Zeszyty Naukowe Uniwersytet Ekonomiczny w Krakowie
Ekonomia
920
ISSN 1898-6447
Zesz. Nauk. UEK, 2013; 920: 83–100

Michał Thlon
Department of Theory of Economics
Cracow University of Economics

A Comparative Analysis of Quantitative Operational Risk Measurement Methods

Abstract

The number of well-known firms joining the list of entities such as Enron, WorldCom, Sumitomo Corp., all of which lost millions of dollars as a result of inadequate operational risk management systems, increases dramatically with each passing year. This has increased the amount of interest in this marginalised aspect of risk. The quantitative estimation and measurement of operational risk proved necessary with the implementation of new operational risk management strategies in companies and financial institutions. Basel Committee on Banking Supervision recommendations, which request banks to use quantitative methods in their operational risk management are an additional motivation to use quantitative methods of estimating operational risk. This article reviews the most important quantitative methods of estimating and measuring operational risk.

Keywords: operational risk, measurement methods, Basel Committee on Banking Supervision, Key Risk Indicators.

1. Introduction – Definition of Operational Risk

The main goals of this paper are to review the most important quantitative methods of operational risk measurement and to analyse the advantages and disadvantages of each of the measurement techniques. The paper's three parts first define the categories of operational risk, next present the most popular methods of estimating operational risk and, lastly, introduce the advantages and disadvantages of each measurement technique before adding final conclusions.

Each company in the market is exposed to various kinds of risk – from market risk to credit risk to a variety of operational risks. Managing such risk has largely been handled as a common-sense kind of thing – an important issue, yes, but not one of utmost importance. The multi-million dollar losses companies have suffered as a result of misconceptions in operational risk management (see Table 1) have finally changed that perception in recent years. While there is no single, unified definition of operational risk, it encompasses those risks that come from the low level of knowledge and responsibility possessed by managers, the quality and consistency of documentation, the transparency and practical results of operational procedures, fraud, legal regulations and many other factors.

The Basel Committee on Banking Supervision defines operational risk as all "the risk of direct or indirect loss resulting from inadequate or failed internal processes, people and systems or from external events" (Bank for International Settlements 2002, p. 2). This definition includes legal risk. However, strategic and reputational risk are not included in this definition for the purpose of a minimum regulatory operational risk capital charge. Operational risk is not directly relevant to the market fluctuations or solvency of partners or customers. The Group of Thirty Global Derivatives Study Group Report defines operational risk in a similar way: "operational risk is a risk of losses resulting from faulty systems, insufficient control, human errors or wrong management" (Kendall 2000, p. 119).

The following categories of risk factors can be distinguished:

1) processes – a category of losses suffered as a result of errors in accepted procedures, an insufficient number, or complete lack of existing procedures. Loss incurred as a result of this category is not due to intentional activities, but more human errors or conduct that is inconsistent with obligatory procedures;

2) people – this category encompasses losses incurred as a result of intentional or unintentional behaviour, of former or present employees, that is detrimental to the employer (Bourque 2003, p. 5);

3) systems – losses suffered as a result of telecommunication and/or information technology damage and/or software damage. Losses of this type are not a result of intentional activities (Harmantzis 2004, p. 3);

4) external events – losses incurred as a result of external factors, including natural disasters (flood, earthquake etc.) or third-party activities (acts of vandalism, the results of riots, and the like).

The above definitions cover all common risk areas, including fraud (inadequate systems and insufficient control), regulation risk (faulty systems and management), and other kinds of risk, from directly harmful natural disasters to administrative misconceptions resulting from personnel being inadequately qualified.

Table 1. Extent of Losses Carried as a Result of Operational Risk

Company	Extent of losses	Date	Causes
Société Générale	US$ 6,615 million	2007–2008	unauthorised trading activities
Allfirst	US$ 691 million	1999–2002	inadequate control, fraud
Princeton Economics International and Republic Securities	US$ 700 million	1995–1999	fraud and custodian conspiracy
Barings Bank	US$ 1,600 million	1993–1995	inadequate control of futures trading, poor segregation of duties
LTCM	US$ 2,500 million	1996–1998	excessive leverage, model risk
Sumitomo Corp.	US$ 2,200 million	1986–1996	unauthorised copper trading, fraud, and forgery

Source: adapted on the basis of (Heffernan 2007), www.erisk.com.

I have provided a broad definition of operational risk, comprising various aspects – from the possibility of losses arising from employee crime to an insufficient return rate on capital caused by withdrawing from some investments at the wrong time. This definition sees the sources of risk in the institution itself, and its ability or lack thereof, to react to various threats which continuously arise from both outside and within the company or institution itself. The multifarious nature of operational risk explains why modeling it is so complex.

2. Classifying the Quantitative Methods Used to Estimate Operational Risk

Due to the complexity of operational risk and huge losses resulting from bad operational risk management, the importance of estimating and measuring this risk is ever growing. Because operational risk issues are still rather new in risk management science, they are as yet dominated by qualitative measurement methods, which are based upon the assessment of exposition to risk done by experts estimating various threat parameters. These comprise descriptive methods, heuristic techniques and risk mapping techniques[1]. However, as economic reality proves, these methods are an inadequate tool for modelling operational risk. Qualitative measurement methods may only be used to complete the results of quantitative risk measurement methods.

Quantitative methods, on the other hand, enable the estimation of risk levels using processed numerical data. Where measuring the exposition to operational

[1] For a more detailed description, see: (Orzeł 2005a, pp. 4–9).

risk is concerned, the numerical data will comprise the information on the real results of past losses as well as the potential results and losses caused by events that can be foreseen.

The quantitative methods used in operational risk management fall into three categories:

1) risk measurement methods recommended by the Basel Committee:
– Basic Indicator Approach – BIA,
– Standardised Approach – SA,
– Advanced Measurement Approach – AMA;

2) statistical methods:
– Value at Risk,
– Monte Carlo simulation,
– scenario analysis,
– Extreme Values Theory,
– Bayes Belief Networks;

3) other quantitative methods:
– comparative analysis methods,
– operational studies methods,
– Six Sigma methods.

Methods recommended by the Basel Committee in the New Capital Accord refer to the ways of calculating the regulation capital for operational risk. The Basel Committee comprises three basic methods[2]:
– Basic Indicator Approach – BIA,
– Standardised Approach – STA – and Alternative Standardised Approach,
– Advanced Measurement Approach – AMA.

Basic Indicator Approach. With the Basic Indicator Approach, the capital charge should be derived as a fixed multiple (alpha) of some aggregate activity measure – gross income[3]. Under the BIA, the capital requirement for operational risk is 15% of the indicator defined as the relevant indicator, which is the average over three years of the sum of net interest income and net non-interest income. The three-year average is calculated on the basis of the last three twelve monthly observations at the end of the financial year (Fend, Zwizlo & Lutz 2006, p. 99). The formula for calculating the capital requirement under the BIA is:

---

[2] The three main approaches are defined in (Bank for International Settlements 2005, pp. 140–152).

[3] Gross income (GI) is defined as net interest income plus net non-interest income. This measure should: be gross of any provisions, be gross of operating expenses including fees paid to outsourcing service providers, exclude realised profits/losses from the sale of securities in the banking book, and exclude extraordinary or irregular items as well as income derived from insurance.

$$K_{\mathrm{BIA}} = \alpha \cdot EI$$

where:

K_{BIA} is the bank's capital requirement for operational risk under BIA,

α is the capital factor (15%),

EI is the exposure indicator – the sum of net interest income and net non--interest income.

Standardised Approach. A more precise methodology, called the Standardised Approach, uses different factors for each business line and calculates operational risk capital as the sum of each factor (beta) times the gross revenue of each business line (see Table 2).

Table 2. Business Lines with Assigned Different Beta Factors

Business Line	β
Corporate finance	18%
Trading and sales	
Payment and settlement	
Commercial banking	15%
Agency services	
Retail brokerage	12%
Retail banking	
Asset management	

Source: adapted on the basis of (Bank for International Settlements 2004, p. 140).

The capital requirement for operational risk is calculated using the following formula:

$$K_{\mathrm{STA}} = \sum_{i=1}^{8} K_{\mathrm{STA},i} = \sum_{i=1}^{8} \beta_i \cdot EI_i,$$

where:

K_{STA} is the capital requirement of the institution under the Standardised Approach,

$\sum_{i=1}^{8} K_{\mathrm{STA},i}$ is the sum of capital requirements in the individual business lines,

$\sum_{i=1}^{8} \beta_i \cdot EI_i$ is the sum of the products of net interest income and net non-interest income for the individual business lines and the beta factors assigned to them.

Alternative Standardised Approach. The Alternative Standardised Approach is a special variant of the Standardised Approach. Its use by a credit institution needs to be authorised by the supervisory authorities. The capital requirement is calculated as follows. The competent authorities may authorise the credit institution to use an alternative indicator for the business lines of retail banking and commercial banking. For these business lines, the relevant alternative indicator is a normalised volume indicator equal to the three-year average of the total nominal loan volume multiplied by 0.035 (Komisja Nadzoru Bankowego 2007, p. 106).

The BIA and the STA with the Alternative STA represent the „top down" approach; here the capital is set at the level of the whole financial institution. Using a system of simple keys, it is then accredited to particular business lines. In these methods the gross financial outcome is the measure that reflects the exposition to operational risk.

Advanced Measurement Approach (AMA). The Basel documentation covers the criteria that must be met for banks to use the AMA framework for operational risk capital allocation[4]. The fundamental quantitative requirement for an AMA operational risk measurement system is that it must have the following elements: internal data, external data, scenario analysis and business environment and internal control factors.

There is a range of internal approaches currently under development, which may be broadly categorised as follows:

– Internal Measurement Approach (IMA). In IMA application, institutions build an operational risk matrix with 56 cells including eight predefined business lines in Standardised Approach by seven operational risk factors proposed by the Committee (see Table 3). For each business line/risk type combination, regulators define an exposure indicator (EI). Banks then use internal data to define the probability of a loss event (PE) per unit of the exposure indicator, and the expected loss given such an event (LGE). Expected losses (EL) by business line and risk type are the product of these three components. Regulators supply a fixed multiplier (gamma) to translate these expected losses into a capital charge, i.e., Value-at-Risk figure for unexpected losses.

---

[4] Among other things: the bank's internal operational risk measurement system shall be closely integrated into its day-to-day risk management processes. The bank must have an independent risk management function for operational risk. There must be regular reporting of operational risk exposures and loss experience. The institution shall have procedures for taking appropriate corrective action. The risk management system must be well documented and the institution shall have routines in place for ensuring compliance and policies for the treatment of non-compliance. The operational risk management systems shall be subject to regular reviews performed by internal and/or external auditors. The validation of the operational risk measurement system by the competent authorities shall include these two elements: 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. More detailed: (Fend, Zwizlo & Lutz 2006, p. 105).

Table 3. Operational Risk Matrix under IMA

Business Line (j)	Risk Factor (i)						
	Internal Fraud	External Fraud	Employment Practices and Workplace Safety	Clients, Products & Business Practices	Damage to Physical Assets	Business Disruption and System Failures	Execution Delivery & Process Management
Corporate finance							
Trading and sales							
Payment and settlement							
Commercial banking							
Agency services							
Retail brokerage							
Retail banking							
Asset management							

Source: adapted on the basis of (Rizkallah 2006, p. 12).

– Loss Distribution Approach (LDA) involves the estimation of two distributions based on internal loss data. One distribution is the loss associated with a single event and the other is the frequency of loss events over a given (usually one year) time horizon. LDA calculates (for each business line and risk type) separately the probability distribution function of the severity and the probability distribution function of the one-year event frequency. Both calculations make use of the loss data. Using these distributions, the banks can compute the probability distribution function of the aggregate operational loss. The total capital to be allocated is the addition of VaR with 99.9% level of confidence across risk types and business lines of this aggregated distribution. In this approach, banks estimate the operational risk separately for each of some eight business lines and seven event types, which can be expressed in a matrix (see Table 3).

– Scorecard approaches use forward-looking risk indicators, built into scorecards, to measure relative levels of risk. In order to qualify for the AMA, the approach must have a sound quantitative basis (Harmantzis 2004, p. 4). Scorecards will aim to determine the causes of operational risk within individual units, focus management attention on those and enable the banks to improve their internal processes, which in the long run enable them to reduce their capital charge. Typical scorecard models are based on expert opinions (of process owners) on operational losses expected for a future period. Each process owner evaluates the likely risks, expected losses, and possible causal factors (Key Risk Indicators, KRI[5]) of the losses. They will try to cover both the severity of risk faced by a business line, and the likelihood of a risk event occurring within different business lines. In other words they make it possible to convert the qualitative scorings of risk (frequency and impact) into quantitative amounts by sanitising and assigning parameters to the scorings (see Table 4).

Table 4. An Example Scale of Frequency and Severity Estimation

Severity		
Level	Descriptor	Examples
5	Catastrophic	– Financial –over $500m lost per occurrence of the risk – Operation – no output for greater than 10 working days
4	Major	– Financial – between $100m and $500m lost per occurrence of the risk – Operation – no output for between 2 and 10 working days
3	Moderate	– Financial – between $10m and $100m lost per occurrence of the risk – Operation – no output for between 1 and 2 working days
2	Minor	– Financial – between $1m and $10m lost per occurrence of the risk – Service / operation – no output for between 30 mins and 1 working day
1	Insignificant	– Financial – up to $1m lost per occurrence of the risk – Operation – no output for up to 30 mins
Frequency / probability		
5	Almost certain probability ≈ 80%	– Is expected to occur in most circumstances (occurring at least once a day, 1 day to 29 days
4	Likely probability ≈ 70%	– Will probably occur in most circumstances (occurring at least once a month), 1 month to 12 months
3	Possible probability ≈ 50%	– Might occur at some time (occurring at least once a year), 1 year to 5 years
2	Unlikely probability ≈ 30%	– Could occur at some time (occurring at least once every 5 years), 5 years to 10 years
1	Rare probability ≈ 10%	– May occur only in exceptional circumstances (occurring at least once every 10 years), 10 years +

Source: adapted on the basis of (Fusca & Ripon 2005).

[5] For a more detailed look, see (Davies *et al*. 2006).

Whereas Advanced Measurement method AMA is a „bottom up" methodology example, where the risk is analysed on each process level and the results are then aggregated for particular business lines and the whole organisation. In this method the regulation capital calculation is the result of using inner operational risk measurement models based upon qualitative and quantitative criteria. The key aspect of this method is constructing a database capable of collecting information on the operational losses of the institution. If the loss breakdown achieved this way is not sufficient for credible calculations, it can be completed by outside data and the scenario analysis method. This method consists of setting several potential scenarios and using quantitative methods to calculate the magnitude of operational risk for each of them. The final, credible collection of losses becomes the basis for creating a model that will make it possible to determine the capital required to cover the operational risk with a certain level of confidence.

Basel Committee recommendations based upon the operational capital indices are an additional factor intensifying the work being done on effective operational risk quantitative measurement methods.

Methods based upon the statistical models are a much larger group of operational risk estimation methods. This group consists of the following methods:

– Value at Risk – in the case of operational risk, it is the Operational VaR,
– Monte Carlo simulation,
– scenario analysis,
– Extreme Value Theory,
– Bayesian Belief Networks.

VaR methods. Value at Risk-based methodology enables the level of risk to be estimated using statistical and simulation models for asset fluctuations and also allows one to measure the largest expected loss that the company can suffer at a given time and confidence level and in regular market conditions. The concept of operational risk management based upon the standard VaR methods is called Operational Value at Risk (OpVaR) methodology. The basis for operational risk modelling in the OpVaR technique is based on an organisation creating its own operational database (including all events that influence system efficiency and accessibility, and bring about potential losses). This database, using statistical methods modified for the purpose of estimating the exposition to operational risk, allows the highest potential loss to be estimated providing conditions as per the standard VaR described above. However, due to the nature of complex operational risk, as well as the conditions set out in VaR methodology, operational risk modelling using this method may not be precise enough[6].

[6] For a more detailed description, see: (Chernobai *et al*. 2005).

Monte Carlo methods. Monte Carlo simulation methods (MC) are methods based upon mathematical problem solving through the random generation of numbers. Operational risk modelling using these techniques goes through four stages. Firstly, data on the frequency of single losses, depending on the event type and line of business line, have to be collected (for example, the frequency of losses resulting from system failure in "retail banking"). The second stage defines risk factors as random variables using the empirical data collected in the first stage. In the same stage their mutual relations and probability distribution has to be defined. For each combination of event type and business line we set the frequency distribution of this event happening and its influence on the size of losses. Then, using the set distributions, we do the simulation of the number of events in a given amount of time. Afterwards, *n*-times we sample from the distribution function of the influence of the given event on the amount of losses and we sum up the resulting financial flows. We repeat this simulation until the expected accuracy is reached. The number of simulations needed varies from a few hundred to over ten thousand. The same actions have to be taken with regard to each event and business line combination. The aggregated loss distribution is thus determined, from which the standard deviation can be estimated with reference to expected, unexpected and catastrophic losses. The most important issue in the operational risk modelling process with the MC method is defining the distributions that correctly describe the frequency of events and their influence on the loss size. This problem is called model risk (Marszal 2001).

This risk consists of two basic parts. The first is finding the right density function, and the second is correctly estimating the parameters of this function. An additional problem that appears here is choosing between modelling the frequency of events causing operational losses and modelling the time between those events. Using the frequency is reasonable when the events take place often (eg. a few times a week) and when this frequency is stable over a longer period of time. When the events take place infrequently (eg. a few times a year) and cause huge losses, the quantity of empirical data is insufficient. It therefore becomes impossible to determine the frequency of events precisely as it changes with time. In such cases it is better to concentrate on modelling the time between the events.

Once the distribution of the frequency of events or the time between them has been determined, the last stage is to simulate the influence of the event on the loss size. Also in this case it is possible to adjust the theoretical probability distributions. A great advantage of using MC method to estimate operational risk is that it is possible to create an automatic prognosis of the complete distribution (distribution function of losses and profits) and not just the number that occur, as is the case with VaR methodology (Orzeł 2005b).

Scenario analysis. Comparative methods using the emergency scenario analysis methodology in operational risk estimation are different from those described above. The purpose of scenario analysis is not to estimate the probability of huge operational losses occurring, but to test the organisation in view of its survival and further activities should losses occur. In the scenario analysis method, three kinds of scenarios are analysed – the optimistic, the probable and the pessimistic. Scenario analysis method is particularly useful in analyses of operational risk on the derivative instruments market. It requires that an assumption be made on the frequency of events and the values of losses they would bring about. The losses that would be possible in a given time are then calculated (Mori, Hiwatashi & Ide 2000). There is insufficient historical data on the frequency of operational risk and attendant losses on the derivative instruments market. The particular usefulness of scenario analysis may be seen in setting the pessimistic scenario so as to define the maximum losses on a given transaction. In short, scenario analysis method is a way to estimate extreme results and irregular events that are detrimental to the organisation, and the scale of both.

EVT methods[7]. Extreme value is one that is significantly different from the average. Using this method to estimate operational risk requires the loss distributions caused by the operational risk to be set at the maximum level that may result from the occurrence of a given event. The extreme value distributions may be described together as the risk level. In an approach based upon the extreme values theory, observations forming the end of the distribution may be approximated by generalised Pareto and Poisson distributions, which are used to generate loss distributions above the given level of values and estimate the level of operational risk.

Bayesian Belief Networks. These methods enable the modelling of operational risk using "Bayes networks". A Bayes network is used to represent, according to probability calculus, the relations (of a probabilistic nature) between events. A Bayes net represents, in a compressed way, the joint probability distribution of the parts of the net. This allows one to draw any kind of conclusion about the value of the parts. Another advantage of these networks is that they may be used to graphically present data and illustrate the multilateral reactions between the sources of uncertainty. The Bayes net concept grew directly out of the concept of conditional probability. In an economy, and especially in the analysis of how companies function, the occurrence of one event is strictly dependent on another.

[7] For a more detailed description, see: (Thlon 2011).

Using a net makes it possible to avoid highly complicated calculations[8]. Calculating one probability a posteriori is linked with the earlier calculation of probabilities. Setting those probabilities enables the estimation of the risk of a given event occurring. If the risk exceeds an acceptable level, the occurrence may be prevented from occurring. Thanks to its graphic structure, a net can be easily created or modified by an expert, who can apply his or her highly specialised knowledge in a simple format (Coleman 2002, p. 11).

What differentiates the Bayes net method from other analysis methods is the variety of possible means of drawing conclusions it provides. Concentrating on the graphical net structure only, we can discover conditional relations of the variables, while in considering the parametrical models assigned to the knots, we find the most probable of the available variables' configurations. The basic concept is this: the Bayes network, built on empirical data in a compressed way, represents the joint distribution of the probability attributes. And the joint distribution is enough to be able to draw any number of conclusions on the probability of attributes. Thus, a reply to any question may be achieved through setting – with the use of the net – the total probability distribution and using it to make the appropriate calculations.

In the Bayes approach, the distribution of the parameters of probability is a way of presenting subjective knowledge with regard to its possible values. The Bayes approach solves the problem of the lack of data by considering the distribution of losses in the so-called "fat tails". This approach combines the qualitative, quantitative, outside data and Key Risk Indicators. Generally speaking, the use of Bayes networks allows for the integration of various information sources and for their effective use in the operational risk management process. For example, consider the simple Bayesian Belief Networks shown in Figure 1.

Other quantitative methods of operational risk measurement are of lesser importance in economic reality than the ones described above; however their role is still too important to exclude them here. There are three groups of these methods:

– comparative analysis methods,
– operational research methods,
– Six Sigma methods.

---

[8] For the X denoting the observed data (on operational losses) and θ representing the model's parameters and missing data, Bayesian inference requires an estimate of the cumulative probability distribution $p(X, \theta)$ for every event, according to these formulas:

$$p(X, \theta) = p(X \mid \theta)p(\theta)$$

$$p(\theta, X) = \frac{p(\theta)p(X \mid \theta)}{\int p(\theta)p(X \mid \theta)d\theta}$$

For a more detailed description, see: (Cruz 2002, p. 177).

Staff Training	
Level 1	0.3
Level 2	0.2
Level 3	0.5

No of Benefits Paid (Volume)	
Low	0.3
Medium	0.6
High	0.1

Number of Erroneous Benefit Payments										
Training	Level 1			Level 2			Level 3			Marginal Probability
Volume	Low	Medium	High	Low	Medium	High	Low	Medium	High	
Low	0.85	0.75	0.65	0.9	0.85	0.7	0.95	0.9	0.85	0.85
Medium	0.15	0.20	0.25	0.1	0.15	0.25	0.05	0.1	0.1	0.10
High	0	0.05	0.1	0	0	0.05	0	0	0.05	0.05

Exposure (S) – Median Benefit	
< 50,000	0.85
50,000–100,000	0.1
>100,000	0.05

Yearly Loss Due to Erroneous Benefit Payment										
Delay	Low			Medium			High			Marginal Probability
Exposure (s)	< 50,000	50,000–100,000	>100,000	< 50,000	50,000–100,000	>100,000	< 50,000	50,000–100,000	>100,000	
<100,000	0.9	0.85	0.80	0.85	0.75	0.65	0.65	0.55	0.40	0.8611
100,000–300,000	0.1	0.10	0.15	0.10	0.20	0.25	0.20	0.25	0.45	0.1015
300,000–500,000	0	0.05	0.05	0.05	0.05	0.09	0.15	0.19	0.11	0.0372
500,000–1,000,000	0	0	0	0	0	0.01	0	0.01	0.04	0.0002

Fig. 1. Example of Bayesian Network

Source: adapted on the basis of (Ganegoda 2008, p. 17).

Comparative analysis methods. Comparative analysis methods are based on the benchmarking concept in its broad meaning. Benchmarking means comparing processes and practices used in the companies considered to be the best in a given field. The results of such analysis become the basis for improving business processes. The core issue in benchmarking is discovering the factors that make the process effective and then finding similar possibilities in one's own company. This is a process of learning and adapting the best practices. Typical phases in benchmarking include: choosing the issues to be compared, preparing an analysis plan and choosing data collection methods, choosing companies to compare, data collection, data comparison, analysis, preparation of recommendations, change implementation planning, implementing the changes, and repeating the process after the changes have been implemented[9].

Operational research methods. Operational research methods are based on the analysis of targeted actions – operations. These studies are an objective decision assessment with the use of mathematical models. The mathematical models are built with the use of probability theory, game theory and other techniques. This is to enable the determination of risk levels and subsequent use of that information when taking decisions or moving to execute a plan.

Risk modelling with the use of operational research has four stages:

– Mathematical model preparation – determine the target of an action, extract the factors determining the possibility of achieving the target and determining the variability range.

– Model solving – finding the optimal decision depending on the analytical shape of the model created.

– Verification of the model and solution – analysis of the solution should be done in view of the practicability and stability of the solution.

– Model implementation.

The importance of this methodology should not be overestimated in operational risk estimations; however, risk models created with the use of operational studies method can be very efficient in supporting the operational risk management process.

Six Sigma methods. Six Sigma methods are techniques aimed at limiting the number of errors and failures afflicting the organisation, in order to allow the organisation to impress its customers to the greatest extent possible. The "sigma" stands for the deviation from the perfect work; each of the indicated sigma levels further reduces the number of errors.

Six Sigma enables the objective measurements that are useful in justifying technology-aimed investments. It also makes it possible to determine the real value of a given technology very precisely and to generate that value more efficiently. The core part of the methodology is the team-choosing process, the determination of the measurements important for the company, the choice of people responsible for given tasks and the setting of the mechanisms that enable the results and progress to be monitored[10]. The Six Sigma method evaluates a problem in five stages: define, measure, analyse, improve and control (DMAIC). Each stage has its own tools – histograms, Pareto graphs, and dissolution graphs. Six Sigma not

[9] For a more detailed description, see: (Nagelmackers 2008, pp. 108–116).

[10] For a more detailed description, see: (Larson 2003).

only helps to make the organisation more efficient and cost-effective but also helps make the systems do more for the customers of the organisation.

Table 5. The Main Advantages and Disadvantages of Chosen Quantitative Methods of Operational Risk Measurement

Method	Advantages	Disadvantages
VaR	– synthetic indicator allowing one to check on actual risk exposition – applied on many levels of the activity, to begin from the measurement of single transaction risk, across each process until enterprise-wide risks are addressed – used to measure various risks, allowing for the aggregation of threats from different areas – addresses the correlation among each of the risks	– the assumption that losses connected with a definite kind of risk follow nicely a Gaussian distribution although it is generally appreciated that this assumption is often wrong; the problem of fat tails of empirical distributions
BNN	– allows management to dynamically observe the changes to the loss distribution with respect to changes in the business and control environment	– has a supplementary character and cannot replace the traditional methods of measuring risk
BIA	– the simple method agreeable with requirements of the regulator – may be adapted easily and immediately by banks or financial institutions: there are no qualitative quantifying criteria	– operates on the assumption that higher income can only be achieved by accepting higher operational risks
SA	– there is no need to collect operational loss data – differentiation between business lines is a suitable step to raise risk sensitivity in calculating the capital requirement for operational risks	– the results of SA are not connected directly to loss data – the operational risk profile varies from one event to another even in the same business line – the indicator of net interest income and net non-interest income only reflects the business volume in each business line but not the level of operational risk – potential diversification effects between business lines are not taken into account by adding up the capital amounts
AMA	– reduces operational risk capital charges – insurance: mitigation of charges when events are insured is only permitted under AMA – suited for large, efficient banks, and those operating internationally	– a complicated, time-consuming, capital-intensive method demanding the fulfillment of numerous requirements

Table 5 cnt'd

Method	Advantages	Disadvantages
EVT	– can be used to quantify risk due to rare events – is a generally accepted method used to measure extremums – well-founded theory based on Fisher--Tippet	– has little effect on the average loss or loss volatility – does not account for losses below the threshold
MC	– the MC simulation makes it possible to mathematically quantify the composition of the frequency and severity loss distributions	– the classic MC method based on the assumption of Gaussian distribution
6 Sigma	– improves supervision systems – mitigates losses – improves quality of business process	– the method has a supplementary character and cannot replace traditional risk measurement methods
Comparative analysis	– the method makes possible creative adapting of best practices	– using this method often requires that a new strategy and innovative procedures be initiated – this is far beyond the initiation of improvements in single processes
Scenario analysis	– enables the supplementation of the loss event database	– the method has a supplementary character and cannot replace traditional risk measurement methods
Operational research	– efficiently supports the process of operational risk management	– is rarely in effect used as independent method of the risk valuation

Source: own work.

3. Conclusions

Use of the quantitative methodology to estimate a company's exposure to operational risk requires the company to keep a database on operational losses. However, because of the operational risk characteristics, insufficient empirical data may exist in that area. Information must therefore be obtained from institutions outside the company. Such information, especially when modified, may be very effective in completing the database with data on the probability of certain threats occurring. Still, a full picture of operational risk may only be achieved by using the qualitative-quantitative approach where quantitative estimation methods are completed by the qualitative methodology using experts' evaluations, experience, intuition and knowledge. Implementation of the modern, integrated systems of measurement and analysis of the operational risk in companies requires increasing – and often still introducing – the systematic approach to data forecasting.

Bibliography

Bank for International Settlements (2002), *Operational Risk Supporting Documentation to the New Basel Capital Accord*, Basel Committee on Banking Supervision, Basel.

Bank for International Settlements (2004), *International Convergence of Capital Measurement and Capital Standards*, Basel Committee on Banking Supervision, Basel, June.

Bank for International Settlements (2005), *Basel II: International Convergence of Capital Measurement and Capital Standards: A Revised Framework*, Basel Committee on Banking Supervision, Basel, November, http://www.bis.org/publ/bcbs118.htm.

Bourque W. (2003), *Buy Side Operational Risk*, Conference Society of Actuaries Conference Investment Risk: The Operational Side, Montreal.

Chernobai A. *et al*. (2005), *Estimation of Operational Value-at-Risk in the Presence of Minimum Collection Thresholds*, Technical Report, University of California, Santa Barbara.

Coleman R. (2002), *Modelling Extremes*, Seoul National University, Statistical Research Center for Complex Systems, International Statistical Workshop, 19–20 June.

Cruz M. (2002), *Modeling, Measuring and Hedging Operational Risk*, John Wiley & Sons, Chichester.

Davies J. *et al*. (2006), *Key Risk Indicators – Their Role in Operational Risk Management and Measurement,* RiskBusiness International, February.

Edhec European Asset Management Practices Survey (2003), http://www.edhec-risk.com/features/RISKArticle1055435618526472492/attachments/Edhec_European_Asset_Management_Practices_Survey.pdf.

Fend W., Zwizlo R., Lutz J. (2006), *Guidelines on Operational Risk,* Oesterreichische Nationalbank, Vienna, August.

Fusca A., Ripon O. (2005), *Operational Risk*, Non-Executive Directors Seminar, 18 October.

Ganegoda A. (2008), *Methods to Measure Operational Risk in the Superannuation Industry*, Working Paper, http://wwwdocs.fce.unsw.edu.au/fce/Research/Research Microsites/ CPS/2008/papers/Ganegoda.pdf.

Harmantzis F. (2004), *Operational Risk Management in Financial Services and the New Basel Accord*, http://papers.ssrn.com/sol3/papers.cfm?abstract_id=579321.

Heffernan S. (2007), *Nowoczesna bankowość*, PWN, Warszawa 2007.

Kendall R. (2000), *Zarządzanie ryzykiem dla menadżerów,* Liber, Warszawa.

Komisja Nadzoru Bankowego (2007), *Obliczanie wymogu kapitałowego z tytułu ryzyka operacyjnego*, Appendix No. 14 to the Resolution No. 1/2007 from 13 March.

Larson A. (2003), *Demystifying Six Sigma: A Company-Wide Approach to Continuous Improvement*, Amacom, New York.

Marszal C. (2001), *Measuring and Managing Operational Risk in Financial Institutions*, John Wiley & Sons, Singapore.

Mori T., Hiwatashi J., Ide K. (2000), *Measuring Operational Risk in Japanese Major Banks*, Bank of Japan, Financial and Payment System Office, Working Paper, July.

Nagelmackers O. (2008), *Benchmarking Operational Risk*, "Journal of Financial Transformation", No. 3, Capco Institute.

Orzeł J. (2005a), *Ilościowe metody pomiaru ryzyka operacyjnego*, "Bank i Kredyt", No. 7.

Orzeł J. (2005b), *Rola metod heurystycznych, w tym grupowej oceny ekspertów, oraz prawdopodobieństwa subiektywnego w zarządzaniu ryzykiem operacyjnym*, "Bank i Kredyt", No 5.
Rizkallah A. (2006), *Operational Risk. A Realistic Framework*, Banque Libano-Française, January.
Thlon M. (2011), *Wykorzystanie teorii wartości ekstremalnych (EVT) w procesie pomiaru ryzyka operacyjnego* [in:] *Osiągnięcia i perspektywy modelowania i prognozowania zjawisk społeczno-gospodarczych*, ed. B. Pawełek, Wydawnictwo Uniwersytetu Ekonomicznego w Krakowie, Kraków.

Analiza porównawcza ilościowych metod pomiaru ryzyka operacyjnego

Z każdym rokiem zwiększa się liczba renomowanych firm na liście takich podmiotów jak Enron, WorldCom, Sumitomo Corp., które straciły miliony dolarów w rezultacie błędnych systemów zarządzania ryzykiem operacyjnym. W rezultacie rośnie zainteresowanie tym dotychczas marginalizowanym rodzajem ryzyka. Ilościowe szacowanie i pomiar tego rodzaju ryzyka muszą iść w parze z wdrożeniem nowych strategii zarządzania ryzykiem operacyjnym zarówno w odniesieniu do przedsiębiorstw, jak i instytucji finansowych. Dodatkowym czynnikiem, który sprawia, że rośnie zainteresowanie ryzykiem operacyjnym, są naciski ze strony regulatorów rynku, m.in. rekomendacje Bazylejskiego Komitetu ds. Nadzoru Bankowego nakładające na banki obowiązek szacowania ryzyka operacyjnego z wykorzystaniem metod ilościowych. Niniejszy artykuł zawiera przegląd najważniejszych ilościowych metod szacowania i pomiaru ryzyka operacyjnego.

Słowa kluczowe: ryzyko operacyjne, metody pomiaru, Bazylejski Komitet ds. Nadzoru Bankowego, kluczowe wskaźniki ryzyka.