modelled scenarios appropriately reflect the operational risk profile;
- Defining approaches to separately identify the frequency and severity for scenario analysis;
- Determining the number of scenarios to be modelled; and
- Establishing the governance process over the scenario selection process and the quality of the workshop output.

While more scenarios can give the appearance of a more granular approach, a higher number of scenarios may result in lower overall quality and a lack of focus on the key operational risks.

²³² Basel Committee on Banking Supervision, “Operational Risk – Supervisory Guidelines for the Advanced Measurement Approaches”, Bank for International Settlements, June 2011: 9. <http://www.bis.org/publ/bcbs196.pdf>.

²³³ Ibid.: pp 22-23.

Strengths and Weaknesses

Strengths

Scenario analyses are particularly useful for quantifying operational risk where data for given ORCs are so limited and/or uncertain that meaningful results cannot be produced from the frequency-severity approach or a BN. For example, legal and regulatory risks have been found to be amongst the major operational risks facing German life and health insurers. For these types of risks, approaches based on historical data often fail, and insurers that quantify these risks via scenario analyses gain significant insight with strategic relevance.

Scenario analysis is also a valuable input to the frequency-severity approach, as it can be used to inform the fitting of distributions and to validate the aggregation of risks.²³⁴ As described previously, scenario analysis is seen as a key advantage in the use of BNs. In comparing scenario analysis to the frequency-severity approach, Dexter et al. state that scenario analysis provides a more pragmatic and transparent approach to the determination of capital; because the scenario analysis directly influences the required capital and does not involve complex interactions between frequency and severity distributions.

Weaknesses

In the *Basel Guidelines for the AMA*, the Basel Committee addresses its concern with inconsistencies in assumptions derived through a scenario-based approach and a loss-based approach:

Although the technicalities of AMA models predominantly based on scenario analysis (Scenario Based Approaches, or SBA) differ from those of AMA models predominantly based on loss data (loss distribution approach, or LDA), a few supervisory expectations and points of attention can be raised in order to make the identification of distributions in the SBA and LDA processes more consistent with each other. Many observed SBA models do not apply statistical inference to raw scenario data; very often the curves are predetermined and the scenario data are used only to estimate the parameters of those distributions.²³⁵ Under such a process, the scenario data risks being distorted by an inappropriate choice of distribution. A bank should thus ensure that the loss distribution(s) chosen to model scenario analysis estimates adequately represent(s) its risk profile.²³⁶

²³⁴ N. Dexter, C. Ford, P. Jakahria, P. Kelliher, D. McCall, et al., "Quantifying Operational Risk in Life Insurance Companies", Developed by the Life Operational Risk working Party, 2006: 18. www.actuaries.org.uk/system/files/documents/pdf/opriskcapital.pdf.

²³⁵ In fact, many banks use the same curve for modelling the severity of the scenario data across all ORCs, regardless of its business, size and complexity. The selection of a single curve across ORCs implies the only admissible driver of variation in the operational risk exposure lies in the scenario driven parameter estimates of the chosen distribution. Source: Basel Committee on Banking Supervision, "Operational Risk – Supervisory Guidelines for the Advanced Measurement Approaches", Bank for International Settlements, June 2011: 8. <http://www.bis.org/publ/bcbs196.pdf>.

²³⁶ In doing so, banks should also consider the potential differences with an LDA in terms of level of granularity and dependence across the ORCs. Source: Basel Committee on Banking Supervision, "Operational Risk – Supervisory Guidelines for the Advanced Measurement Approaches", Bank for International Settlements, June 2011: 8. <http://www.bis.org/publ/bcbs196.pdf>.

In discussing the use of scenario analysis for the determination of operational risk capital, Dutta and Babbel discuss the following challenges that have arisen historically:

- The inability to use scenario data as a direct input in the internal models that calculate operational risk capital based on internal data;
- The difficulty in expressing scenarios in quantitative forms and combining the information from scenario analyses with internal loss data, which often resulted in unrealistically high capital indications;
- The difficulty in correctly interpreting and incorporating external loss data into scenario analysis; and
- The scepticism about the quality and believability of scenario data.²³⁷

In addition to the above, Corrigan and Luraschi identify the following challenges and limitations with scenario analysis:

- Bias in scenario selection: It is difficult to know where to draw the line in judging how many and what types of scenarios should be included in the assessment;
- Allowance for complexity: Humans are also generally very poor at resolving the complexity of the interactions that characterise complex scenarios and hence may miss sources of operational loss, such as those arising from negatively reinforcing feedback loops;
- Difficulty in aggregation: Assessing the interdependencies between the scenarios can be very challenging, as they are typically framed individually; and
- Lack of allowance for uncertainty: Use of point estimates overstates the degree of uncertainty associated with scenarios.²³⁸

Rosengren discusses challenges from a regulatory perspective in scenario-based models used for banks. He raises the following questions:

- Is the capital level coherent for banks with similar risk exposures?
- How consistent is the relationship between the internal loss experience of the organization and the estimate of operational risk exposure?
- Does the process provide a way to determine the level and change in operational risk?
- Can the process be explained to investors, the board, senior management, and business line managers?²³⁹

In a February 2012 presentation titled “Swiss Solvency Test – Where to from now,” Hansjörg Furrer, Head of Quantitative Risk Management Division of Insurance FINMA, spoke about the increasing resistance against

²³⁷ K.K. Dutta and D.F. Babbel, “Scenario Analysis in the Measurement of Operational Risk Capital: A Change of Measure Approach”, *Wharton School of the University of Pennsylvania*, July 5, 2012: 2.

<http://fic.wharton.upenn.edu/fic/papers/12/12-15.pdf>.

²³⁸ J. Corrigan and P. Luraschi, “Operational risk modelling framework”, *Milliman Research Report*, February 13, 2013: 19.

<http://www.milliman.com/uploadedFiles/insight/life-published/operational-risk-modelling-framework.pdf>.

²³⁹ Dr. Eric Rosengren, Executive Vice President, Federal Reserve Bank of Boston, July 19, 2006 presentation titled “Scenario Analysis and the AMA”, July 19, 2006: 26.

http://www.boj.or.jp/en/announcements/release_2006/data/fsc0608be9.pdf.

the concept of scenarios.²⁴⁰ His presentation slides note that the scenarios for the Swiss Solvency Test (SST) were introduced at the very beginning of the SST (pre-financial crisis) as a means to overcome the deficiencies of analytical models and were unquestioned at that time. The slides continue that in the post-financial crises, the scenario concept is criticized because of alleged misspecification, double-counting, arbitrary return periods, and competitive disadvantages with EU insurers.²⁴¹

Current Market Practice for Insurers

With the introduction of ORSA in Canada, the quantification of operational risk is evolving rapidly. Most insurers have indicated that they intend to rely on the methodology outlined in the Minimum Capital Test 2015²⁴² in the early phases of ORSA reporting. It is expected that Canadian insurers will also seek to demonstrate that their own operational risk profile and risk management programs are similar to the industry. Many insurers have identified the development of a more sophisticated approach to quantify operational risk as a component of their medium-term plans.

Many Canadian insurers are still at a very early stage of development when it comes to sophisticated modelling approaches for operational risk, and economic capital in general. Thus, the remainder of this section reports on current market practices from an international perspective based on the results of KPMG's 2012 and 2013 global economic capital modeling surveys of insurers (2012 Survey and 2013 Survey). The results of the KPMG surveys are supplemented with findings based on assignments completed by KPMG with international clients in the area of operational risk modeling. Respondents to both the 2012 Survey and the 2013 Survey included life and general insurers from Asia, North America, South Africa, and Europe. There were 35 respondents to KPMG's 2013 survey on operational risk modeling practices. In the 2012 Survey, questions on operational risk were addressed only to insurers using internal models or partial internal models. In the 2013 Survey, the questions on operational risk were addressed to all insurers including those using factor-based approaches. Thus, the results of the 2012 Survey and those of the 2013 Survey are not always comparable.

The divergence of responses regarding approaches and techniques used to model operational risk is indicative of the challenges encountered by insurers in developing effective operational risk capital modeling. This variability in responses also reflects the different stages reached by insurers on their model development journey, particularly when it comes to the following areas: developing the operational risk framework, selecting frequency and severity distributions, collecting internal loss data, and/or establishing external loss data agreements with providers such as ORIC. The results of the survey indicate that stochastic modeling with expert judgment is used by a majority of insurers operating in the U.K. and other European countries for modeling operational risk. European insurers appear to be ahead of other regions in their development of approaches for modeling operational risk capital. Insurers operating in other regions of the world tend to rely more frequently on factor-based approaches.

²⁴⁰ A general introduction of the Swiss Solvency Test is presented in the next section of this research paper.

²⁴¹ H. Furrer, "Swiss Solvency Test – Where to from now", *FINMA presentation documents*, February 28, 2012: 11. http://www.ccfz.ch/files/prmia_furrer_hansjoerg_28_february_public.pdf.

²⁴² OSFI, "Minimum Capital Test for Federally Regulated Property and Casualty Insurance Companies", Section 7.1, modified 2014-09-25, accessed October 22, 2014, <http://www.osfi-bsif.gc.ca/Eng/fi-if/rq-ro/gdn-ort/gld/Pages/mct2015.aspx#Toc-7.1>.

The following discussion of current market practices is based primarily on the results of the 2013 Survey with some comparisons (where relevant) to findings from the 2012 Survey.

What is the right level of operational risk capital to hold?

There are a number of drivers influencing the level of operational risk capital that might be appropriate for an insurer to hold, some of which are quite subtle. Understanding the levers available to management within the modeling framework to adjust capital is critical. It is not a trivial task to maintain the quality of the capital calculation and the value add to the business of engaging business risk owners in the process while also calculating a capital amount that is acceptable to an insurer's board of directors as well as its regulator.

Most insurers who participated in the survey hold operational risk capital in the range of 5% to 15% of their total economic capital; although there are significant outliers at both ends of the range. Some insurers hold less than 5%, and others hold nearly 20% of their total economic capital for operational risk. The results of the 2013 Survey indicate that, on average, operational risk capital accounts for around 10% of the total economic capital of insurers.

Senior management and ultimately the board of directors are likely to expect operational risk capital to be in this range. As a result, models producing a higher level of operational risk capital may raise concerns around the quality of the risk management procedures in place or the quality of the modeling process. To address concerns stemming from model results, adjustments may have been made to reduce capital levels. Such adjustments may include capping frequency or severity distributions to ensure operational risk capital levels remain within a reasonable range or ignoring relevant loss data, which could be challenged by the regulator and/or result in significant capital add-ons.

What approaches are used to model operational risk loss events?

Numerous regulators, including the U.K. Prudential Regulation Authority (PRA), have developed standard formulae to derive the total capital required. The operational risk capital within the standard formulae is determined using a factor-based approach that is dependent on data such as earned premiums, technical provisions, basic solvency capital requirement, and expenses incurred. Insurers may use the standard formula applicable in their jurisdiction or develop their own internal model or partial internal model.

In the 2013 Survey, KPMG asked respondents about their approach to modeling operational risk as part of their individual capital assessment (ICA). Most respondents reported applying judgment in order to set their 1-in-200 year operational risk stresses. In practice, most insurers use workshops to estimate the frequency and severity of operational risk loss events, either estimating capital requirements directly in the workshops or using the frequency and severity estimates determined through these workshops to fit a loss distribution.

Of the 35 respondents, 12 indicated that they use a stochastic approach, incorporating expert judgment; seven indicated they use a deterministic approach; and five insurers reported using a factor-based approach similar to the one used under the PRA's standard formula. All but one of the participants using stochastic modeling are large insurers, perhaps reflecting the fact that insurers who have invested in this approach have developed internal models in preparation for Solvency II. As described previously in this research paper, the stochastic model approach is consistent with the market practice for the banking sector's AMA.

Most of the respondents who are using the standard formula to assess their ICA operational risk are either small or medium insurers. As of February 2014, only one respondent with insurance liabilities higher than £10bn is using the standard formula to determine the operation risk capital as an add-on to its internal model, making this insurer an outlier in this respect.

None of the Solvency II standard formula respondents are using a loss data stochastic modeling approach for their operational risk ICA. These insurers are split evenly amongst the use of the other methods. For internal model and partial internal model respondents, the most popular method for calculating operational risk ICA is a stochastic modeling approach incorporating expert judgment.

According to feedback received through the 2013 Survey, the calculation of operational risk capital under Solvency II continues to be of concern. It is particularly true for insurers who continue to rely on the standard formula to calculate their operational risk capital. This approach has well documented limitations including: not being risk sensitive, being simplistic, rewarding low pricing and reserving, and not rewarding insurers for having robust governance and control frameworks in place. Furthermore, the operational risk capital calculated is generally inconsistent with ICA capital.

What are the techniques used to model operational risk loss events?

In contrast to the 2012 Survey which addressed this question to internal or partial internal model participants only, the 2013 Survey question was addressed to all respondents (including participants relying on a factor-based approach). As a result, KPMG observed:

- The factor-based (i.e., standard formula) approach being used (none of the internal model participants selected this option in the 2012 Survey); and
- A number of survey respondents selecting the “Other” option.

The “Other” techniques used to model operational risk loss events include the Bayesian belief network (two respondents reported using this approach) and expert judgment.

In order to compare the results from the two surveys, KPMG split the responses into the different types of approaches used for calculating Solvency II operational risk and investigated the difference between the ICA approach (2013 Survey) and the internal model approach (2012 Survey) in respect of respondents opting for an internal model or a partial internal model approach. KPMG observed that most insurers have already, or are in the process of, aligning their ICA and Solvency II approaches.

A review of survey results also showed that a similar proportion of respondents reported using the scorecard and deterministic approaches in the two surveys. A scorecard approach is a self-assessment technique based on the experience and the opinions of a number of internal experts; to estimate the economic capital, these experts estimate the frequency and severity of operational risk loss events occurring in light of the quality of the controls in place. A deterministic approach to operational risk requires insurers to hold capital for operational risk considering a series of adverse scenarios with attributed probabilities.

A comparison of survey results also showed an increase in the proportion of insurers estimating operational risk capital based on a stochastic modeling approach that involves simulating severity and frequency distributions selected based on expert judgment. Over the same period, the proportion of insurers relying on a stochastic modeling approach based on historical loss data decreased significantly. The main reason for this

shift can be explained by the different insurers participating in the surveys; however, KPMG noted that some insurers also changed their approach since the 2012 Survey.

For larger insurers, a stochastic model using expert judgment to set assumptions (usually via scenario workshops) is typically the methodology of choice. Such a method allows insurers the ability to develop a comprehensive analysis of operational risk exposures between business units and across risk types and facilitates meaningful comparisons of operational risk profiles across the business. In using this approach, however, it is important for insurers to exercise a high degree of care to avoid introducing spurious complexity that can hinder transparency, management understanding, and results communication.

Most insurers have acknowledged for some years that the measurement of operational risks is an area in need of significant improvement. The ongoing uncertainty around the implementation of Solvency II allied with a lack of guidance in the area of operational risk from regulators means that operational risk continues to be an area of challenge for insurers.

Emerging good practice favours a stochastic approach with the use of expert judgment to set frequency and severity estimates in scenario workshops for the risks modelled, with both internal and external data used to inform the workshops. This approach has the advantage of capturing both historic losses and incorporating a forward-looking element, which is essential to a robust consideration of potential operational risk losses given the paucity of tail event data.

What are current industry practices for scenario workshops and scenario analysis?

Insurers using scenario workshops to set assumptions typically conducted them on an annual basis. However, any significant change in risk profile would trigger a review of the assumptions within the traditional annual review process.

When considering which ORCs to model, insurers generally incorporate a range of data sources including:

- Operational risk taxonomies;
- Any internal loss data;
- External loss data (ORIC, Aon OpBase, Fitch First, and/or proprietary data sets);
- Risk and controls assessments;
- KRIs; and
- The previous year's scenarios.

Selecting scenarios is an iterative process, and the specific scenarios modelled may change from year to year and vary widely from insurer to insurer. The number of scenarios modelled also varies, ranging from 28 to 72 scenarios for the insurers KPMG reviewed.²⁴³

Current good practice is to document and justify the rationale for all of the data points populated by the scenario workshops. It is also good practice to use visualisation tools to assist workshop participants in understanding the sensitivity of scenarios resulting from the chosen distribution and the data points selected

²⁴³ These observations are based on the feedback from survey participants as well as KPMG client assignments.

based on a 1-in-200 year severity assessment. Most insurers also include, as part of their model documentation, evidence of sign-off by the first line of defence (i.e., business risk owners) and challenge or review of the scenario workshops by the second line of defence (i.e., risk oversight functions).

What sources of operational risk loss data are most frequently used?

Although most large insurers now have operational risk loss databases, they tend to be less than five-years old. Therefore, it is not generally possible to use internal operational risk loss event data to fit distributions empirically with any degree of confidence, particularly in the tail.

There are a number of sources that insurers can rely on for external operational risk loss data. The most extensive database in existence, which collects operational risk loss information specifically for the insurance industry, is that assembled by the 32-member ORIC. This database includes information from most major U.K.-based insurers and covers over 5,000 operational risk events. ORIC recently augmented the consortium database of member losses with a set of publicly available loss data, thereby increasing the quantity of tail events in its data.

AON's OpBase is another database option for insurers. OpBase contains 19,500 operational risk losses with over 4,000 specific to the insurance sector. Historically this database had largely been used by the banking industry, but Aon is now actively promoting the database to the insurance industry; and two large insurers have recently signed up for this product.

Another source of external data is Fitch's FIRST Database, a research tool that contains 6,500 real life case studies analysing external operational risk events. The FIRST Database is a stand-alone product as well as an integrated component of Algo OpVantage, an enterprise-wide operational risk management solution.

Although these external data sets are available, none of the respondents to the KPMG surveys mentioned relying only on external data; some insurers indicated that they use a combination of internal and external data. These responses are in line with KPMG's observations over the last few years and reflect the practical difficulties of scaling external data sets to be fit for purpose for an individual insurer's operational risk capital assessment.

In the 2013 Survey, 41% of respondents reported that they were using internal risk loss data and scenarios. In preparation for Solvency II, it is expected that insurers will collect more data internally. As part of the 2013 Survey, 35% of respondents reported that they use a combination of internal and external data with an allowance for expert judgment, and 24% of respondents indicated that they use no internal or external sources but rather model the risks on plausible operational loss scenarios.

How does the standard formula compare with the ICA?

In the 2012 Survey, risk capital questions were based on the standard formula capital requirement; and in the 2013 Survey, participants were asked to respond based on the methods used in their year-end 2012 ICA calculation.

Historically, operational risk always contributed a material amount to an insurer's capital requirements; and similarly in the 2013 Survey, respondents indicated that operational risk amounted to 8% of pre-diversified and 10% of post-diversified capital. As the factor-based (i.e., standard formula) approach for calculating

operational risk is a move towards a standardised approach, KPMG asked participants how the operational risk capital calculated using the standard formula compared to the operational risk capital within the ICA.

When comparing year-over-year responses, a higher proportion of respondents (69%) indicated that the operational risk capital would be lower when using the standard formula than under the ICA. Interestingly, the proportion of respondents who confirmed that the operational risk capital determined using the standard formula would be higher than under the ICA also increased (from 18% to 29%). The survey question did not specify whether insurers were asked for a comparison based on pre- or post-diversified capital.

Current Practice for Stochastic Modeling

While using a stochastic approach is common, differences are observed in the:

- Number of scenarios modelled;
- Choice of frequency and severity distributions;
- Parameterisation of the frequency and severity distributions;
- Aggregation methodology; and
- Quality of documentation.

The choices of Poisson distribution for frequency and lognormal distribution for severity are common, although other distributions are in use throughout the industry. Negative binomial and Bernoulli are both used for frequency. Gamma, normal, and generalised Pareto are all used for severity. Some caps are applied to severity where there is appropriate justification.

Insurers typically assume a low (e.g., 20% or even 0%) correlation between most risks and a higher correlation between risks that have a logical causal relationship. Some insurers use a wider range of correlations with as many as four categories (zero, low, medium, high) in use.

The number of simulations run by insurers varies widely ranging from a low of 10,000 simulation runs to some insurers running up to one million simulations, with a median of 100,000.

Most insurers model a separate severity outcome for each occurrence of a risk event; insurers generally parameterise severity using two data points, an average and severe (usually one-in-20 or one-in-25 year) event.

REGULATORY REGIMES

This section of the research paper begins with a description of the existing regulatory requirements related to operational risk for the banking sector as set out by Basel II. Next, key positions of the IAIS' *ICPs-October 2013* that address operational risk are discussed, followed by a summary of the current regulatory requirements related to solvency for insurers in the following countries (presented in alphabetic order):

- Australia;
- Bermuda;
- Canada;
- Europe and Solvency II;
- South Africa;
- Switzerland;
- U.S.; and
- Other countries.

Each section begins with the identification of the primary sources used in preparing this research paper. Generally, the information presented was collected from the web site of each regulatory authority.

Basel II

Sources

The information presented in this section of the research paper is based in large part on the Basel Committee's publication titled *International Convergence of Capital Measurement and Capital Standards – A Revised Framework Comprehensive Version* (June 2006). This document, referred to as the Basel Revised Framework, is a compilation of the June 2004 Basel II Framework, the elements of the *1988 Accord* that were not revised during the Basel II process, the *1996 Amendment to the Capital Accord to Incorporate Market Risks*, and the 2005 paper on the *Application of Basel II to Trading Activities and the Treatment of Double Default Effects*.

Background

Basel II is built upon three pillars of supervision: minimum capital requirements, supervisory review, and market discipline. The major objectives of Basel II, as identified by the Basel Committee in the "Introduction" section of the Basel Revised Framework, include the implementation of a framework that would:

- Strengthen the soundness and stability of the international banking system;
- Maintain a sufficient consistency such that the regulation of capital adequacy would not be a significant source of competitive inequality among internationally active banks;

- Introduce significantly more risk-sensitive capital requirements;
- Promote the adoption of stronger risk management practices by the banking industry;
- Use, to a much greater extent, the assessments of risk determined by banks' internal systems as inputs to the calculation of required capital; and
- Preserve the benefits of a framework that can be applied as uniformly as possible at a national level.²⁴⁴

The Basel Committee stressed that Basel II was designed to establish minimum levels of capital; national regulatory authorities are free to adopt requirements that result in higher levels of minimum capital. The Basel Committee also stressed the importance of the second and third pillars (i.e., supervisory review and market discipline, respectively) upon which Basel II was constructed.

The minimum capital requirements of Pillar 1 are calculated separately for credit risk, market risk, and operational risk. Basel II "provides a range of options for determining the capital requirements for credit risk and operational risk to allow banks and supervisors to select approaches that are most appropriate for their operations and their financial market infrastructure."²⁴⁵ Details of the calculations are contained within the Basel Revised Framework as well as in additional guidance material published by the Basel Committee.

Calculation of Operational Risk Capital

Basel II allows for the use of three different methods for the determination of operational risk capital. These methods include:

- Basic indicator approach (BIA);
- Standardised approach (SA); and
- Advanced measurement approaches (AMA).

These methods are viewed as a continuum of increasing sophistication and risk sensitivity. The BIA and SA essentially define operational risk as a proportion of a bank's gross income. A bank with substantial exposure to operational risk losses would be expected to use the AMA instead of either the BIA or SA; however, a bank may be permitted to use the BIA or SA for some parts of its operations and the AMA for others.

Basic Indicator Approach (BIA)

Under the BIA, the operational risk capital that a bank is required to hold is determined as the average over the previous three years of a fixed percentage (denoted alpha, α) of positive annual gross income. Figures for any year in which the annual gross income is negative or zero are excluded from both the numerator and denominator when calculating the average. The operational risk capital charge is expressed as

$$K_{BIA} = [\sum(GI_{1...n} \times \alpha)] / n$$

²⁴⁴ Basel Committee on Banking Supervision, "International Convergence of Capital Measurement and Capital Standards – A Revised Approach – Comprehensive Version", Bank for International Settlements, June 2006: s.4. <https://www.bis.org/publ/bcbs128.pdf>.

²⁴⁵ Ibid.: 7.

where:

K_{BIA} = the capital charge under the Basic Indicator Approach

GI = annual gross income, where positive, over the previous three years

N = number of the previous three years for which gross income is positive

α = 15%, which is set by the [Basel] Committee, relating the industry wide level of required capital to the industry wide level of the indicator.²⁴⁶

Standardised Approach (SA)

Under the SA, a bank's activities are divided into eight business lines:

- Corporate finance;
- Trading and sales;
- Retail banking;
- Commercial banking;
- Payment and settlement;
- Agency services;
- Asset management; and
- Retail brokerage.

Similar to the BIA, gross income serves as a broad indicator for the scale of business operations and thus the potential for operational risk exposure. Unlike the BIA, however, the calculations of the SA are performed at a business line level instead of on an overall basis for the total operations of the bank. Under the SA, the operational risk capital charge is expressed as

$$K_{TSA} = \{\sum_{\text{years } 1-3} \max[\sum(GI_{1-8} \times \beta_{1-8}), 0]\} / 3$$

where:

K_{TSA} = the capital charge under the Standardised Approach

GI_{1-8} = annual gross income in a given year, as defined above in the Basic Indicator Approach, for each of the eight business lines

β_{1-8} = a fixed percentage, set by the [Basel] Committee, relating the level of required capital to the level of the gross income for each of the eight business lines.²⁴⁷

The values of β range from a low of 12% to a high of 18% depending on the business line.

²⁴⁶ Basel Committee on Banking Supervision, "International Convergence of Capital Measurement and Capital Standards – A Revised Approach – Comprehensive Version", Bank for International Settlements, June 2006: s.649. <https://www.bis.org/publ/bcbs128.pdf>.

²⁴⁷ Ibid.: s.654.

Advanced Measurement Approaches (AMA)

Prior supervisory approval is required for the use of the AMA. Under the AMA, a bank determines capital for operational risk based on its internal operational risk measurement system. Such system is required to comply with the standards, both qualitative and quantitative, set out by the Basel Committee in the Basel Revised Framework. The qualitative standards are articulated in Section 666, and the quantitative standards are set out in Sections 667 through 679.

Qualitative Standards²⁴⁸

For approval to use the AMA, a bank is required to meet the following qualitative standards:

- The bank must have an independent operational risk management function that is responsible for the design and implementation of the bank's operational risk management framework.
- The bank's internal operational risk measurement system must be closely integrated into the day-to-day risk management processes of the bank.
- There must be regular reporting of operational risk exposures and loss experience to business unit management, senior management, and to the board of directors.
- The bank's operational risk management system must be well documented.
- Internal and/or external auditors must perform regular reviews of the operational risk management processes and measurement systems.
- The validation of the operational risk measurement system by external auditors and/or supervisory authorities must include the following:
 - Verifying that the internal validation processes are operating in a satisfactory manner; and
 - Making sure that data flows and processes associated with the risk measurement system are transparent and accessible.

Quantitative Standards

The "AMA Soundness Standard" states:

Given the continuing evolution of analytical approaches for operational risk, the Committee is not specifying the approach or distributional assumptions used to generate the operational risk measure for regulatory capital purposes. However, a bank must be able to demonstrate that its approach captures potentially severe 'tail' loss events. Whatever approach is used, a bank must demonstrate that its operational risk measure meets a soundness standard

²⁴⁸ Basel Committee on Banking Supervision, "International Convergence of Capital Measurement and Capital Standards – A Revised Approach – Comprehensive Version", Bank for International Settlements, June 2006: s.666. <https://www.bis.org/publ/bcbs128.pdf>.

comparable to that of the internal ratings-based approach for credit risk, (i.e. comparable to a one year holding period and a 99.9th percentile confidence interval).²⁴⁹

The quantitative standards for use of an AMA include the following:²⁵⁰

- Any internal operational risk measurement system must be consistent with the scope of operational risk as defined by the Basel Committee (i.e., the risk of loss resulting from inadequate or failed internal processes, people and systems or from external events including legal risk but excluding strategic and reputational risk) and the following loss event types:
 - Internal fraud;
 - External fraud;
 - Employment practices and workplace safety;
 - Clients, products and business practices;
 - Damage to physical assets;
 - Business disruption and system failures; and
 - Execution, delivery and process management.
- A bank will be required to calculate its regulatory capital requirement as the sum of expected loss and unexpected loss unless the bank can demonstrate that it is adequately capturing expected loss in its internal business practices.
- A bank's risk measurement system must be sufficiently granular to capture the major drivers of operational risk affecting the shape of the tail of the loss estimates.
- Risk measures for different operational risk estimates must be added for purposes of calculating the regulatory minimum capital requirement. However, the bank may be permitted to use internally determined correlations in operational risk losses across individual operational risk estimates, provided it can demonstrate to the satisfaction of the national supervisor that its systems for determining correlations are sound, implemented with integrity, and take into account the uncertainty surrounding any such correlation estimates (particularly in periods of stress). The bank must validate its correlation assumptions using appropriate quantitative and qualitative techniques.
- Any operational risk measurement system must have certain key features including the use of:
 - Internal data;
 - Relevant external data;
 - Scenario analysis; and
 - Factors reflecting the business environment and internal control systems.

²⁴⁹ Basel Committee on Banking Supervision, "International Convergence of Capital Measurement and Capital Standards – A Revised Approach – Comprehensive Version", Bank for International Settlements, June 2006: s.667.
<https://www.bis.org/publ/bcbs128.pdf>.

²⁵⁰ Ibid.: 669.

(The Basel Committee refers to the above four as the “fundamental elements” that are required for use of AMA.)

- A bank needs to have a credible, transparent, well-documented and verifiable approach for weighting these fundamental elements in its overall operational risk measurement system. In all cases, the bank’s approach for weighting the four fundamental elements should be internally consistent and avoid the double counting of qualitative assessments or risk mitigants already recognised in other elements of the framework.

Further details of the requirements associated with internal data, relevant external data, scenario analysis, and factors reflecting the business environment and internal control systems are set out in the Basel Revised Framework as well as subsequent publications by the Basel Committee on the AMA.

Other Publications by the Basel Committee Related to Operational Risk

There are a number of publications of the Basel Committee on the topic of operational risk that are valuable in addition to the Basel Revised Framework. The descriptions of such documents in this section of the research paper are taken from the executive summaries and the introduction sections of each publication.

Results from the 2008 Loss Data Collection Exercise for Operational Risk and Observed range of practice in key elements of Advanced Measurement Approaches (AMA)

The mandate of the Operational Risk Subgroup of the Standards Implementation Group (SIGOR) includes identifying and participating in the resolution of practical challenges that are associated with the successful development, implementation, and maintenance of an AMA framework. In 2008, SIGOR conducted a loss data collection exercise (LDCE). This was the first international effort to collect information on all four data elements that are used in the AMA for operational risk in the Basel II Framework.

Results from the 2008 Loss Data Collection Exercise for Operational Risk and Observed range of practice in key elements of Advanced Measurement Approaches (AMA), both dated July 2009, present the results of the LDCE. The first paper focuses on:

- Internal loss data;
- Scenario analysis; and
- Operational risk capital.

The second paper discusses:

- The business environment and internal control factors (BEICFs);
- External loss data; and
- AMA range of practice.

The Basel Committee reports:

The LDCE and Range of Practice results provide a unique opportunity to assess operational risk data and practices across regions, thus furthering SIGOR’s goal of promoting

consistency in implementation of the Basel II Accord. The findings also present an opportunity for banking institutions to compare their operational risk management frameworks with those of other institutions and to identify potential areas for improvement.²⁵¹

Operational Risk Supervisory Guidelines for the Advanced Measurement Approaches

This publication (also prepared by SIGOR), dated June 2011, is structured in the following sections:

- Introduction;
- Governance (verification and validation; use test and experience);
- Data (gross loss definition; gross versus net internal loss amounts; internal loss data thresholds; date of internal losses; grouped losses); and
- Modelling (granularity; distributional assumptions; correlation and dependence; use of the four data elements).

In the Introduction to this paper, the Basel Committee comments:

Because operational risk is an evolving discipline, this paper is intended to be an evergreen document, and as further issues are identified and expectations for convergence towards a narrower range of appropriate practices are developed, these too will be added to this document.²⁵²

Principles for the Sound Management of Operational Risk

In the preface to this June 2011 publication, the Basel Committee states:

... The Committee has determined that the 2003 Sound Practices paper should be updated to reflect the enhanced sound operational risk management practices now in use by the industry. This document – *Principles for the Sound Management of Operational Risk and the Role of Supervision* – incorporates the evolution of sound practice and details eleven principles of sound operational risk management covering (1) governance, (2) risk management environment and (3) the role of disclosure. By publishing an updated paper, the Committee enhances the 2003 sound practices framework with specific principles for the management of operational risk that are consistent with sound industry practice.²⁵³

²⁵¹ Basel Committee on Banking Supervision, "Results from the 2008 Loss Data Collection Exercise for Operational Risk", *Bank for International Settlements*, July 2009: 1. <http://www.bis.org/publ/bcbs160a.pdf>.

²⁵² Basel Committee on Banking Supervision, "Operational Risk – Supervisory Guidelines for the Advanced Measurement Approaches", *Bank for International Settlements*, June 2011: s.2. <http://www.bis.org/publ/bcbs196.pdf>.

²⁵³ Basel Committee on Banking Supervision, "Principles for the Sound Management of Operational Risk", *Bank for International Settlements*, June 2011: s.2. <http://www.bis.org/publ/bcbs195.pdf>.

IAIS

Source

The primary source for this section of the research paper is the IAIS' *ICP-October 2013*. Specifically, the section refers to:

- Section 16 Enterprise Risk Management for Solvency Purpose; and
- Section 17 Capital Adequacy.

Throughout the world, insurance regulators have turned to the ICPs of the IAIS in the review of existing and the development of new solvency requirements.

General Description

The ICPs clearly identify operational risk as one of the key categories of risk to be considered. Section 16.1 is titled "Enterprise risk management framework – risk identification and measurement." This section states:

16.1 The supervisor requires the insurer's enterprise risk management framework to provide for the identification and quantification of risk under a sufficiently wide range of outcomes using techniques which are appropriate to the nature, scale and complexity of the risks the insurer bears and adequate for risk and capital management and for solvency purposes.

Risk identification

16.1.1 The ERM framework should identify and address all reasonably foreseeable and relevant material risks to which an insurer is, or is likely to become, exposed. Such risks should include, at a minimum, underwriting risk, market risk, credit risk, operational risk and liquidity risk and may also include, for example, legal risk and risk to the reputation of the insurer.²⁵⁴

The IAIS explicitly recognizes that not all risks can be easily quantified. Section 16 of the ICPs states:

16.1.13 Where a risk is not readily quantifiable, for instance some operational risks or where there is an impact on the insurer's reputation, an insurer should make a qualitative assessment that is appropriate to that risk and sufficiently detailed to be useful for risk management. An insurer should analyse the controls needed to manage such risks to ensure that its risk assessments are reliable and consider events that may result in high operational costs or operational failure. Such analysis is expected to inform an insurer's judgments in assessing the size of the risks and enhancing overall risk management.²⁵⁵

²⁵⁴ IAIS, "Insurance Core Principles, Standards, Guidance and Assessment Methodology", (1 October 2011, including amendments 12 October 2012 and 19 October 2013): s.16.1 and s.16.1.1, accessed on February 27, 2014, <http://www.iaisweb.org/Insurance-Core-Principles-material-adopted-in-2011-795>.

²⁵⁵ Ibid.: s.16.1.13.

Sections 17.6 and 17.7 are grouped under the heading “Structure of regulatory capital requirements – approaches to determining regulatory capital requirements.” Section 17.7 provides an overview of the IAIS’ expectations and states:

17.7 The supervisor addresses all relevant and material categories of risk in insurers and is explicit as to where risks are addressed, whether solely in technical provisions, solely in regulatory capital requirements or if addressed in both, as to the extent to which the risks are addressed in each. The supervisor is also explicit as to how risks and their aggregation are reflected in regulatory capital requirements.²⁵⁶

Sections 17.7.5 and 17.7.6 are directed at the treatment of risks that are difficult to quantify and state:

17.7.5 The IAIS recognises that some risks, such as strategic risk, reputational risk, liquidity risk and operational risk, are less readily quantifiable than the other main categories of risks. Operational risk, for example, is diverse in its composition and depends on the quality of systems and controls in place. The measurement of operational risk, in particular, may suffer from a lack of sufficiently uniform and robust data and well developed valuation methods. Jurisdictions may choose to base regulatory capital requirements for these less readily quantifiable risks on some simple proxies for risk exposure and/or stress and scenario testing. For particular risks (such as liquidity risk), holding additional capital may not be the most appropriate risk mitigant and it may be more appropriate for the supervisor to require the insurer to control these risks via exposure limits and/or qualitative requirements such as additional systems and controls.

17.7.6 However, the IAIS envisages that the ability to quantify some risks (such as operational risk) will improve over time as more data become available or improved valuation methods and modelling approaches are developed. Further, although it may be difficult to quantify risks, it is important that an insurer nevertheless addresses all material risks in its own risk and solvency assessment.²⁵⁷

Australia

Sources

This section is based on the following prudential standards and prudential practice guides of the APRA:

- *Prudential Standards GPS 110 Capital Adequacy* (January 2013) and *Prudential Standards LPS 110 Capital Adequacy*, January 2013;
- *Prudential Standard GPS 118 Capital Adequacy: Operational Risk Charge* (January 2013) and *Prudential Standard LPS 118 Capital Adequacy: Operational Risk Charge*, January 2013; and

²⁵⁶ IAIS, “Insurance Core Principles, Standards, Guidance and Assessment Methodology”, (1 October 2011, including amendments 12 October 2012 and 19 October 2013): s.17.7, accessed on February 27, 2014, <http://www.iaisweb.org/Insurance-Core-Principles-material-adopted-in-2011-795>.

²⁵⁷ Ibid.: s.17.7.5 and s.17.7.6.

- *Prudential Practice Guide GPG 230 – Operational Risk* (February 2006) and *Prudential Practice Guide LPG 230 – Operational Risk*, March 2007.

Background

Prudential Standards GPS 110 Capital Adequacy addresses the requirements for general insurers, and *Prudential Standards LPS 110 Capital Adequacy* sets out the requirements for life insurers. In this section of the research paper, these two standards are referred to collectively as *Prudential Standards 110*.

The key requirements of *Prudential Standards 110* are that an insurer must:

- Have an Internal Capital Adequacy Assessment Process (ICAAP);
- Maintain required levels of capital;
- Determine the prescribed capital amount considering a range of risk factors that may adversely influence its ability to fulfill its obligations. These factors include insurance risk, insurance concentration risk (for general insurers only), asset risk, asset concentration risk, and operational risk;
- Comply with any supervisory adjustment to capital imposed by APRA;
- Make certain public disclosures about its capital adequacy position;
- Seek APRA's consent for certain planned capital reductions; and
- Inform APRA of any significant adverse changes in its capital position.

Prudential Standards 110 specify the minimum requirements for an insurer's ICAAP and establish a risk-based approach for measuring the capital adequacy of an insurer. The required level of capital for regulatory purposes is referred to as the Prudential Capital Requirement (PCR) and is intended to reflect the full range of risks to which an insurer is exposed.

According to *Prudential Standards 110*,

The PCR for a regulated institution equals:

- a) a prescribed capital amount determined either:
 - i. by applying the 'Standard Method' set out in this Prudential Standard; or
 - ii. by using an internal model developed by the regulated institution to reflect the circumstances of its business – the Internal Model based Method (IMB Method); or
 - iii. by using a combination of the methods specified in (i) or (ii) above; plus
- b) any supervisory adjustment determined by APRA.²⁵⁸

²⁵⁸ APRA, "Prudential Standard GPS 110 Capital Adequacy", January 2013: s.22. <http://www.apra.gov.au/GI/PrudentialFramework/Documents/GPS-110-Capital-Adequacy-January-2013.pdf>, and APRA, "Prudential Standard LPS 110 Capital Adequacy", January 2013: s.24. <http://www.apra.gov.au/lifs/PrudentialFramework/Documents/LPS-110-Capital-Adequacy-January-2013.pdf>.

For life insurers using the Standard Method, the prescribed capital amount is determined as the sum of risk charges for insurance risk, asset risk, asset concentration risk, and operational risk; there is a reduction for an aggregation benefit and an adjustment for a combined stress scenario. For general insurers using the Standard Method, the prescribed capital amount is determined as the sum of risk charges for insurance risk, insurance concentration risk, asset risk, asset concentration risk, and operational risk; there is a reduction for an aggregation benefit. “The Asset Concentration Risk Charge and the Operational Risk Charge are not included in the calculation of the aggregation benefit.”²⁵⁹ The two differences in the Standard Method for life and general insurers include: (1) the absence of an insurance concentration risk charge for life insurers and (2) the absence of an adjustment for a combined stress scenario for general insurers.²⁶⁰ *Prudential Standards 110* describe each of the risk charges in general terms and contain references to further prudential standards that set out the detailed requirements for determining the risk charge.

For general insurers, the prescribed capital amount under the Standard Method is intended to be sufficient such that if the insurer was to start the year with a capital base equal to the prescribed capital amount and losses occurred at the 99.5% confidence level that the assets remaining would be at least sufficient to provide for the central estimate of the insurance liabilities and other liabilities at the end of the year. The requirement is the same for life insurers except that “central estimate of the insurance liabilities” is replaced with “adjusted policy liabilities.” The other liabilities to be provided for exclude those liabilities that satisfy the criteria for inclusion in the capital base.

Operational Risk and APRA Prudential Standards

The method for determining the operational risk charge is set out in *Prudential Standard GPS 118 Capital Adequacy: Operational Risk Charge (Prudential Standard GPS 118)* for general insurers and in *Prudential Standard LPS 118 Capital Adequacy: Operational Risk Charge (Prudential Standard LPS 118)* for life insurers.²⁶¹

General Insurers

For general insurers, the operational risk charge is calculated as the sum of the operational risk charges for inwards reinsurance business (ORCI) and for business that is not inwards reinsurance business (ORCNI).

²⁵⁹ APRA, “Prudential Standard GPS 110 Capital Adequacy”, January 2013: s.33. <http://www.apra.gov.au/GI/PrudentialFramework/Documents/GPS-110-Capital-Adequacy-January-2013.pdf>, and APRA, “Prudential Standard LPS 110 Capital Adequacy”, January 2013: s.38. <http://www.apra.gov.au/lifs/PrudentialFramework/Documents/LPS-110-Capital-Adequacy-January-2013.pdf>.

²⁶⁰ APRA, “Prudential Standard GPS 110 Capital Adequacy”, January 2013: s.24. <http://www.apra.gov.au/GI/PrudentialFramework/Documents/GPS-110-Capital-Adequacy-January-2013.pdf>, and APRA, “Prudential Standard LPS 110 Capital Adequacy”, January 2013: s.29. <http://www.apra.gov.au/lifs/PrudentialFramework/Documents/LPS-110-Capital-Adequacy-January-2013.pdf>.

²⁶¹ This section is based on the following APRA Prudential Standards:
General insurers: APRA, “Prudential Standard GPS 118 Capital Adequacy: Operational Risk Charge”, January 2013. <http://www.apra.gov.au/GI/PrudentialFramework/Documents/GPS-118-Capital-Adequacy-Operational-Risk-Charge-January-2013.pdf>, and
Life insurers: APRA, “Prudential Standard LPS 118 Capital Adequacy”, January 2013. <http://www.apra.gov.au/lifs/PrudentialFramework/Documents/LPS-118-Capital-Adequacy-Operational-Risk-Charge-January-2013.pdf>.

The ORCI is calculated as

$$\text{ORCI} = 2\% \times \{\text{maximum}(GP_1, NL) + \text{maximum}(0, |GP_1 - GP_0| - 0.2 \times GP_0)\},$$

and the ORCNI is calculated as:

$$\text{ORCNI} = 3\% \times \{\text{maximum}(GP_1, NL) + \text{maximum}(0, |GP_1 - GP_0| - 0.2 \times GP_0)\}.$$

where,

GP_1 is written premium²⁶² revenue (gross of reinsurance) for the 12 months ending on the reporting date;

GP_0 is written premium revenue (gross of reinsurance) for the 12 months ending on the date 12 months prior to the reporting date;

NL is the central estimate of insurance liabilities (net of reinsurance) at the reporting date; and

$|GP_1 - GP_0|$ is the absolute value of the difference between GP_1 and GP_0 .

Further details are set out in the *Prudential Standard GPS 118*.

Life Insurers

For life insurers, the operational risk charge is calculated as the sum of the operational risk charges for risk business (ORCR), investment-linked business (ORCI), and for other business (ORCO).

The ORCR is calculated as:

$$\text{ORCR} = A \times \{\text{maximum}(GP_1, NL_1) + \text{maximum}(0, |GP_1 - GP_0| - 0.2 \times GP_0)\}$$

where:

A is 2% for a statutory fund that is a specialist reinsurer and 3% for other funds;

GP_1 is premium income (gross of reinsurance) for the 12 months ending on the reporting date;

NL_1 is the adjusted policy liabilities (net of reinsurance) at the reporting date;

GP_0 is premium income (gross of reinsurance) for the 12 months ending on the date 12 months prior to the reporting date; and

$|GP_1 - GP_0|$ is the absolute value of the difference between GP_1 and GP_0 .

The ORCI and the ORCO are calculated as follows:

$$\text{ORCI or ORCO} = B \times \{NL_1 + \text{maximum}(0, GP_1 - 20\% \times GL_0) + \text{maximum}(0, C_1 - 20\% \times GL_0)\}$$

where:

B is 0.15% for a statutory fund that is a specialist reinsurer and 0.25% for other funds;

NL_1 is the adjusted policy liabilities (net of reinsurance) at the reporting date;

GP_1 is premium income (gross of reinsurance) for the 12 months ending on the reporting date;

²⁶² Written premium revenue includes fire services levy, other levies imposed by state and territory governments, and revenue relating to portfolio transfers and unclosed business.

GL_0 is the adjusted policy liabilities (gross of reinsurance) at the date 12 months prior to the reporting date; and

C_1 is all payments to meet liabilities to policy owners (gross of reinsurance) for the 12 months ending on the reporting date.

Further details are set out in the *Prudential Standard LPS 118*.

Operational Risk and APRA PPGs

Prudential Practice Guide GPG 230 – Operational Risk (GPG 230) addresses operational risks for general insurers, and *Prudential Practice Guide LPG 230 – Operational Risk (LPG 230)* addresses operational risks for life insurers. These prudential practice guides begin with the following:

Prudential Standard GPS [LPS] 220 Risk Management (GPS [LPS] 220) sets out APRA's requirements of general insurers [life companies] in relation to risk management. This prudential practice guide aims to assist insurers [life companies] in complying with those requirements in relation to operational risk and, more generally, to outline prudent practices in relation to operational risk management.

Subject to the requirements of GPS [LPS] 220, insurers [life companies] have the flexibility to configure their operational risk management framework in the way most suited to achieving their business objectives.

Not all the practices outlined in this prudential practice guide will be relevant for every insurer [life company] and some aspects may vary depending upon the size, complexity and risk profile of the insurer [life company].²⁶³

GPG 230 and *LPG 230* identify examples of operational risks typically faced by general insurers and life insurers, respectively; these types of risks are described in a previous section of this research paper.

Bermuda

Sources

Within the regulations for insurers in Bermuda, operational risk is addressed by the BMA in the following:

- The *Insurance Code of Conduct*, which is applicable to all insurers;
- *Insurance (Prudential Standards) Amendment Rules 2013* (collectively referred to as the *2013 Prudential Standards*)
 - (*Class C, Class D and Class E Solvency Requirement*) – BR 100/2013;

²⁶³ APRA, "Prudential Practice Guide GPG 230 Operational Risk", February 2006: 3. <http://www.apra.gov.au/GI/PrudentialFramework/Documents/Prudential-Practice-Guide-GPG-230-Operational-Risk.pdf>, and APRA, "Prudential Practice Guide LPG 230 Operational Risk", March 2007: 3. <http://www.apra.gov.au/lifs/PrudentialFramework/Documents/Prudential-Practice-Guide-LPG-230-Operational-Risk.pdf>.

- (Class 3A Solvency Requirement) – BR 111/2013;
 - (Class 4 and 3B Solvency Requirement) – BR 112/2013; and
 - (Insurance Group Solvency Requirement) – BR 114/2013.
- *Guidance Notes, Standards and Application Framework for the Use of Internal Capital Models for Regulatory Capital Purposes – Revised*, September 2012 (referred to as the *Standards for ICM*).

The 2013 Prudential Standards amended the Prudential Standard Rules of 2011 and came into effect on January 1, 2014.

These are the primary sources, along with the *Insurance Act 1978*, that were relied on for completing this section of the research paper.

Background

Bermuda has a multi-license system of regulation that categorizes general insurers into six classes (1, 2, 3, 3A, 3B, and 4) and long-term insurers (typically life insurers) into five classes (A, B, C, D, and E). There is one class for special purpose insurers, and the classification system also provides for composite companies.²⁶⁴ Details are set out in the (Bermuda) *Insurance Act 1978* and are included as Appendix C of this research paper.

In Bermuda, regulatory capital is determined in accordance with the Bermuda Solvency Capital Requirement (BSCR) or from an approved internal model that, for regulatory purposes, requires determination of capital at the 99% TVaR.²⁶⁵ The “Background” section of the *Standards for ICM* provides the following summary of recent activity by the BMA related to the standard capital formula, the use of an internal capital model (ICM), and the applicability of the rules and standards to the different classes of insurers.

On 31st December 2008, the Authority issued Rules under the Insurance Act 1978 prescribing a standard risk-based capital formula, the Bermuda Solvency Capital Requirement (BSCR), for the determination of an insurer’s enhanced capital requirement (ECR). These Rules, which were amended in 2010 to include both Class 4 and Class 3B insurers (with similar rules introduced for Class 3A and E insurers in 2011), also include a provision allowing an insurer to apply to the Authority for approval to use an ICM in substitution for the BSCR to calculate its ECR.

While Class 4, Class 3B, Class 3A and Class E insurers are currently within the scope of the Rules, other classes are not. The Rules will be further revised to include other classes, namely long-term Classes C and D, but it is anticipated that the framework outlined herein

²⁶⁴ <http://www.bma.bm/insurance/licensing/SitePages/Home.aspx>, accessed January 10, 2014.

²⁶⁵ BMA, “Insurance (prudential standards) (class C, class D and class E solvency requirement) amendment rules 2013 BR 110/2013”, page 84.
[http://www.bma.bm/legislation/Insurance/Insurance%20\(Prudential%20Standards\)%20\(Class%20C,%20Class%20D%20and%20Class%20E%20Solvency%20Requirement\)%20Amendment%20Rules%202013.pdf](http://www.bma.bm/legislation/Insurance/Insurance%20(Prudential%20Standards)%20(Class%20C,%20Class%20D%20and%20Class%20E%20Solvency%20Requirement)%20Amendment%20Rules%202013.pdf).

will remain appropriate. For Class 3A insurers (and Class C in due course), the standards outlined in this paper will be applied on a proportionate basis.²⁶⁶

The *2013 Prudential Standards* set out requirements for insurers to file with the BMA a comprehensive report comprising a solvency self-assessment of the insurer's material risks (including operational risk) and the determination of both the quality (types of capital) and quantity of the CISSA [commercial insurer's solvency self assessment] capital required to cover these risks, while remaining solvent and achieving the insurer's business goals.²⁶⁷ Details of the contents required for such reports are set out Table 14B of the *2013 Prudential Standards*.

[The Insurance Code of Conduct](#)

The *Insurance Code of Conduct* requires insurers to adopt a sound risk management and internal controls framework. Operational risk is specifically cited among the list of material risks to be addressed by an insurer's risk management framework.

Section 4.1.5 of the *Insurance Code of Conduct* is titled "Systems and Operations Risk (Operational risk)." This section sets out BMA's expectations with respect to the risk management framework and operational risk. The risk management framework is expected to:

- Define the systems and operations risk and establish tolerance limits for each material risk area;
- Establish a system to identify the operational risk exposures and to capture and track near-miss data;
- Establish a system of effective internal reporting and operating controls to manage and mitigate the risk;
- Establish measurement techniques (such as stress and scenario testing) to assess vulnerability; and
- Establish frequent reviews to ensure mitigation strategies (such as an early warning system) are effectively deployed and the risk is within a tolerable limit.

[2013 Prudential Standards for Long-Term Insurers and the Determination of Operational Risk Capital](#)

The formula for the BSCR is set out in Schedule 1 (Paragraph 4) for Class D and Class E insurers and in Schedule XIII for Class C insurers of *BR 100/2013*. The formula includes explicit risk capital calculations for:

- Fixed income investment risk;

²⁶⁶ BMA, "Standards and application framework for the use of internal capital models for regulatory capital purposes - revised", September 2012: Sections 12 and 13. <http://www.bma.bm/document-centre/policy-and-guidance/INSURANCE%20II/Guidance%20Note%20-%20Standards%20and%20Application%20Framework%20for%20the%20Use%20of%20Internal%20Capital%20Models%20for%20Regulatory%20Capital%20Purposes.pdf>

The 2013 amended rules, which became effective January 1, 2014, are described later in this section of the research paper.

²⁶⁷ BMA, "Insurance (prudential standards) (class C, class D and class E solvency requirement) amendment rules 2013 BR 110/2013", Table 14B, page 88. [http://www.bma.bm/legislation/Insurance/Insurance%20\(Prudential%20Standards\)%20\(Class%20C,%20Class%20D%20and%20Class%20E%20Solvency%20Requirement\)%20Amendment%20Rules%202013.pdf](http://www.bma.bm/legislation/Insurance/Insurance%20(Prudential%20Standards)%20(Class%20C,%20Class%20D%20and%20Class%20E%20Solvency%20Requirement)%20Amendment%20Rules%202013.pdf).

- Equity investment risk;
- Credit risk;
- Long-term interest rate and liquidity risk;
- Long-term insurance mortality risk;
- Long-term insurance stop loss risk;
- Long-term insurance riders risk;
- Long-term insurance morbidity and disability risk;
- Long-term insurance longevity risk;
- Long-term variable annuity guarantee risk;
- Long-term other insurance risk; and
- Operational risk.

The calculation of the risk capital associated with each of the above risks is specified by formulae in the *2013 Prudential Standards*.

For operational risk, the risk capital calculation formula is:

$$C_{op} = \rho * ACov$$

where:

ρ = an amount between 1% and 10% as determined by the BMA in accordance with Table 13, which in turn is dependent upon the sum of scores derived from Tables 13A through 13F.

ACov = BSCR after Covariance amount or an amount approved by the BMA.²⁶⁸

Tables 13A through 13F of the *2013 Prudential Standards* reflect the following characteristics of the insurer:

- Table 13A – corporate governance;
- Table 13B – risk management function;
- Table 13C – risk identification process;
- Table 13 D – risk measurement process;
- Table 13E – risk response process; and
- Table 13F – risk monitoring and reporting process.

²⁶⁸ BMA, "Insurance (prudential standards) (class C, class D and class E solvency requirement) amendment rules 2013 BR 110/2013", paragraph 13, page 35.

[http://www.bma.bm/legislation/Insurance/Insurance%20\(Prudential%20Standards\)%20\(Class%20C,%20Class%20D%20and%20Class%20E%20Solvency%20Requirement\)%20Amendment%20Rules%202013.pdf](http://www.bma.bm/legislation/Insurance/Insurance%20(Prudential%20Standards)%20(Class%20C,%20Class%20D%20and%20Class%20E%20Solvency%20Requirement)%20Amendment%20Rules%202013.pdf).

2013 Prudential Standards for General Insurers and the Determination of Operational Risk Capital

The formula for the BSCR for small and medium sized entities (BCSR-SME) is set out in Schedule 1 (Paragraph 4) of the *2013 Prudential Standards BR 111/2013* for Class 3A insurers; similarly the BSCR formula is set out in Schedule 1 (Paragraph 4) of the *2013 Prudential Standards BR 112/2013* for Class 4 and Class 3B insurers. The formula includes explicit risk capital calculations for:

- Fixed income investment risk;
- Equity investment risk;
- Interest rate and liquidity risk;
- Premium risk;
- Reserve risk;
- Credit risk;
- Catastrophe risk; and
- Operational risk.

The calculation of the risk capital associated with each of the above risks is specified by formulae in the *2013 Prudential Standards*.

For operational risk, the risk capital calculation formula is:

$$C_{op} = \rho * ACov$$

where:

ρ = an amount between 1% and 10% as determined by the BMA in accordance with Table 7, which in turn is dependent upon the sum of scores derived in a number of related tables.

ACov = BSCR after covariance amount or an amount approved by the BMA.²⁶⁹

For Class 3A insurers, Tables 7A and 7B of the *2013 Prudential Standards* reflect characteristics of the insurer related to corporate governance and the risk management function. While for Class 4 and Class 3B insurers, Tables 7A through 7F of the *2013 Prudential Standards* are similar to those of long-term insurers described previously (i.e., Tables 13A through 13F).

For general insurers of all sizes, internal models are not cited as an option for the determination of regulatory capital in the *2013 Prudential Standards*. The *2013 Prudential Standards* set out requirements for reporting of the CISSA for general insurers.

²⁶⁹ BMA, "Insurance (prudential standards) (class 4 and class 3B solvency requirement) amendment rules 2013 BR 112/2013", paragraph 9, page 16.

[http://www.bma.bm/legislation/Insurance/Insurance%20\(Prudential%20Standards\)%20\(Class%204%20and%20Class%203B%20Solvency%20Requirement\)%20Amendment%20Rules%202013.pdf](http://www.bma.bm/legislation/Insurance/Insurance%20(Prudential%20Standards)%20(Class%204%20and%20Class%203B%20Solvency%20Requirement)%20Amendment%20Rules%202013.pdf).

2013 Prudential Standards for Insurance Groups

The formula for the BSCR for insurance groups (Group BSCR) is set out in Schedule 1 (Paragraph 4) of the *2013 Prudential Standards BR 114/2013*. The formula includes explicit risk capital calculations that are similar to those for both long-term and general insurers. Thus, a detailed description of the Bermuda regulations for groups is not included in this research paper.

Commercial Insurer Risk Assessment

The commercial insurer risk assessment (CIRA) is designed to serve as an assessment tool to enhance the BMA's risk-based supervisory framework. CIRA was effective on December 31, 2008 for Class 4 insurers only. The CIRA Framework, which is described in the *CIRA Guidance Note*, assesses the quality of an insurer's risk management function with respect to its operational risk exposures.²⁷⁰ CIRA is required to be completed by the insurer and submitted to BMA with the BSCR. To the extent that an insurer has strong and effective standards related to the corporate governance and risk management functions for the oversight of its operational risk exposures, CIRA will result in a credit.

The CIRA Framework is focused on the following eight operational risk exposures:

- Business process risks;
- Business continuity risks;
- Compliance risks;
- Information systems risks;
- Distribution channels risks;
- Fraud risks;
- Human resources risks; and
- Outsourcing risks.

The CIRA Framework analyzes the implementation of specified procedures and processes related to the risk management of operational risk. The *CIRA Guidance Note* reports:

The Authority does not wish to provide exhaustive criteria to assess each operational risk area, since insurers vary in nature, scale and complexity. The Authority has, however, taken a principles-based approach whereby the insurer's Corporate Governance function is responsible for demonstrating to the Authority that the assessment is appropriate for the insurer's operations.²⁷¹

²⁷⁰ BMA, "Guidance Note #17 – Commercial Insurer Risk Assessment", page 2. <http://www.bma.bm/document-centre/policy-and-guidance/INSURANCE%20II/Guidance%20Note%20No.%2017%20-%20Commercial%20Insurer%20Risk%20Assessment.pdf>.

²⁷¹ *Ibid.*: 6.

The *CIRA Guidance Note* includes examples of specific actions that may be incorporated into risk management processes and procedures addressing operational risk. The *CIRA Guidance Note* includes a detailed 8-page risk management questionnaire/scorecard with the following parts:

- Corporate governance;
- Risk management function;
- Risk identification;
- Risk measurement;
- Risk response;
- Risk monitoring and reporting; and
- Operational risk charge calculation instructions.

The detailed questionnaire/scorecard is not reproduced as part of this research paper but can be found on the BMA website.²⁷²

[Standards for ICM](#)

According to the *Standards for ICM*, Section B.8. Calibration Test:

Output from the ICM used to determine regulatory capital is defined as the amount of capital required to meet all obligations using a TVaR metric subject to a confidence level of 99%, inclusive of existing business and business expected to be written over a one-year period with reserve development over a one year time horizon and losses due to market, credit and operational risks.²⁷³

In the *Standards for ICM*, operational risk is specifically listed among the risk categories that are required to be considered by the ICM. Insurers are required to consider the same risks for an ICM that are identified in the *CIRA Guidance Note*.

Similar to the requirements of Basel II, if operational risk is explicitly modeled using historical data, BMA requires an insurer to be able to describe the sources of data used for the assessment of operational risk, including:

- Internal loss and event data;
- External loss and event data with details of any external data providers; and

²⁷² BMA, "Guidance Note #17 – Commercial Insurer Risk Assessment", Appendix I, Pages 10 through 17.

<http://www.bma.bm/document-centre/policy-and-guidance/INSURANCE%20II/Guidance%20Note%20No.%2017%20-%20Commercial%20Insurer%20Risk%20Assessment.pdf>.

²⁷³ BMA, "Standards and application framework for the use of internal capital models for regulatory capital purposes - revised", September 2012: Sections B.8 Calibration Test, page 22. <http://www.bma.bm/document-centre/policy-and-guidance/INSURANCE%20II/Guidance%20Note%20-%20Standards%20and%20Application%20Framework%20for%20the%20Use%20of%20Internal%20Capital%20Models%20for%20Regulatory%20Capital%20Purposes.pdf>.

- Scenario analysis.²⁷⁴

The *Standards for ICM* recognize that there may be an overlap between operational risk and other risk categories. If operational risks are considered elsewhere in the ICM, the insurer is required to be able to provide sufficient documentation to evidence this.

The *Standards for ICM* provide examples of sub-categories within major risk categories of typical model structure and anticipated tests that the BMA may ask an insurer to run. For operational risk, the typical risks cited include people, processes, and external events. Examples of model structure and anticipated tests include:

- Simple factor-based frameworks with outside-in comparison tests;
- Internal data driven loss models with goodness of fit tests; and
- Scenario / expert opinion-based frameworks with sensitivity tests.²⁷⁵

Canada

Sources

The main sources of information relied on for this section are OSFI communications issued during 2013 and 2014 to the insurance industry about proposed changes in the minimum capital test (MCT) for P&C insurers and in the minimum continuing capital and surplus requirements (MCCSR) for life insurers.

Property and Casualty Insurers

Prior to January 1, 2015, the federal solvency regime in Canada did not require a capital charge to be explicitly determined for operational risk. In describing the existing requirements for P&C insurers in Canada, OSFI stated:

OSFI has established a supervisory target capital ratio (supervisory target) of 150% that provides a cushion above the minimum requirement, both to cope with volatility in markets and economic conditions, innovations in the industry, consolidation trends and international developments, and to provide for risks not explicitly addressed in the calculation of policy liabilities or the MCT. Such risks include systems, data, strategic, management, fraud, legal and other operational and business risks. An adequate supervisory target provides additional capacity to absorb unexpected losses beyond those covered by the minimum MCT and to address capital needs through ongoing market access.²⁷⁶

²⁷⁴ BMA, "Standards and application framework for the use of internal capital models for regulatory capital purposes - revised", September 2012: Sections B.120, pages 46 and 47. <http://www.bma.bm/document-centre/policy-and-guidance/INSURANCE%20II/Guidance%20Note%20-%20Standards%20and%20Application%20Framework%20for%20the%20Use%20of%20Internal%20Capital%20Models%20for%20Regulatory%20Capital%20Purposes.pdf>.

²⁷⁵ Ibid.: Section C.114, page 69.

²⁷⁶ OSFI, "Guideline – Minimum Capital Test for Federally Regulated Property and Casualty Insurance Companies", January 1, 2013: 5. <http://www.osfi-bsif.gc.ca/Eng/Docs/mct2013.pdf>.

Starting in 2013, OSFI undertook a review process that would result in changes to its standard formula, including the incorporation of an explicit capital charge for operational risk. The purpose of this revision was to create a more robust risk based capital framework that would be in better alignment to the risks faced by P&C insurers.

In May 2013, OSFI issued a discussion paper to the P&C industry for consultation on proposed changes to the regulatory framework. In describing the proposed approach for operational risk in its discussion paper, OSFI stated:

The proposed approach should be regarded as a first step in setting an explicit risk charge for operational risk. The initial methodology will focus on a few risk proxies only. As more information and loss experience data is gathered, OSFI will consider including more risk proxies and enhance the measure of the risk exposure if warranted.

The proposed formula for calculating the operational risk margin aims to provide a simple and reasonable measure of the risk exposure using readily available data. Other more complex risk measures were explored but were not retained as they were not providing more precision in measuring operational risk requirements.²⁷⁷

A quantitative impact study (QIS) accompanied OSFI's discussion paper, and insurers prepared their analyses in the summer of 2013. OSFI issued the following documents in response to the feedback it received:

- *Capital Impact Summary of the Proposed Changes to the 2015 Regulatory Capital Framework for Property and Casualty Insurers;*
- *Summary of Industry's Comments on OSFI's Discussion Paper: Proposed Changes to the Regulatory Capital Framework for Federally Regulated Property and Casualty Insurers including Earthquake Risk Exposure;*
- *Disclosure on OSFI's Review of Insurance Risk Factors;* and
- *Draft capital-related new exhibits of the regulatory return.*

OSFI also released a communication, dated December 20, 2013, on the subject of the draft MCT guideline for public consultation.²⁷⁸ Appendix A of OSFI's communication contained details regarding proposed adjustments in the draft MCT Guideline.

Originally, OSFI proposed a 40% cap in order to limit the operational risk charge for insurers that have high volume and low complexity business with high levels of reinsurance. As of December 2013, OSFI had reduced the cap to 30%; it would be calculated in relation to the capital/margin required calculated at target before operational risk and diversification credit.

On September 24, 2014, OSFI released the final version of the 2015 MCT Guideline. This guideline, which is effective starting January 1, 2015, contains an explicit formula to incorporate operational risk margin as part of the overall capital requirement.

²⁷⁷ OSFI, "Discussion Paper on OSFI's Proposed Changes to Regulatory Capital Framework for Federally Regulated Property and Casualty Insurers", May 2013: 20. <http://www.osfi-bsif.gc.ca/Eng/Docs/MCTDC.pdf>.

²⁷⁸ OSFI, "Minimum Capital Test Guideline", September 24, 2014, accessed on October 27, 2014, <http://www.osfi-bsif.gc.ca/Eng/fi-if/rg-ro/gdn-ort/gl-ld/Pages/mct2015-let.aspx>.

The 2015 MCT Guideline operational risk margin formula is driven by the capital/margin required, the written premiums (direct, assumed, and ceded premiums), and the increase in gross written premiums above a given threshold. Under this formula, the operational risk margin is calculated as

$$\text{Operational risk margin} = \text{MIN} \{30\% CR_0, (8.50\% CR_0 + 2.50\% P_w + 1.75\% P_a + 2.50\% P_c + 2.50\% P_\Delta) + \text{MAX}(0.75\% P_{\text{aig}}, 0.75\% P_{\text{cig}})\},$$

where:

CR_0 = total capital required for the reporting period, before operational risk margin and diversification credit;

P_w = direct premiums written in the past 12 months;

P_a = assumed premiums written in the past 12 months arising from third party reinsurance;

P_c = ceded premiums written in the past 12 months arising from third party reinsurance;

P_{aig} = assumed premiums written in the past 12 months arising from intra-group pooling arrangements;

P_{cig} = ceded premiums written in the past 12 months arising from intra-group pooling arrangements; and

P_Δ = growth in gross premiums written in the past 12 months (premium growth charge).

OSFI calculates the premium growth charge using gross premiums written (direct plus assumed premiums written). A 2.5% risk factor is applied to the total amount of gross premiums written in the current year above a 20% growth threshold compared to the gross premiums written in the previous year.

OSFI's formula for operational risk margin includes different risk factors for reinsurance transactions involving third party reinsurers and intra-group pooling arrangements. The risk factor for premiums ceded to third party reinsurers captures the operational risks that remain with the ceding insurers after a portion of the insurance risk has been transferred to the third-party reinsurer. The risk factor for premiums assumed from or ceded to intra-group pooling arrangements "captures the additional operational risks associated with pooling premiums within a group compared to a company that does not enter into transactions moving the premiums from a company to another within a group."²⁷⁹ Insurers require prior approval from OSFI to apply the risk factor for intra-group pooling arrangements and these risk factors are only applicable to reinsurance pooling arrangements between associated Canadian federally or provincially regulated insurers.

Life Insurers

Currently, the federal solvency regime in Canada does not require a capital charge explicitly for operational risk. In describing the existing requirements for life insurers in Canada, OSFI states:

The MCCSR/TAAM [test of adequacy of assets and margin requirements] ratio compares capital available to capital required as calculated for specified risks. If considering only the risks where calculations are specified, a minimum MCCSR/TAAM ratio of 100% may be considered acceptable. However, life insurers are exposed to more risks than those where

²⁷⁹ OSFI, "Minimum Capital Test for Federally Regulated Property and Casualty Insurance Companies", January 1, 2015, accessed on September 29, 2014, <http://www.osfi-bsif.gc.ca/Eng/fi-if/rg-ro/gdn-ort/gl-ld/Pages/mct2015.aspx>.

calculations are specified. Thus, the minimum MCCR/TAAM ratio for life insurers is set at 120% rather than 100% to cover operational risk that is not explicitly calculated, but is part of the minimum requirement under MCCR/TAAM. In addition, OSFI has established a supervisory target capital ratio of 150% that is intended to cover the risks specified in the minimum MCCR/TAAM ratio as well as to provide a margin for other types of risks not included in the calculation. Other risks may include strategic and reputational risk, as well as risks not explicitly addressed by the actuary when determining policy liabilities.²⁸⁰

Similar to its work for P&C insurers, OSFI is in the midst of evaluating changes to its standard formula for life insurers that would incorporate an explicit adjustment for operational risk. On November 1, 2013, OSFI released a fifth quantitative impact study (OSFI-QIS#5)²⁸¹ for life insurers. OSFI stated:

At this time, we are requesting that insurance entities participate in a fifth quantitative impact study [(OSFI-QIS#5)] to gather information related to all potential methods developed to date for determining capital requirements. [OSFI-QIS#5] includes changes to credit, market, insurance and operational risk calculations based on feedback received on QIS#4, additional analysis and more specific data.²⁸²

In the “Ops Risk Data” tab of the MS Excel spreadsheet provided by OSFI for OSFI-QIS#5, a total solvency buffer for operational risk is calculated as the sum of:

- Solvency buffer for business volume;
- Solvency buffer for large increase in business volume; and
- Solvency buffer risk charge.

The solvency buffers for business volume and for large increase in business volume are determined by applying risk factors to:

- Direct premiums for individual life, group life, and other;
- Reinsurance premiums assumed; and
- Account values, separately for segregated funds, annuity liabilities, universal life, and deposit products (including mutual funds, GICs, and other).

Different factors apply to the different categories of business. The operational risk solvency buffer includes a 5% risk charge on the total solvency buffer for all other risks by jurisdiction. This charge would cover some operational risk related to the existing in-force business.²⁸³

²⁸⁰ OSFI, “Guideline – Minimum Continuing Capital and Surplus Requirements (MCCR) for Life Insurance Companies”, Effective: January 1, 2013: pp 5-6. <http://www.osfi-bsif.gc.ca/Eng/Docs/MCCR2013.pdf>.

²⁸¹ It is expected that the formula and some of the factors will be recalibrated in OSFI’s sixth quantitative impact study and eventually, in the final framework.

²⁸² OSFI, “Life Insurance Capital Standardized Approach – Quantitative Impact Study No. 5”, November 1, 2013: 1, accessed on January 18, 2014, http://www.osfi-bsif.gc.ca/Eng/fi-if/rq-ro/gdn-ort/pp-do/Pages/qis5_let.aspx.

²⁸³ OSFI, “Life Insurance Capital Standardized Approach – Quantitative Impact Study No. 5 – Summary Worksheets (Version 2)”, November 1, 2013: 1, accessed on January 18, 2014, http://www.osfi-bsif.gc.ca/Eng/fi-if/rq-ro/gdn-ort/pp-do/Pages/qis5_index.aspx.

Europe and Solvency II

Sources

This section of the research paper is based in large part on the:

- Web site of the Bank of England;
- Text of *Directive 2009/138/EC of the European Parliament and of the Council of 25 November 2009 on the taking-up and pursuit of the business of Insurance and Reinsurance (the Directive)*;
- EIOPA publication titled *CEIOPS' Advice for Level 2 Implementing Measures on Solvency II: SCR standard formula – Article 111 (f) Operational Risk*, October 2009;
- *EIOPA Report on the fifth Quantitative Impact Study (S2-QIS5) for Solvency II*, March 2011;
- EIOPA publication titled *EIOPA Final Report on Public Consultation No. 13/008 on the Proposal for Guidelines on the System of Governance*, September 2013, and *Guidelines on System of Governance*, 2013; and
- EIOPA publications titled *EIOPA Final Report on Public Consultation No. 13/011 on the Proposal for Guidelines on the Pre-application for Internal Models*, September 2013, and *Guidelines on Pre-Application of Internal Models*, 2013.

Background and General Description

In October 2013, the European Commission announced that Solvency II would become effective January 1, 2016. "On implementation, Solvency II will be adopted by all 28 European Union (EU) Member States plus three of the European Economic Area (EEA) countries."²⁸⁴

Solvency II is a new regulatory framework for the European insurance industry that adopts a risk-based approach. This new framework replaces Solvency I, which was a minimum harmonization regime introduced in the early 1970s.

Solvency II will establish new capital requirements, valuation techniques, and standards for governance and reporting. The intent is to harmonize the regulations across the EU, replacing a system that includes 13 insurance directives²⁸⁵ under which different countries have implemented the Solvency I rules in different ways (particularly for group supervision) with a single unified regime.

One of the goals of Solvency II is to streamline insurance supervision towards a single market, enabling EU insurers to operate with a single license throughout member countries. This goal will be achieved by introducing a unified legal framework for the prudential regulation of all insurers operating in the EU. Solvency II is expected to maximize harmonization and be consistent with the principles used in banking supervision.

Solvency II incorporates the following key principles:

²⁸⁴ <http://www.bankofengland.co.uk/pru/pages/solvency2/default.aspx>, accessed January 16, 2014.

²⁸⁵ <http://www.lloyds.com/the-market/operating-at-lloyds/solvency-ii>, accessed January 16, 2014.

- Market consistent balance sheets;
- Risk-based capital;
- ORSA;
- Senior management accountability; and
- Supervisory assessment.

Solvency II is similar in structure to the Basel II regulation. Both are based on three pillars that include quantitative and qualitative requirements as well as market discipline, and include specific components that focus on capital, risk, supervision, and disclosure. The following table compares the three pillars of Basel II to those of Solvency II as labeled by the Basel Committee and EIOPA, respectively.

Pillar	Basel II	Solvency II
1	minimum capital requirements	capital adequacy
2	supervisory review	systems of governance
3	market discipline	reporting

There are notable differences in the regulatory framework for insurers operating under Solvency II and the regulatory framework applicable to the banking industry under Basel II, particularly with respect to Pillar 1. One of the main differences is that Basel II is built on separate models for investment, credit, and operational risks; while Solvency II focuses on a risk-based portfolio analysis by applying an integrated approach that takes into account dependencies between risk categories. Furthermore, Basel II concentrates on the asset side, while Solvency II's assessment of capital adequacy applies economic principles on the total balance sheet including both the assets and liabilities.

Pillar 1 of Solvency II addresses the quantitative requirements for insurers with the aim to ensure that insurers are adequately capitalized with risk-based capital. All valuations in this pillar are to be done in a prudent and market-consistent manner. In addressing capital adequacy, Pillar 1 sets forth the solvency capital requirement (SCR) and the minimum capital requirement (MCR):

- The SCR is the level of capital required to give 99.5% confidence that assets will be sufficient to cover liabilities over the following 12 months; and
- The MCR is the level of capital required to give the national supervisor 85% confidence that assets will be sufficient to cover liabilities over the following 12 months.

An insurer can calculate its capital requirements using one of the following three approaches:

Standard formula – The standard formula is a risk-sensitive framework designed to capture the standard risks a firm may face and calculate the capital requirements from these risks. The standard formula categorises risks into risk modules for capital purposes, with an allowance for aggregation and diversification across the modules. The risk modules are market risk, credit risk, underwriting risk (life and non-life), and operational risk. There are adjustments for the loss-absorbing capacity of deferred taxes and technical provisions, as well as for the risk associated with holding intangible assets.

Undertaking specific parameters – In some circumstances, a firm may change the parameters in the standard formula to ones more appropriate to their business. This can only be applied to certain risks, and their estimation will follow a specified methodology, with ultimate approval from the regulator.

Full or Partial Internal models – For firms whose risk profile is not appropriately captured by the standard formula or who require their capital requirement to be more closely aligned to their risk profile, a full or partial internal model allows a more bespoke assessment.²⁸⁶

The use of internal models will be subject to stringent standards and prior supervisory approval.

Pillar 2 of Solvency II imposes standards for risk management and governance within an insurer's organization. This pillar also gives supervisors powers to challenge insurers on risk management issues. It includes the ORSA, which requires an insurer to undertake its own forward-looking self-assessment of its risks, corresponding capital requirements, and adequacy of capital resources.

Pillar 3 of Solvency II is focused on the transparency of reporting for supervisors and the public. Under this pillar, insurers are required to prepare a private annual report to supervisors and a public solvency and financial condition report that increases the level of disclosure by insurers. Insurers will be required to submit reports to the regulator with core information on a quarterly and annual basis.

Calculation of Operational Risk Capital under Solvency II using the Standard Approach

To better understand the solvency capital requirement of Solvency II, it is valuable to review the text of Articles 101 and 107 of the *Directive*.

Article 101 is titled "Calculation of the Solvency Capital Requirement" and states:

1. The Solvency Capital Requirement shall be calculated in accordance with paragraphs 2 to 5.
2. The Solvency Capital Requirement shall be calculated on the presumption that the undertaking will pursue its business as a going concern.
3. The Solvency Capital Requirement shall be calibrated so as to ensure that all quantifiable risks to which an insurance or reinsurance undertaking is exposed are taken into account. It shall cover existing business, as well as the new business expected to be written over the following 12 months. With respect to existing business, it shall cover only unexpected losses.

It shall correspond to the Value-at-Risk of the basic own funds of an insurance or reinsurance undertaking subject to a confidence level of 99,5 % over a one-year period.²⁸⁷

Article 107 is titled "Capital requirement for operational risk" and states:

²⁸⁶ Prudential Regulation Authority, "Policy: Europe & UK – Pillar 1 Capital adequacy", Bank of England, June 2013. <http://www.bankofengland.co.uk/pru/Documents/solvency2/pillar1.pdf>.

²⁸⁷ <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32009L0138>, accessed January 14, 2014.

1. The capital requirement for operational risk shall reflect operational risks to the extent they are not already reflected in the risk modules referred to in Article 104. That requirement shall be calibrated in accordance with Article 101(3).
2. With respect to life insurance contracts where the investment risk is borne by the policy holders, the calculation of the capital requirement for operational risk shall take account of the amount of annual expenses incurred in respect of those insurance obligations.
3. With respect to insurance and reinsurance operations other than those referred to in paragraph 2, the calculation of the capital requirement for operational risk shall take account of the volume of those operations, in terms of earned premiums and technical provisions which are held in respect of those insurance and reinsurance obligations. In this case, the capital requirement for operational risks shall not exceed 30 % of the Basic Solvency Capital Requirement relating to those insurance and reinsurance operations.²⁸⁸

Article 107 refers to Article 104, which is titled “Design of the Basic Solvency Capital Requirement” and states:

1. The Basic Solvency Capital Requirement shall comprise individual risk modules, which are aggregated in accordance with point (1) of Annex IV.

It shall consist of at least the following risk modules:

- (a) non-life underwriting risk;
- (b) life underwriting risk;
- (c) health underwriting risk;
- (d) market risk;
- (e) counterparty default risk.

2. For the purposes of points (a), (b) and (c) of paragraph 1, insurance or reinsurance operations shall be allocated to the underwriting risk module that best reflects the technical nature of the underlying risks.

3. The correlation coefficients for the aggregation of the risk modules referred to in paragraph 1, as well as the calibration of the capital requirements for each risk module, shall result in an overall Solvency Capital Requirement which complies with the principles set out in Article 101.

4. Each of the risk modules referred to in paragraph 1 shall be calibrated using a Value-at-Risk measure, with a 99,5 % confidence level, over a one-year period.

Where appropriate, diversification effects shall be taken into account in the design of each risk module.

²⁸⁸ <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32009L0138:EN:NOT>, accessed January 14, 2014.

5. The same design and specifications for the risk modules shall be used for all insurance and reinsurance undertakings, both with respect to the Basic Solvency Capital Requirement and to any simplified calculations as laid down in Article 109.

6. With regard to risks arising from catastrophes, geographical specifications may, where appropriate, be used for the calculation of the life, non-life and health underwriting risk modules.

7. Subject to approval by the supervisory authorities, insurance and reinsurance undertakings may, within the design of the standard formula, replace a subset of its parameters by parameters specific to the undertaking concerned when calculating the life, non-life and health underwriting risk modules.

Such parameters shall be calibrated on the basis of the internal data of the undertaking concerned, or of data which is directly relevant for the operations of that undertaking using standardised methods.

When granting supervisory approval, supervisory authorities shall verify the completeness, accuracy and appropriateness of the data used.²⁸⁹

The EIOPA publication titled *CEIOPS' Advice for Level 2 Implementing Measures on Solvency II: SCR standard formula – Article 111 (f) Operational Risk* (October 2009) contains details of the feedback received from industry on the proposals for the calculation of the operational risk capital charge as well as for the design and calibration of the operational risk module. This section of the research paper focuses on the formula for calculating the operational risk capital charge as reported in the EIOPA publication.

The operational risk capital charge (SCR_{op}) is driven by earned premiums and technical provisions (with a floor of zero), both gross of reinsurance. In this formula, technical provisions are exclusive of risk margin to avoid circularity issues. The factors are calibrated to meet Solvency II's requirement for a 99.5% VaR and a one-year time horizon. The SCR_{op} , which is determined as a function of the Solvency II basic solvency capital requirement (BCSR), is calculated as

$$SCR_{op} = \min\{BSCR_{cap} \cdot BSCR; Op_{In\ ul}\} + UL_f \cdot Exp_{ul}$$

where:

$BSCR_{cap}$ = 30% as per the Level 1 text Article 107;

$Op_{In\ ul}$ = basic operational risk charge for all business other than unit-linked business (gross of reinsurance);

UL_f = factor charge to be applied to the amount of annual expenses (gross of reinsurance) incurred in respect of unit-linked business; and

Exp_{ul} = amount of annual expenses (gross of reinsurance) incurred in respect of unit-linked business.

$Op_{In\ ul}$ is determined as

²⁸⁹ <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32009L0138:EN:NOT>, accessed January 15, 2014.

$$Op_{In\ ul} = \max (Op_{premiums}; Op_{provisions})$$

where:

$$Op_{premiums} = P_{life_f} * (Earn_{life} + Earn_{SLT\ Health} - Earn_{life-ul}) + P_{nl_f} * (Earn_{nl} + Earn_{non-SLT\ Health}) + \text{Max}(0, P_{life_f} * (\Delta Earn_{life} - \Delta Earn_{life-ul})) + \text{Max}(0, P_{nl_f} * \Delta Earn_{non-life});$$

$$Op_{provisions} = TP_{life_f} * (TP_{life} + TP_{SLT\ Health} - TP_{life-ul}) + TP_{nl_f} * (TP_{nl} + TP_{non-SLT\ Health}) + \text{Max}(0, P_{life_f} * (\Delta TP_{life} - \Delta TP_{life-ul})) + \text{Max}(0, P_{nl_f} * \Delta TP_{non-life});$$

P_{life_f} , P_{nl_f} , TP_{life_f} , P_{nl_f} = charge factors calibrated in accordance with Solvency II requirements;

$Earn_{life}$ = total earned life premium including unit-linked business;

$Earn_{SLT\ Health}$ = total earned premiums corresponding to health insurance that correspond to health SLT with a floor of zero;

$Earn_{life-ul}$ = total earned life premium for unit-linked business;

$Earn_{nl}$ = total earned non-life premium;

$Earn_{non-SLT\ Health}$ = total earned premiums corresponding to health insurance that correspond to health non-SLT;

Δ = change in earned premiums and technical provisions from year t-1 to t for earned premiums and technical provisions that have exceeded an increase of 10%; furthermore, no offset is allowed between life and non-life Δ ;

TP_{life} = total life insurance technical provisions including unit-linked business and life-life obligations on non-life contracts such as annuities;

$TP_{SLT\ Health}$ = technical provisions corresponding to health insurance that correspond to health SLT;

$TP_{life-ul}$ = total life insurance technical provisions for unit-linked business;

TP_{nl} = total non-life technical provisions (excluding life like obligations on non-life contracts such as annuities); and

$TP_{non-SLT\ Health}$ = technical provisions corresponding to health insurance that correspond to health non-SLT.

Operational Risk and Feedback from S2-QIS5

The EIOPA publication *EIOPA Report on the fifth Quantitative Impact Study (S2-QIS5) for Solvency II* (March 2011) reports on the feedback related to the latest proposals for calculating operational risk capital. As part of this publication, EIOPA states:

Very few comments were made with regard to operational risk. Nevertheless, the answers from participants have shown that most undertakings would opt for the standard formula

approach rather than to develop internal models for this specific risk. There may be different drivers for this trend such as the difficulties to develop such models (cost, complexity, timing), and this result needs to be viewed in light of the limited data available in [S2-QIS5] on internal models.

...

Qualitative feedback on operational risk was scarce and mainly focused on the method being too crude and not giving adequate incentives for good risk management practices. In this light it is surprising that most undertakings which plan to use partial internal models indicated an intention to use the standard formula methodology to assess their operational risk. Operational risk will often simply be added to the other risks without diversification, as in the standard formula. Groups also intended to use the standard formula for operational risk due to a lack of data and in the awareness that it lacks risk-sensitivity.²⁹⁰

System of Governance

As part of the system of governance, Solvency II requires a written policy on operational risks. Guideline 19 Operational risk management, the EIOPA Guidelines on the System of Governance is directed to local regulators, and also has direct application for insurers. It specifies that:

1.44. In accordance with Article 44 of Solvency II Directive, national competent authorities should ensure that in the risk management policy, the undertaking covers at least the following with regard to operational risk:

- a) identification of the operational risks it is or might be exposed to and assessment of the way to mitigate them;
- b) activities and internal processes for managing operational risks, including the IT system supporting them; and
- c) risk tolerance limits with respect to the undertaking's main operational risk areas.

1.45. In accordance with Article 44 of Solvency II Directive, national competent authorities should ensure that the undertaking has processes to identify, analyse and report on operational risk events. For this purpose, it should establish a process for collecting and monitoring operational risk events.

1.46. In accordance with Article 44 of Solvency II Directive, national competent authorities should ensure that for the purposes of operational risk management, the undertaking develops and analyses an appropriate set of operational risk scenarios based on at least the following approaches:

- a) the failure of a key process, personnel or system; and

²⁹⁰ EIOPA, "EIOPA Report on the fifth Quantitative Impact Study (QIS5) for Solvency II", 14 March 2011:71. http://eiopa.europa.eu/fileadmin/tx_dam/files/publications/reports/QIS5_Report_Final.pdf.

- b) the occurrence of external events.²⁹¹

Pre-Application Phase of Internal Operational Risk Models

The EIOPA publication *EIOPA Final Report on Public Consultations No. 13/011 on the Proposal for Guidelines on the Pre-application for Internal Models* (September 2013) specifies that information submitted to the national competent authorities as part of the pre-application process for the use of internal models in the determination of solvency capital requirements includes the operational risk category within the scope of the internal model. The guidelines specifically focus on documentation standards including requirements related to expert judgments, validation, probability distribution forecast, use test, model change processes, external models, and data (internal and external).

South Africa

Sources

This section of the research paper is based in large part on the following documents from the web site of the FSB:

- *Solvency Assessment and Management 2013 Update*, March 2013;
- *Internal Model Approval Process (IMAP) Guide* (April 2011, Version 1) (referred to as *IMAP Guide*) and *Internal Model Approval Process (IMAP) Contents of Application (CoA) Template*, August 2011, Version 1.0 (referred to as *IMAP CoA*); and
- *Solvency Assessment and Management – Third South African Quantitative Impact Study (SA QIS3) – Technical Specifications* (referred to as *SA QIS3 Technical Specifications*).

Background and General Introduction

The FSB and the South African insurance industry began work on the Solvency Assessment and Management (SAM) project in 2009. The objective was to develop a risk-based supervisory regime for the prudential regulation of all insurers operating in South Africa. Under the new regulatory framework, an insurer will be able to calculate its solvency capital requirement (SCR) using a standard formula, an internal model, or a combination of the two. The *IMAP Guide* comments that the approval of internal models for statutory purposes will be a phased-in approach; the *IMAP CoA* specifically requires an insurer to provide risk-specific evidence for the category of operational risk. In this research paper, the discussion of the South African proposed capital requirements focuses on the standard formula and not on internal models.

In the Introduction section of the *Solvency Assessment and Management 2013 Update*, the FSB reports:

²⁹¹ EIOPA, "Guidelines on System of Governance", EIOPA-CP-13/08, 2013: 10.
https://eiopa.europa.eu/fileadmin/tx_dam/files/publications/guidelines/System_of_Governance/Final_EN_SoG_Clean.pdf.

Significant progress has been made in this regard with more than 100 documents representing the SAM governance structure's view on various components of the SAM framework in various stages of production. For reference, a list of these documents is provided in Annexure 2.

In addition to the production of these documents, further significant work has been conducted, with two quantitative impact studies having been completed. A separate study gauging the readiness of insurers and groups to implement the Pillar II component of the SAM framework has also been conducted, with the report for this exercise expected to be published soon.²⁹²

As of February 2014, the FSB had undertaken three quantitative impact studies. Returns for the third South African Quantitative Impact Study (SA QIS3) are due to the FSB in April 2014. In *SA QIS3 Technical Specifications*, the FSB stated that the third quantitative impact study is important in moving from the development phase to the implementation phase of the project.

The regulatory requirements set out in the SAM Framework have been developed to be consistent with emerging solvency regulations in other countries, particularly Solvency II, as well as consideration of the IAIS' ICPs. The "Valuation" section of *SA QIS3 Technical Specifications* states:

The primary objective for valuation as set out in Article 75 of the Framework Solvency II Directive (Directive 2009/138/EC) requires an economic, market-consistent approach to the valuation of assets and liabilities. According to the risk-based approach of SAM, when valuing balance sheet items on an economic basis, insurers should consider the risks that arise from holding a balance sheet item, using assumptions that market participants would use in valuing the asset or the liability.

According to this approach, insurers and reinsurers value assets and liabilities as follows:

- a) Assets should be valued at the amount for which they could be exchanged between knowledgeable willing parties in an arm's length transaction;
- b) Liabilities should be valued at the amount for which they could be transferred, or settled, between knowledgeable willing parties in an arm's length transaction.

When valuing financial liabilities under point (b) no subsequent adjustment to take account of the change in own credit standing of the insurers or reinsurer should be made.

Valuation of all assets and liabilities, other than technical provisions should be carried out, unless otherwise stated in conformity with International Financial Report Standards (IFRS) as prescribed by the International Accounting Standards Board (IASB). They are therefore considered a suitable proxy to the extent they reflect the economic valuation principles of SAM.²⁹³

²⁹² FSB, "Solvency Assessment and Management 2013 Update", March 2013: 5.

<https://www.fsb.co.za/Departments/insurance/Documents/SAM%202013%20Update.pdf>.

²⁹³ FSB, "Solvency Assessment and Management – Third South African Quantitative Impact Study (SA QIS3) – Technical Specifications", page 8, accessed January 18, 2014,

<https://www.fsb.co.za/Departments/insurance/Documents/SA%20QIS3%20Technical%20Specifications.pdf>.

The SCR

The *SA QIS3 Technical Specifications* set out the requirements currently being evaluated for determining the SCR and defines the standard formula as

$$SCR = BCSR + Adj + SCR_{OP} + SCR_{Part}$$

where:

BCSR = basic solvency capital requirement;

SCR_{op} = capital requirement for operational risk;

Adj = adjustment for the risk absorbing effect of deferred taxes; and

SCR_{Part} = capital requirement for strategic participations.²⁹⁴

The BCSR combines capital requirements for market risk, life underwriting risks, and non-life underwriting risk.

With respect to calibration of the standard formula, the *SA QIS3 Technical Specifications* state:

The SCR should correspond to the Value-at-Risk of the basic own funds of an insurer or reinsurer subject to a confidence level of 99.5% over a one-year period. The parameters and assumptions used for the calculation of the SCR reflect this calibration objective.

To ensure that the different modules of the standard formula are calibrated in a consistent manner, this calibration objective applies to each individual risk module.

For the aggregation of the individual risk modules to an overall SCR, linear correlation techniques are applied. The setting of the correlation coefficients is intended to reflect potential dependencies in the tail of the distributions, as well as the stability of any correlation assumptions under stress conditions.²⁹⁵

Operational Risk and the SA QIS3²⁹⁶

Section SCR.4 of the *SA QIS3 Technical Specifications* addresses operational risk. In this section, the FSB states that the operational risk module is designed to address operational risks to the extent that such are not explicitly reflected in other risk modules. The formula considered in the third quantitative impact study is similar to that of Solvency II described previously in this research paper. Similar to the Solvency II formula, the premiums and technical provisions used in the calculations are on a gross basis (i.e., prior to cessions for reinsurance); furthermore, the technical provisions used in the calculations are exclusive of risk margin. The solvency capital requirement for operational risk (SCR_{op}) is calculated as

²⁹⁴ FSB, "Solvency Assessment and Management – Third South African Quantitative Impact Study (SA QIS3) – Technical Specifications", pp. 110-116, accessed January 18, 2014, <https://www.fsb.co.za/Departments/insurance/Documents/SA%20QIS3%20Technical%20Specifications.pdf>.

²⁹⁵ Ibid.: 112.

²⁹⁶ Ibid.: pp. 124-126.

$$SCR_{op} = \min\{0.3 \cdot BSCR; Op_1\} + 0.25 \cdot Exp_{ul}$$

where:

BSCR = basic SCR; and

Op_1 = basic operational risk charge for all business other than life insurance where the investment risk is borne by the policyholders.

Op is determined as

$$Op = \max (Op_{premiums}; Op_{provisions})$$

where:

$$Op_{premiums} = 0.04 \cdot (Earn_{life} + Earn_{SLT\ Health} - Earn_{life-ul}) + 0.03 \cdot Earn_{nl} + \text{Max}(0, 0.04 \cdot (Earn_{life} - 1.1 \cdot pEarn_{life} - (Earn_{life-ul} - 1.1 \cdot pEarn_{life-ul}))) + \text{Max}(0, 0.03 \cdot (Earn_{nl} - 1.1 \cdot pEarn_{nl}));$$

$$Op_{provisions} = 0.0045 \cdot \text{Max}(0, TP_{life} - TP_{life-ul}) + 0.03 \cdot \text{Max}(0, TP_{nl});$$

$Earn_{life}$ = earned premium during the previous 12 months for life insurance obligations;

$Earn_{life-ul}$ = earned premium during the previous 12 months for life insurance obligations where the investment risk is borne by the policyholders;

$Earn_{nl}$ = earned premium during the previous 12 months for non-life insurance obligations;

$pEarn_{life}$ = earned premium during the 12 months prior to the previous 12 months for life insurance obligations;

$pEarn_{life-ul}$ = earned premium during the 12 months prior to the previous 12 months for life insurance obligations where the investment risk is borne by the policyholders;

$pEarn_{nl}$ = earned premium during the 12 months prior to the previous 12 months for non-life insurance obligations;

TP_{life} = life insurance obligations;

$TP_{life-ul}$ = life insurance obligations where the investment risk is borne by the policyholders;

TP_{nl} = non-life insurance obligations; and

EXP_{ul} = Amount of annual expenses incurred during the previous 12 months in respect of life insurance where the investment risk is borne by the policyholders.

Switzerland and the Swiss Solvency Test

Sources

This section of the research paper is based in large part from the *Swiss Financial Market Supervisory Authority FINMA (FINMA) Circular 2008/44 SST (SST Circular)*.²⁹⁷

- *Insurance Supervision Act (ISA; SR 961.01)*;
- *Insurance Supervision Ordinance (ISO; SR 961.11)*; and
- *Circular 2008/44 SST - Swiss Solvency Test (SST)*, reference FINMA Circ. 08/44 “SST”, issue date of 28 November 2008 with date of entry into force 1 January 2009 (referred to as *SST Circular*).

Background and General Introduction

In accordance with the *Insurance Supervision Act (ISA; SR 961.01)* and the *Insurance Supervision Ordinance (ISO; SR 961.11)*, both of which were effective on January 1, 2006, the FINMA evaluates the solvency of insurance companies domiciled in Switzerland and their branches in accordance with the Swiss Solvency Test (SST). The *SST Circular* articulates the rules of both the *ISA* and the *SST*. The *SST Circular* states:

In the SST, insurance companies are to use a suitable risk model for determining the TC [target capital]. Either the standard model specified by FINMA or an internal model is to be used. An internal model is to be used whenever the standard model is not able to appropriately model all the relevant risks of an insurance company.

...

Groups and reinsurance companies must develop an internal model, save for individually approved exceptions.

Where the standard model is employed, the parameters used have to be adjusted by an insurance company where their correspondence to the insurance company’s specific risk situation is insufficient. The adjustments are to be documented. They are to be justified to FINMA in a comprehensible manner and will be approved by FINMA provided that they are appropriate.²⁹⁸

Key Attributes of the SST

Key attributes of the SST include:

- Market-consistent balance sheet – Insurers must determine and value all assets and liabilities in accordance with economic principles and in a market-consistent manner.

²⁹⁷ The SST Circular is dated November 28, 2008, with a date for entry into force of January 1, 2009, and last amendments dated June 1, 2012. <http://www.finma.ch/e/regulierung/Documents/finma-rs-2008-44-e.pdf>.

²⁹⁸ FINMA, “Circular 2008/44 SST – Swiss Solvency Test (SST)”, November 28, 2008: pp. 12 and 16. <https://www.finma.ch/e/regulierung/Documents/finma-rs-2008-44-e.pdf>.

- Specified risk categories – *The SST Circular* specifies the minimum risks that must be considered including insurance, market, and credit. Examples of insurance risks are specified for non-life, life, and health insurers. Parameter and random risk are required to be modeled.
- 99% confidence level risk measurement – The relevant measure of risk is formed by the expected shortfall of the change in the risk-bearing capital with a confidence level of 99% and a time horizon of one year.
- Annual scenario analysis – In addition to scenarios specified by FINMA, an insurer is required to define its own scenarios taking into account its own individual risk situation. The results of the scenario analysis are expected to be incorporated into the insurer's risk management framework.
- Inclusion of risk margin – The risk margin is defined as the cost of capital to cover the risk-bearing capital over the lifetime of insurance liabilities. According to the *SST Circular*, the purpose of the risk margin: "Pursuant to art. 42 sect. 4 ISO, the market-consistent value of the insurance liabilities is the result of adding the discounted best estimate and the risk margin."²⁹⁹ The TC is thus higher than the one-year risk capital by the amount of the risk margin.
- Annual reporting – Insurers must determine the target capital and risk-bearing capital at least once a year and report their findings to FINMA in a comprehensive SST report. Required contents for the SST Report are set out in the *SST Circular*.

Operational Risk and the SST

Operational risk is not a specified risk category in the SST. The *SST Circular* states:

To date insurance companies have captured and assessed operational risks on their own responsibility and periodically discussed the findings of this assessment with FINMA. At the current time, no quantitative consideration of operational risks is generally required in the SST unless an insurance company were to be expressly requested by FINMA to do this for serious reasons. Operational risks are to be appropriately taken into account in risk management. FINMA is currently looking into further developing the SST for the purpose of a systematic, quantitative assessment of operational risks.³⁰⁰

Operational risks are treated qualitatively in the Swiss Quality Assessment (SQA), which is comprised of two annual questionnaires – the Swiss Quality Assessment Corporate Governance Tool and the Swiss Quality Assessment Risk Management/Internal Control System Tool.³⁰¹ The Swiss Federal Office of Private Insurance (FOPI) describes the SQA as follows:

Together with the Swiss Solvency Test (SST), the Swiss Quality Assessment (SQA) constitutes a central element of the new insurance supervision regime, which was introduced on 1 January 2006 by the new Insurance Supervision Act (ISA). FOPI supplements these

²⁹⁹ FINMA, "Circular 2008/44 SST – Swiss Solvency Test (SST)", November 28, 2008: 11.

<https://www.finma.ch/e/regulierung/Documents/finma-rs-2008-44-e.pdf>.

³⁰⁰ *Ibid.*:15.

³⁰¹ H. Furrer, "Swiss Solvency Test – Where to from now?", *FINMA presentation documents*, February 28, 2012: 13.

http://www.ccfz.ch/files/prmia_furrer_hansjoerg_28_february_public.pdf.

modern supervision tools with traditional means of supervision, achieving an integrated, modern overall concept taking [taking] account of the challenges of the insurance industry and strengthening policyholder protection.

The main focus of qualitative insurance supervision is on corporate governance, risk management, and internal control. As a matter of principle, a qualitative evaluation without the active participation of the insurance undertakings is hardly feasible. The regulator therefore relies on inclusion of the undertakings and has chosen the method of self-assessment for this purpose.³⁰²

United States

Main Sources of Information

This section of the research paper is developed based primarily on the following NAIC sources:

- L. Felice and S. Hall, *The Increasing Importance of Sound Operational Risk Management*, CIPR Newsletter, NAIC & the Center for Insurance Policy and Research (CIPR), October 2013;
- S. Hall, *The use of Internal Models in U.S. Insurance Regulation*, CIPR Newsletter, NAIC and CIPR, October 2013;
- NAIC, *Risk-Based Capital General Overview*, July 15, 2009;
- NAIC and CIPR, *Own Risk and Solvency Assessment (ORSA)*, last updated May 2, 2014; and
- NAIC and CIPR, *Risk-Based Capital*, last updated May 14, 2014.

Background and General Introduction

The NAIC has utilized a risk-based capital (RBC) system since the early 1990s for U.S. insurers. The NAIC's *Risk-Based Capital General Overview* states:

The NAIC's RBC regime began in the early 1990s as an early warning system for U.S. insurance regulators. The adoption of the U.S. RBC regime was driven by a string of large-company insolvencies that occurred in late 1980s and early 1990s. The NAIC established a working group to look at the feasibility of developing a statutory risk-based capital requirement for insurers. The RBC regime was created to provide a capital adequacy standard that is related to risk, raises a safety net for insurers, is uniform among the states, and provides regulatory authority for timely action.

...

The Risk Based Capital Formula was developed as an additional tool to assist regulators in the financial analysis of insurance companies. The purpose of the formula is to establish a

³⁰² <http://www.finma.ch/archiv/bpv/e/themen/01345/index.html?lang=en>, accessed on February 10, 2014.

minimum capital requirement based on the types of risks to which a company is exposed. Separate RBC models have been developed for each of the primary insurance types: Life, Property/Casualty, Health and Fraternal. This reflects the differences in the economic environments facing these companies.³⁰³

In describing RBC, the NAIC states that it is intended to be a minimum regulatory capital standard and not necessarily the full amount of capital that an insurer would want to hold to meet its safety and competitive objectives. Furthermore, the NAIC comments that the RBC is not designed to be used as a stand-alone tool in determining financial solvency of an insurance company.³⁰⁴

Risks Considered in the RBC Calculations

Distinct RBC models apply to life insurers, P&C insurers, and health organizations. These models reflect the differences in risk and the unique economic environments that influence these different types of insurers. Common risks identified in the RBC models include:

- Asset risk – affiliates;
- Asset risk – other (including credit risk, interest rate risk, and market risk);
- Underwriting risk or insurance risk; and
- Business risk.

Internal Models

With respect to the use of internal models for the regulation of U.S. insurers, the NAIC states:

In contrast to the banking industry, state insurance regulators have adopted a cautious and targeted approach to the use of internal models and are taking steps to introduce internal models incrementally, while maintaining a number of controls as they are introduced. The NAIC first introduced models more than 20 years ago in its risk-based capital (RBC) regime. The NAIC RBC regime limits the use of modeling to specific products and risk models within an otherwise standardized approach. Partial models are limited currently to life and annuity products with guarantees subject to interest rate or market fluctuation risk.

Models are also used for cash flow testing, stress and scenario testing, and, in the future, RBC for catastrophe risk will use internal models.³⁰⁵

³⁰³ NAIC, "Risk-Based Capital", last updated August 26, 2014.

http://www.naic.org/cipr_topics/topic_risk_based_capital.htm, accessed October 28, 2014.

³⁰⁴ NAIC, "Risk-Based Capital", last updated May 14, 2014. http://www.naic.org/cipr_topics/topic_risk_based_capital.htm, accessed June 25, 2014.

³⁰⁵ S. Hall, "The Use of Internal Models in U.S. Insurance Regulation", NAIC & the Center for Insurance Policy and Research, October 2013: 23. http://www.naic.org/cipr_newsletter_archive/vol9_internal_models.pdf.

Recognition of Operational Risk in U.S. Insurance Regulation

ORSA

In 2008, the NAIC launched the Solvency Modernization Initiative (SMI) with the intent to critically examine and update the existing U.S. supervisory framework for insurers. Key areas of focus for the SMI include capital requirements as well as governance and risk management. The NAIC has concluded that RBC will continue to form the backstop function for insurer solvency but that additional capital assessments evaluating prospective solvency will be required; these additions will be included in ORSA.

The NAIC describes ORSA as follows:

In essence, an ORSA is an internal process undertaken by an insurer or insurance group to assess the adequacy of its risk management and current and prospective solvency positions under normal and severe stress scenarios. An ORSA will require insurers to analyze all reasonably foreseeable and relevant material risks (i.e., underwriting, credit, market, operational, liquidity risks, etc.) that could have an impact on an insurer's ability to meet its policyholder obligations.³⁰⁶

The ORSA concept is embedded in the IAIS' ICPs and is in various stages of implementation in the U.S., Europe, and other jurisdictions. In the U.S., large- and medium-size insurers will be required to regularly conduct an ORSA starting in 2015.

The NAIC *ORSA Guidance Manual*, last updated March 2013, has no explicit guidance for the consideration of operational risk. Nonetheless, operational risk is specifically listed as an example of material risks that requires assessment by the insurer; other specified risks include credit, market, liquidity, and underwriting.

RBC Formula

In October 2013, the NAIC reported the following on the topic of incorporating recognition of operational risk within the RBC formula:

State insurance regulators, working together through the NAIC, have been looking at whether and how best to incorporate internal and external aspects of operational risk more explicitly into the risk-based capital (RBC) formulas. In 2013, the Capital Adequacy (E) Task Force turned its attention to operational risk. The Task Force's Solvency Modernization RBC (E) Subgroup, Chaired by Alan Seeley of New Mexico's Office of the Superintendent of Insurance, has been charged as follows: "Evaluate options for developing an operational risk charge in each of the RBC formulas and provide a recommendation to the Capital Adequacy (E) Task Force as to treatment of operational risk in the RBC formulas."

...

³⁰⁶ "Own Risk and Solvency Assessment (ORSA)", NAIC & the Center for Insurance Policy and Research, last updated August 19, 2014. http://www.naic.org/cipr_topics/topic_own_risk_solvency_assessment.htm.

The Subgroup's short-term goals include: identifying appropriate risk exposure proxies; developing a simple factor-based capital requirement within the RBC formulas as early as 2014; and starting a process for identifying how and where the current RBC formulas could address operational risk. In the long run (three to five years to implementation), the Subgroup plans to follow and provide input into further development and use of an operational risk database and other potential qualitative aspects that could lead to a more risk-sensitive RBC approach.³⁰⁷

Other Countries

Sources

This section of the research paper is based on the following two reports:

- J. Corrigan and P. Luraschi, *Operational risk modelling framework*, Milliman Research Report, February 13, 2013;
- KPMG, *Evolving Insurance Regulation – A new dawn*, March 2013; and
- Dr. M. McHugh, *Introduction of a new risk-based capital framework in Singapore – Convergence or divergence in relation to Solvency II?*, Munich Re, December 2013.

The first two reports include summaries of existing regulatory requirements for insurers in major jurisdictions around the world. The final report is focused on the latest proposals for a risk-based capital framework for insurers in Singapore.

Brazil

The insurance regulatory authority in Brazil is the Superintendence of Private Insurance (SUSEP), SUSEP is “responsible for the supervision and control of the insurance, open private pension funds and capitalization markets in Brazil.”³⁰⁸ SUSEP has been engaged in the modernization of its supervisory and regulatory procedures with the aim of compatibility with international standards. Originally, SUSEP had decided not to implement Solvency II as a framework. It was, however, implementing the rules and directives required to manage each risk category individually. It is understood that this decision was due to the level of maturity of market players and to the investment constraints that could arise in a framework implementation approach, particularly for smaller insurers. SUSEP has already issued directives relative to insurance risk, credit risk and market risk management. Operational risk management has also been extensively discussed in the market place and surrounding regulation was expected in 2013.

In late January 2014, SUSEP applied to the EIOPA for Solvency II equivalence for its insurance solvency regime. As of March 2014, negotiations were taking place between the EIOPA and SUSEP regarding an

³⁰⁷ L. Felice and S. Hall, “The Increasing Importance of Sound Operational Risk Management”, *NAIC & the Center for Insurance Policy and Research*, October 2013: 5.

http://www.naic.org/cipr_newsletter_archive/vol9_op_risk_management.pdf.

³⁰⁸ <http://www.susep.gov.br/english-susep/index>, accessed January 19, 2014.

agreement to evaluate the degree of compliance of Brazil's insurance regulatory framework with the upcoming Solvency II rules.

Japan

For life insurers, Japan's statutory solvency requirement includes a capital charge for operational risk that is recognized through the management-related risk capital (MRC). The MRC is calculated as

$$\text{MRC} = (R1 + R2 + R3 + R7 + R8) \times (\text{Risk Factor})$$

where:

R1 = risk capital for insurance risk;

R2 = risk capital for interest-crediting risk capital;

R3 = risk capital for asset risk;

R7 = risk capital for products with minimum guarantee benefits;

R8 = risk capital for insurance risk relating to third-sector products; and

Risk factor = 3% in cases where profit for the year is a negative value and 2% in cases where profit for the year is a positive value or zero.

China, Hong Kong, and Taiwan

Corrigan and Luraschi report that China and Hong Kong do not have specific capital charges for operational risk. Taiwan's risk-based capital regime does specify an operational risk capital charge (C4) that is calculated as

$$C4 = x\% \text{ of premium income} + 0.25\% \text{ of assets under management}$$

where:

x = 0.5% for life business, 1% for annuity business, and 1.5% for all other business.

Korea

In Korea, risk-based capital (RBC) was implemented in April 2011, after going through a transition stage where insurers could choose to apply the previous Solvency Margin approach until March 2011. Under the current RBC regime, a standard model is used to measure capital for insurance, market, interest, credit, and operational risks.

In order to differentiate and manage risk at a company-specific level, the implementation of an internal economic capital model has recently been encouraged by the regulators. Regulators have been proactively developing qualification standards for internal models and publishing the related manuals for its approval process, while a task force representing major insurers in Korea has also been formed to coordinate with its development.

Russia

The last jurisdiction Corrigan and Luraschi report on is Russia. They state:

No detailed requirements on operational risk are available in Russia. However, operational risk management frameworks do exist, which state that operational risk should be controlled by the company's headquarters. This control should include the collection of loss data, the testing of operational systems (at least every six months), and the use of operational risk transfer to third parties if required. Contrary to usual practice, legal risk is considered separately from operational risk (along with strategic and reputational risk).³⁰⁹

Singapore

In 2012 the Monetary Authority of Singapore (MAS) released its first Consultation Paper on Risk-Based Capital 2 (RBC 2), which aims to enhance the comprehensiveness of the risk coverage and risk sensitivity of the current framework. The proposals include the explicit assessment of additional risks including operational risk, a calibration of the regime to a 99.5% level of sufficiency over a one-year time horizon and two solvency intervention levels, which overall aligns with emerging international practice. The plan was for the RBC 2 standards to be implemented by the end of 2013, with a two-year parallel run transition with the existing framework.

The following discussion of the MAS' proposed treatment of operational risk is based on a December 2013 Munich Re publication titled *Introduction of a new risk-based capital framework in Singapore – Convergence or divergence in relation to Solvency II?*, authored by McHugh.

In Singapore, the capital required is derived based on the calculation of the total risk requirements (TRR) as prescribed by the standardised approach. Within the standardised approach, capital requirements for each specified risk category is currently determined by applying a factor-based approach.

McHugh summarized the current MAS proposals for operational risk and the associated criticisms as follows:

The capital requirement for operational risk is quantified as 4% (0.25% for unit-linked business) of the higher of the past three years' averages of a) earned premium income and b) gross policy liabilities. However, this value is restricted to a maximum of 10% of an insurer's TRR. (Proposal 3)

The criticism regarding the proposed formula is twofold:

First, as the quantification of the operational risk charge is volume-based, an increase of premiums due to a price increase will lead to a higher capital requirement. The existence and extent of risk controls, however, is not taken into account. Second, the formula does not distinguish between different lines of business. SAS [Singapore Actuarial Society] argues that differences in product design could lead to differences in operational risk.

³⁰⁹ J. Corrigan and P. Luraschi, "Operational risk modelling framework", *Milliman Research Report*, February 13, 2013: 63, <http://www.milliman.com/uploadedFiles/insight/life-published/operational-risk-modelling-framework.pdf>.

A comparison with Solvency II reveals that at least the first part of the criticism applies to the European regulatory system as well. Similar to RBC 2, the capital charge for operational risk under Solvency II is the higher of a) premium-based and b) provision-based requirements. However, there are two major differences to RBC 2. First, while premium-based requirements within RBC 2 are solely dependent on premiums, the European regime also accounts for growth figures above a threshold level of 20%. Second, unlike RBC 2, the provision-based component distinguishes between two lines of business by applying a risk charge on non-life provisions that is almost seven times the charge on life business. As such, the second part of the above-mentioned criticism is not valid for Solvency II.³¹⁰

³¹⁰Dr. M. McHugh, "Introduction of a new risk-based capital framework in Singapore – Convergence of divergence in relation to Solvency II?", *Munich Re*, December 2013: 3. http://www.munichre.com/site/corporate/get/documents_E-2113795143/mr/assetpool.shared/Documents/5_Touch/Publications/302-08131_en.pdf.

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APPENDIX A – BASEL II MAPPING OF BUSINESS LINES

Level 1	Level 2	Activity Groups
Corporate Finance	Corporate Finance	Mergers and acquisitions, underwriting, privatisations, securitisation, research, debt (government, high yield), equity, syndications, IPO, secondary private placements
	Municipal/Government Finance	
	Merchant Banking	
	Advisory Services	
Trading & Sales	Sales	Fixed income, equity, foreign exchanges, commodities, credit, funding, own position securities, lending and repos, brokerage, debt, prime brokerage
	Market Making	
	Proprietary Positions	
	Treasury	
Retail Banking	Retail Banking	Retail lending and deposits, banking services, trust and estates
	Private Banking	Private lending and deposits, banking services, trust and estates, investment advice
	Card Services	Merchant/commercial/corporate cards, private labels and retail
Commercial Banking	Commercial Banking	Project finance, real estate, export finance, trade finance, factoring, leasing, lending, guarantees, bills of exchange
Payment and Settlement ³¹¹	External Clients	Payments and collections, funds transfer, clearing and settlement
Agency Services	Custody	Escrow, depository receipts, securities lending (customers) corporate actions
	Corporate Agency	Issuer and paying agents
	Corporate Trust	

³¹¹ Payment and settlement losses related to a bank's own activities would be incorporated in the loss experience of the affected business line.

Level 1	Level 2	Activity Groups
Asset Management	Discretionary Fund Management	Pooled, segregated, retail, institutional, closed, open, private equity
	Non-Discretionary Fund Management	Pooled, segregated, retail, institutional, closed, open
Retail Brokerage	Retail Brokerage	Execution and full service

Principles for business line mapping³¹²

- a) All activities must be mapped into the eight level 1 business lines in a mutually exclusive and jointly exhaustive manner.
- b) Any banking or non-banking activity which cannot be readily mapped into the business line framework, but which represents an ancillary function to an activity included in the framework, must be allocated to the business line it supports. If more than one business line is supported through the ancillary activity, an objective mapping criteria must be used.
- c) When mapping gross income, if an activity cannot be mapped into a particular business line then the business line yielding the highest charge must be used. The same business line equally applies to any associated ancillary activity.

³¹² Supplementary business line mapping guidance

There are a variety of valid approaches that banks can use to map their activities to the eight business lines, provided the approach used meets the business line mapping principles. Nevertheless, the Committee is aware that some banks would welcome further guidance. The following is therefore an example of one possible approach that could be used by a bank to map its gross income:

Gross income for retail banking consists of net interest income on loans and advances to retail customers and SMEs treated as retail, plus fees related to traditional retail activities, net income from swaps and derivatives held to hedge the retail banking book, and income on purchased retail receivables. To calculate net interest income for retail banking, a bank takes the interest earned on its loans and advances to retail customers less the weighted average cost of funding of the loans (from whatever source – retail or other deposits).

Similarly, gross income for commercial banking consists of the net interest income on loans and advances to corporate (plus SMEs treated as corporate), interbank and sovereign customers and income on purchased corporate receivables, plus fees related to traditional commercial banking activities including commitments, guarantees, bills of exchange, net income (e.g. from coupons and dividends) on securities held in the banking book, and profits/losses on swaps and derivatives held to hedge the commercial banking book. Again, the calculation of net interest income is based on interest earned on loans and advances to corporate, interbank and sovereign customers less the weighted average cost of funding for these loans (from whatever source).

For trading and sales, gross income consists of profits/losses on instruments held for trading purposes (i.e. in the mark-to-market book), net of funding cost, plus fees from wholesale broking.

For the other five business lines, gross income consists primarily of the net fees/commissions earned in each of these businesses. Payment and settlement consists of fees to cover provision of payment/settlement facilities for wholesale counterparties. Asset management is management of assets on behalf of others.

- d) Banks may use internal pricing methods to allocate gross income between business lines provided that total gross income for the bank (as would be recorded under the Basic Indicator Approach) still equals the sum of gross income for the eight business lines.
- e) The mapping of activities into business lines for operational risk capital purposes must be consistent with the definitions of business lines used for regulatory capital calculations in other risk categories, i.e. credit and market risk. Any deviations from this principle must be clearly motivated and documented.
- f) The mapping process used must be clearly documented. In particular, written business line definitions must be clear and detailed enough to allow third parties to replicate the business line mapping. Documentation must, among other things, clearly motivate any exceptions or overrides and be kept on record.
- g) Processes must be in place to define the mapping of any new activities or products.
- h) Senior management is responsible for the mapping policy (which is subject to the approval by the board of directors).
- i) The mapping process to business lines must be subject to independent review.

APPENDIX B – BASEL II DETAILED LOSS EVENT TYPE CLASSIFICATION

Event-Type Category (Level 1)	Definition	Categories (Level 2)	Activity Examples (Level 3)
Internal Fraud	Losses due to acts of a type intended to defraud, misappropriate property or circumvent regulations, the law or company policy, excluding diversity/discrimination events, which involves at least one internal party	Unauthorised Activity	Transactions not reported (intentional) Transaction type unauthorised (w/monetary loss) Mismatching of position (intentional)
		Theft and Fraud	Fraud / credit fraud / worthless deposits Theft / extortion / embezzlement / robbery Misappropriation of assets Malicious destruction of assets Forgery Check kiting Smuggling Account take-over / impersonation / etc. Tax non-compliance / evasion (wilful) Bribes / kickbacks Insider trading (not on firm's account)
External Fraud	Losses due to acts of a type intended to defraud, misappropriate property or circumvent the law, by a third party	Theft Fraud	Theft/Robbery Forgery Check kiting
		Systems Security	Hacking damage Theft of information (w/monetary loss)

Event-Type Category (Level 1)	Definition	Categories (Level 2)	Activity Examples (Level 3)
Employment Practices and Workplace Safety	Losses arising from acts inconsistent with employment, health or safety laws or agreements, from payment of personal injury claims, or from diversity / discrimination events.	Employee Relations	Compensation, benefit, termination issues Organised labour activity
		Safe Environment	General liability (slip and fall, etc.) Employee health & safety rules events Workers compensation
		Diversity & Discrimination	All discrimination types
Clients, Products & Business Practices	Losses arising from an unintentional or negligent failure to meet a professional obligation to specific clients (including fiduciary and suitability requirements), or from the nature or design of a product.	Suitability, Disclosure & Fiduciary	Fiduciary breaches / guideline violations Suitability / disclosure issues (KYC, etc.) Retail customer disclosure violations Breach of privacy Aggressive sales Account churning Misuse of confidential information Lender liability
		Improper Business or Market Practices	Antitrust Improper trade / market practices Market manipulation Insider trading (on firm's account) Unlicensed activity Money laundering
		Product Flaws	Product defects (unauthorised, etc.) Model errors
		Selection, Sponsorship & Exposure	Failure to investigate client per guidelines Exceeding client exposure limits
		Advisory Activities	Disputes over performance of advisory activities
Damage to Physical Assets	Losses arising from loss or damage to physical assets from natural disaster or other events.	Disasters and other events	Natural disaster losses Human losses from external sources (terrorism, vandalism)

Event-Type Category (Level 1)	Definition	Categories (Level 2)	Activity Examples (Level 3)
Business disruption and system failures	Losses arising from disruption of business or system failures	Systems	Hardware Software Telecommunications Utility outage / disruptions
Execution, Delivery & Process Management	Losses from failed transaction processing or process management, from relations with trade counterparties and vendors	Transaction Capture, Execution & Maintenance	Miscommunication Data entry, maintenance or loading error Missed deadline or responsibility Model / system misoperation Accounting error / entity attribution error Other task misperformance Delivery failure Collateral management failure Reference Data Maintenance
		Monitoring and Reporting	Failed mandatory reporting obligation Inaccurate external report (loss incurred)
		Customer Intake and Documentation	Client permissions / disclaimers missing Legal documents missing / incomplete
		Customer / Client Account Management	Unapproved access given to accounts Incorrect client records (loss incurred) Negligent loss or damage of client assets
		Trade Counterparties	Non-client counterparty misperformance Misc. non-client counterparty disputes
		Vendors & Suppliers	Outsourcing Vendor disputes

APPENDIX C – BERMUDA CLASSIFICATION FOR INSURERS

The following is from the BMA website licensing page.³¹³

Bermuda has a multi-license system of regulation which categorises general insurance companies into six classes, long-term insurance companies into five classes, a class for Special Purpose Insurers and provides for composite companies.

CLASS 1:

A single-parent captive insurance company underwriting only the risks of the owners of the insurance company and affiliates of the owners.

Class 1 insurers are required to maintain minimum capital and surplus of \$120,000.

CLASS 2:

Multi-owner captives which are defined as insurance companies owned by unrelated entities, provided that the captive underwrites only the risks of the owners and affiliates of the owners and/or risks related to or arising out of the business or operations of the owners and affiliates.

A Class 2 license will also apply to single-parent and multi-owner captives writing no more than 20 percent of net premiums from risks which are not related to, or arising out of, the business or operations of their owners and affiliates.

Class 2 insurers are required to maintain minimum capital and surplus of \$250,000.

CLASS 3:

Applies to insurers and reinsurers not included in Class 1, 2, 3A, 3B, or 4. This includes structured reinsurers' writing third party business; insurers writing direct policies with third party individuals; single-parent, group, association, agency or joint venture captives where more than 20 percent of net premiums written is from risks which are unrelated to the business of the owners.

Captive Insurers underwriting more than 20% and less than 50% unrelated business.

Class 3 insurers are required to maintain minimum capital and surplus of \$1 million.

CLASS 3A:

Small commercial insurers whose percentage of unrelated business represents 50% or more of net premiums written or net loss and loss expense provisions and where the unrelated business net premiums are less than \$50 million.

Class 3A insurers are required to maintain minimum capital and surplus of \$1 million.

³¹³ <http://www.bma.bm/insurance/licensing/SitePages/Home.aspx>, accessed January 10, 2014.

CLASS 3B:

Large commercial insurers whose percentage of unrelated business represents 50% or more of net premiums written or net loss and loss expense provisions and where the unrelated business net premiums are more than \$50 million.

Class 3B insurers are required to maintain capital and surplus of \$1 million.

CLASS 4:

Insurers and reinsurers underwriting direct excess liability insurance and/or property catastrophe reinsurance risks.

Class 4 insurers are required to maintain minimum capital and surplus of \$100 million.

SPECIAL PURPOSE INSURERS:

In order for a company to receive consideration for registration as an SPI, it would have to meet the following criteria:

- The insurer is carrying on insurance business in the area of insurance-linked securitisations;
- The insurer is established to enter into a single transaction or a single set of transactions;
- The insurer's obligations are fully collateralised; and
- Transactions are carried out with a limited number of sophisticated participants.

LONG-TERM - CLASS A:

A single-parent long-term captive insurance company underwriting only the long-term business risks of the owners of the insurance company and affiliates of the owners.

Class A insurers are required to maintain minimum capital and surplus of \$120,000.

LONG-TERM - CLASS B:

Multi-owner long-term captives which are defined as long-term insurance companies owned by unrelated entities, provided that the captive underwrites only the long-term business risks of the owners and affiliates of the owners and/or risks related to or arising out of the business or operations of their owners and affiliates.

A Class B license will also apply to single-parent and multi-owner long-term captives writing no more than 20 percent of net premiums from risks which are not related to, or arising out of, the business or operations of their owners and affiliates.

Class B insurers are required to maintain minimum capital and surplus of \$250,000.

LONG-TERM - CLASS C:

Long-term insurers and reinsurers with total assets of less than \$250 million; and not registrable as a Class A or Class B insurer.

Class C insurers are required to maintain minimum capital and surplus of \$500,000.

LONG-TERM - CLASS D:

Long-term insurers and reinsurers with total assets of \$250 million or more, but less than \$500 million; and not registrable as a Class A or Class B insurer.

Class D insurers are required to maintain minimum capital and surplus of \$4,000,000.

LONG-TERM - CLASS E:

Long-term insurers and reinsurers with total assets of more than \$500 million; and not registrable as a Class A or Class B insurer.