OPERATIONAL RISK ESTIMATION USING THE VALUE-AT-RISK (VAR) METHOD: CASE STUDY OF THE EXTERNAL BANK OF ALGERIA (EBA)

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ABSTRACT

This study aims to shed light on the application of the value-at-risk (VaR) method to estimate operational risks at the level of the External Bank of Algeria (EBA), by taking a comprehensive view of operational risks and studying how to assess them using value at risk, and then trying to apply the latter at the level of the External Bank of Algeria to two events using two different approaches (Monte Carlo and the scheduling process). This was based on the case study approach with the use of the interview as a tool for data collection, and the use of Excel to analyze it. Through this study, it became clear that it is possible to determine the maximum loss that the Algerian External Bank could be exposed to - due to operational risks - for the coming year at different levels of confidence, as well as to determine the capital requirements necessary to cover it, taking into account several requirements to ensure its proper application, foremost of which is the provision of a comprehensive and accurate database, sophisticated and specialized programs and qualified human cadres, all this to create greater flexibility in dealing with volatile risks in the modern business environment.

Keywords*:* operational risk, value at risk, risk assessment, capital requirements.

JEL Classification: G32, C69, G59

INTRODUCTION

Financial institutions have long clarified the obvious fact that “reputation is everything”, especially in businesses dealing with intangibles that require public and customer trust (Riel, 2004, p. 52), such as banking, the loss of reputation can lead to catastrophic consequences such as the devastating loss of Arthur Andersen's reputation in the wake of the Enron scandal, despite this recognition, operational risk modeling is still in its infancy as financial institutions have been rather slow to absorb operational risk measurement and management tools to protect their capital (Power, 2007).

Value-at-risk (VaR) is one of the most advanced methods for measuring operational risk, by estimating the maximum potential losses that risk exposure can generate at a certain area of confidence, and accordingly, the capital requirements necessary to cover those risks are determined (Jorion, 2007).

OpVaR, according to its varying approaches, has succeeded in finding its place within any risk management system, but it is considered somewhat limited and superficial because of the qualitative nature of this risk, as it depends more on the autonomy of its users, and despite its limitations, OpVaR is always the first step towards defining a quantitative model for operational risk (Power, 2006).

Problematic: The application of the VaR method to measure operational risks is a contract and difficult to apply on the ground because it requires the availability of a long series of intensive and complex data, and therefore the problem of the study can be crystallized in the following question:

Can the value at risk(VaR) method be applied to estimate the maximum operational risk at the level of the Algerian External bank (EBA) ?

This problem includes a set of sub-questions:

- How can operational risk be estimated using the value-at-risk method ?
- How can the minimum regulatory capital needed to cover operational risk be determined using the value-at-risk method ?

Study Hypotheses

In light of the problematic issue, the main hypothesis of this study can be formulated as follows:

The proper application of the value-at-risk method to estimate the operational risks in the Algerian External bank requires the existence of some basic requirements that are not available in the bank under study.

Under this hypothesis, several partial hypotheses are included as follows:

- The nature of operational risk statements makes it more difficult to estimate the value at risk to them.
- The application of the value-at-risk method is useful in providing accurate estimates of the capital requirements required to cover the risk.

Study Objective

The main objective of this study is to clarify how to measure operational risk using the value-at-risk method with two different approaches (Monte Carlo and the scheduling process), and how this can be used to calculate the minimum organizational capital necessary to cover operational risk.

The importance of the study: The importance of this study stems from the vitality and novelty of its topic related to estimating the value exposed to operational risks, and its importance lies in the fact that the latter provides a cumulative measure of risk, as it gives one number that expresses the maximum loss that can be tolerated, this number can be translated into the solvency of the bank, which may lead to increased transparency and harmony in dealing with this type of risk.

The study approach: In line with the nature of the research, in order to study and address the problem at hand and prove the validity or error of the hypotheses, two basic approaches were adopted: the descriptive approach to build the theoretical background of the subject, by highlighting the various concepts related to operational risks and the stages of estimating the value exposed to operational risks, and the case study approach by trying to project the theoretical aspect on the field of study by estimating the value exposed to operational risks at the External Bank of Algeria.

LITERATURE REVIEW

- A study, Ja'nel Esterhuysen, Paul Styger, Gary van Vuuren (2008), entitled: "Calculating operational value-at-risk (OpVaR) in a retail bank", an article in Sajems: This study aims to clarify how to calculate the value at operational risk and how this can be used to calculate the minimum organizational capital for operational risk under the AMA approach of the Basel Committee. A distinction has also been made between economic and organizational capital, as well as clarifying how OpVaR models can be used to calculate both types of capital. This study has also been illustrated by the example of differences in organizational capital when using the AMA and the SA standard approach, as it concluded that economic capital converges with organizational capital using the AMA standard approach, unlike the SA standard approach.

- The study of Haid Marwan, Melwah Mariam, (2019) entitled: "Operational Risks in Insurance Companies: Their Databases and Quantitative Measurement Models According to Solvency Requirements 2", published in the Journal of Economics and Development: This study aimed to know the characteristics of operational risk databases in insurance companies and study the most important quantitative models used to calculate them based on Basel II requirements, by addressing the most important concepts related to operational risks at the level of insurance companies, and how to estimate their operational risks using the value-at-risk model, starting with analyzing the data collection process and determining both intensity and frequency distributions, leading to determining the amount of value at-risk OpVaR based on the distribution of the total losses obtained.

This study found that the main reason for the use of databases in insurance companies is the problem of the lack of internal data for the financial analysis of operational risks, and the inability of quantitative methods, specifically the OpVaR method , to measure operational risk levels with a high degree of accuracy and control.

Structure of the Study

To answer the problem at hand, this study was divided into three axes as follows:

- The first axis: Introduction to operational risks.
- The second axis: Estimating operational risks using value at risk.
- The third axis: Applying the value-at-risk method in the Algerian foreing bank.

INTRODUCTION TO OPERATIONAL RISK

Concept of Operational Risk

There is not a single consensus on the definition of operational risk yet, as some define it by identifying what it involves such as risks arising from human error, fraud, process failure, technological breakdown, and external factors (e.g. lawsuits, fire risk, natural disasters, customer dissatisfaction, loss of reputation, etc.). (Wong C.Y., 2013).

There is a set of divergent definitions that must be mentioned before reaching general definitions:

- Value at Risk (VaR) is a statistical technique used to measure the risk of loss on a portfolio. It estimates the maximum potential loss over a given time period within a certain confidence level (Pearson, 2019).
- VaR quantifies the worst expected loss over a target horizon at a given confidence level. It is commonly used in finance for risk management and regulatory purposes.
- VaR represents the maximum loss that will not be exceeded with a specific probability during a specified time period, often used in the assessment of market risk (Dowd, 2005).

Kingsley et al., defines it as “the risk of loss resulting from failures in operational processes or the systems that support them, including those that adversely affect reputation, and the legal execution of contracts and claims.” This definition includes both strategic and business risks, that is, operational risks arise from the disruption of people, processes and systems within the organization. Strategic and commercial risks arise outside the company and stem from external causes such as political unrest, changes in organizational or government policy, changes in the tax system, mergers and acquisitions, changes in market conditions, etc. (Linda, Jacob, & Anthony, 2004). As for the Basel II Committee, it defined it as "the risk of EBAring losses resulting from the inefficiency or failure of internal processes, the human element, systems and external events" (Supervision, 2004, p. 664).

This definition includes legal risks but excludes strategic risks, reputational risks and regulatory risks ((BIS), 2006). Maintaining capital to face losses arising from operational risks is an essential part and not an option.

Types of Operational Risks

According to the Basel Committee, operational risks are divided into the following types: (salah, 2007).

Implementation and Management of Operations

These are losses resulting from the wrong processing of operations, customer accounts, the bank's daily operations, weaknesses in control and internal audit systems, and failure to carry out transactions (Chapelle, 2018).

Human Element

Losses caused by employees (intentionally or unintentionally), as well as acts that aim to cheat or misuse property or circumvent the law, regulations or company policy by officials or employees, as well as losses arising from the relationship with customers, shareholders, regulators and any third party (Ron S. Kenett, 2010).

Automated Systems and Communications

Losses arising from the disruption of work or failure of systems due to infrastructure, information technology, or non-availability of systems, and any malfunction or malfunction of systems (Thirlwell, 2010).

Events Related to the External Environment

Losses arising from the work of a third party, including external fraud and any damage to property and assets, and losses as a result of a change in laws that affects the bank's ability to continue working (Girling, 2013).

OPERATIONAL RISK MANAGEMENT USING VALUE AT RISK

The Basel Committee recognized the need to cover operational risks and not only rely on improving performance at the level of banks, but also to allocate part of the private funds to cover them (HUSEYNLI, 2022), which is known as capital adequacy (Michel Crouhy, 2013). In accordance with the second agreement, the Basel Committee has developed three approaches to calculate the capital necessary to cover operational risks, among which banks can choose: the basic indicator input, the standard input, and the advanced measurement input ((BCBS), 2006).

The advanced measurement approach in calculating the capital requirement to meet operational risks is based on advanced internal models in the bank (Mammadov, 2020), by measuring the amount of exposure to these risks through the internal measurement system used, and approved by the Banking Supervision Authority.

According to this method, the Bank relies on its statistical data based on its previous qualitative experience (such as regular reports, periodic review, ...) and quantity **(**validity of the measurement method, detailed data on internal and external losses, dates of their occurrence, and the region or country in which the losses occurred,...), then it depends on statistical modeling, after measuring the magnitude of these risks using one of the models (Babayev, 2016) , the special funds necessary to cover them are determined (Jan Lubbe, 2010). There are several methods that fall within the framework of the advanced measurement approach: the Internal Measure Approach, the Loss Distribution Approach and the Scorecards method. (mesdaa, 2017)**.**

The Concept of Operational Value Exposure (OpVaR)

A common way to model operational risk is to use an actuarial approach that expresses the amount of maximum loss expected over a time horizon typically estimated at one year and at a specified confidence level, this loss figure is called Operational Value at Risk (OpVaR). (Wong C.Y., 2013).

Stages of Operational Risk Assessment Using Value at Risk

The process of assessing operational risk using VaR goes through the following stages:

Building The Database:

The lack of accurate data on operational risk events is the biggest obstacle to implementing accurate models to measure operational risk. (Linda, Jacob, & Anthony, 2004) According to Basel II, the main sets of data to be used are: internal loss database, external loss database, scenario analysis, factors affecting the business environment and internal control systems:

- Building an internal loss database: Although internal data is most useful in determining the allocation of operational losses to the bank, it should not be the only data source to measure operational risk. In fact, internal data may provide information whose quality is entirely under the control of the bank (as opposed to external databases), can be used as a check for internal self-assessment, and can allow at least certain types of operational events to capture the best risk trends and impact of internal risk reduction efforts. (Saita, 2007).

- Building an external loss database: Developing an internal historical database of operational risk events is very costly and time-consuming, and therefore internal data must be complemented by external data obtained from other organizations. However, external data must be measured and adjusted to reflect institutional differences in the mix of business units, level of activity, geography and risk control mechanisms across companies. Moreover, competing companies are reluctant to disclose sensitive and detailed information about their internal processes and procedures to competitors. (Linda, Jacob, & Anthony, 2004).

- Scenario analysis: Internal and external loss databases focus on what has already happened, while scenario analysis contributes to suggesting what may happen, even if it has not happened before, and then it should be intended not only to supplement existing internal data when estimating the impact of potentially rare but highly impactful events, but also to represent an ongoing exercise to anticipate potential new risks that may result from changes in the external environment as well as from internal changes. (Saita, 2007).

The following figure defines the distribution of losses based on the three previous sources:

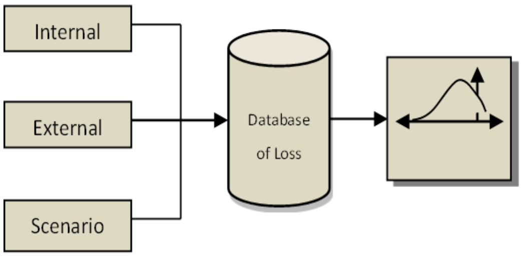


Figure 01: Building a Loss Event Database

Source: Abadi, A.F. Financial risk management in Islamic banking and finance. Dar Al-Fikr, 2015, p 286.

Formation Of Operational Risks Based on The Distribution Of Losses

The formation of operational risks is based on the distribution of the aforementioned operational losses within an area of dimensions that determines both the frequency and severity of risks. The first dimension of this distribution is the frequency of operational risks that occur and lead to an unwanted incident. The second dimension is about the severity of operational risks, that is, the impact they have on this institution before and after taking risk control measures (Fawzan, 2015). The frequency and severity of risks should be grouped in a matrix or grid similar to Figure 02.The network represents different combinations of business line and event type, ideally the network should be comprehensive and each cell should not have overlapping types of risks. (Wong C.Y., 2013).

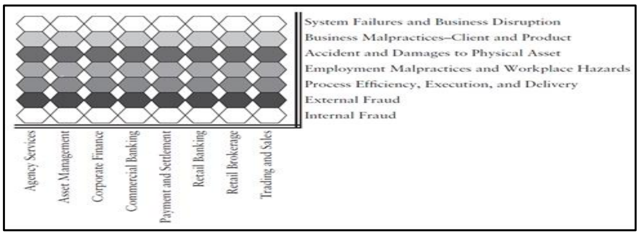


Figure 02: Operational Risk Factor grid

Source : Wong, M. C. Y. *Bubble value at risk: A countercyclical risk management approach*. John Wiley & Sons, Singapore. 2013, p 187.

The space defined across the frequency and intensity dimensions can be divided into four subspaces as follows: (a) low probability and low risk, (b) low probability and high risk, (c) high probability and low risk, and (d) high probability and high risk. (Fawzan, 2015).

Of course, not all elements need quantitative modeling, let's consider Figure 03, which shows the zonal map of operational risks:

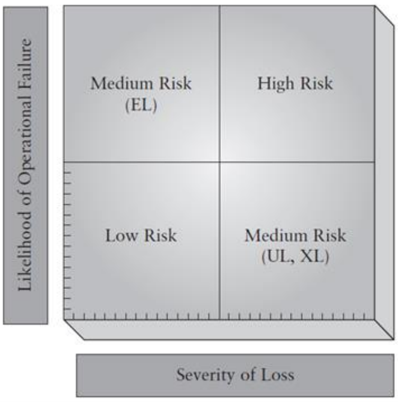


Figure 03: the zonal map of operational risks

Source: Wong, M. C. Y.. *Bubble value at risk: A countercyclical risk management approach* John Wiley & Sons, Singapore. 2013, p. 188.

Obviously, resources should not be spent on items with low probability and low risk (e.g. staff being late for work) (Lam, 2014). An extremely frequent and high-risk event, on the other hand, is an anomaly that should be investigated immediately and not modeled (e.g. a bank was hit with ten robberies in one year) (PETITJEAN, 2013). Hence the focus on quantitative modeling is areas marked 'expected loss' and'unexpected loss/extraordinary loss'. The expected loss (EL) is the loss resulting from the failure of the operation, the unexpected loss (UL) is usually due to weak internal control, and the exceptional loss (XL) is often one of the catastrophic events (Wong C.Y., 2013), this division is shown in the loss distribution Figure 03.

Determination Of Opvar

Given Figure 02, each network cell is assumed to be a risk factor independent of the others. Thus, OpVaRs are simply the sum of the values at risk for each risk factor without regard to the correlation between them (Panjer, 2006).

For a given risk factor, historical loss data is collected for the observed events, which is used to model the frequency distribution f (n) and severity distribution g (x|n = 1) where x is the loss for the event,n is the number of events per year. Hence g (x|n = 1) is the loss density function conditioned by a single event (i.e. loss per event). This is illustrated by the following two diagrams in Figure 04.

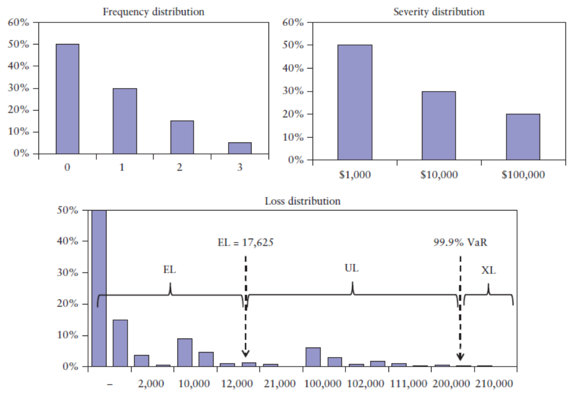


Figure 04: Distribution of Operational Risk Losses

Source : Wong, M. C. Y. Bubble value at risk: A countercyclical risk management approach John Wiley & Sons, Singapore. 2013, p. 189.

Since OpVaR is typically measured at a one-year horizon, density f (n) is the probability that n events will occur annually, and then we use a process called convolution to combine f (n) andg (x|n = 1) to derive the loss distribution, this can be done simplistically by scheduling, which is to systematically record all possible transitions in severity for each n (Hasan Dinçer, 2017).

The amount of loss at the tail is then quantified at 99.9% which represents the OpVaR. We consider the area outside OpVaR to be an extraordinary loss XL. The area between EL and XL gives an unexpected loss of UL, from the chart we find that: (OpVaR = EL+UL). Under the Basel II loss allocation approach, banks' operational risk capital is a function of the sum of the OpVaR of all line-of-business groups against the event type (BL-ET) (Ainura Tursunalieva, Nonparametric estimation of operational value-at-risk (OpVaR), 2016).

OpVaR is defined as 99.9% over a one-year horizon, using OpVaR for regulatory capital. Many experts believe that the OpVaR model cannot be meaningfully designed due to data scarcity and is just a check mark to meet regulatory requirements (Ainura Tursunalieva, 2016).

In the absence of an effective model, the autonomy of a vigilant risk manager is crucial, for example operational risk events tend to occur in a (interconnected) sequence - the Enron Worldcom scandals occurred around the same time, and similarly as recently in 2012 the Libor manipulation scandal, the money laundering of a UK bank involving Mexican drug lords, and another UK bank's alleged dealings with Iran (a country under US sanctions). This was no coincidence - the scandal will lead to increased scrutiny by regulators, leading to more scandals being revealed, a vigilant risk manager who closely monitors events would have realised operational risk capital by the amount of loss expected from similar recent events (Blackhurst, 2022)

APPLYING THE VALUE-AT-RISK METHOD IN THE ALGERIAN EXTERNAL BANK:

Applying value-at-risk techniques to measure operational risk is more complex than applying them to market and credit risk, since the calculation of this indicator depends more on the autonomy of its users, and therefore the opinion of an expert who benefits from several years of experience is very important because he is familiar with predicting the occurrence of operational risk.

Identifying The Network Of Risk Factors

As mentioned earlier, for the calculation of OpVaR, operational risks are formed within a network called the risk factor network, where the network represents different groups of business lineand type of event, and based on this network, both the frequency and severity of risk are determined for each risk factor.

We have a set of data on the operational events to which the Algerian External Bank is exposed, which represents the study sample as follows: To estimate the OpVaR of the bank, a sample of these events was selected.

- The Algerian External Bank is constantly exposed to the breakdown of computers allocated for payments and settlements, due to the age of the used devices and their depreciation, which affects the work process, as their frequency is on average 3 times per year. As for the value of the loss, it varies according to whether the failure is simple or complex. The loss may range from 2000 DZD to 4000 DZD if the failure is technical and requires simple maintenance operations, and it may range from 10,000 DZD to 17,000 DZD if the failure requires changing one of the components of the device, and sometimes it may amount to changing the device completely, so the loss then ranges from 35,000 DZD to 50,000 DZD.

- The Algerian External bank was exposed to numerous misappropriations of funds by employees within the bank who transferred them abroad, amounting in total to about 1.8245 DZD billion over nine years.

In order to determine the network of risk factors, it is necessary to distribute the previous data on the line of business and the type of event, and the following table shows this according to the classification of the Basel Committee:

Table 01: Operational Risk Factor Network

Dividing Losses by Activities		Type of event						
		Internal Fraud	External Fraud	Process efficiency and proper implementation	Work malpractice and workplace hazards	Accident and Damage to Physical Asset	Business malpractice - Customer and Product	System failure and business disruption
commercial and sales	Repeat of risk assessment							
	Total Losses							
Brokering	Repeat of risk assessment							
	Total Losses							
Retail Banking	Repeat of risk assessment							
	Total Losses							
Payment and Adjustments	Repeat of risk assessment					**27**		
	Total Losses					485 thousand DZD		
Business	Repeat of risk assessment							
	Total Losses							
Corporate Finance	Repeat of risk assessment	**4**						
	Total Losses	1.8245 Billion DZD						
Asset Management	Repeat of risk assessment							
	Total Losses							
Agency Services	Repeat of risk assessment							
	Total Losses							

Source: Prepared by the two researchers based on the bank's data.

Based on the above, we conclude that there are two main risk factors: computer failure and embezzlement.

Formation of Operational Risks Based on The Distribution of Losses

We mentioned earlier that not all risk factors need to be quantitatively modeled, but only those that belong to expected and unexpected losses. These factors must be divided into four partial spaces according to the area map of operational risks (see Figure 03). Therefore, in order to form the operational risks that must be quantitatively modeled, we first need to challenge the frequency and value of loss for each risk factor:

Determining The Frequency And Value of Loss For The Event of Computer Failure

The following table shows the frequency and loss value of the computer failure event for the period 2012-2020:

Table 02: Frequency of computer failure event and loss value per event for the period 2012-2020

Loss Value for Event V (Thousand DZD)	N Event Frequency	Years
50	1	**2012**
4	2	**2013**
12	2	**2014**
44	4	**2015**
2	3	**2016**
36	3	**2017**
11	4	**2018**
18	3	**2019**
3	5	**2020**
180	**27**	**Total**

Source: Prepared by the two researchers based on the bank's data.

Through the previous table, we note that the total frequency of disruption of the bank's computers has reached 27 events distributed over 9 years from 2012 to 2020, while the total value of losses per event reached 180 thousand DZD during the same period.

Determining The Frequency And Value Of The Loss For The Misappropriation Event

The following table shows the frequency and value of loss for the Embezzlement Event for the period 2009 to 2018,by year:

Table 03: Frequency of Embezzlement Event and Loss Value per Event 2009-2018

The value of the loss for the event (DZD million)	Frequency	Years
4.5	1	**2009**
-	0	**2010**
-	0	**2011**
-	0	**2012**
20	2	**2013**
500		
-	0	**2014**
1300	1	**2015**
-	0	**2016**
-	0	**2017**
-	0	**2018**
1824	**4**	**Total**

Source: Prepared by the two researchers based on the data of the following sites:
-https://www.echoroukonline.com -https://www.zawya.com

Through the previous table, we note that the total frequency of the embezzlement event in the bank reached 4 events during the period from 2009 to 2018, while the total value of losses per event amounted to 1824.5 million DZD.

Based on the previous results and by studying the frequency and loss value of the two studied risk factors (computer failure event and embezzlement event) shown in Tables 02 and 03, the following was found:

- The first risk factor (computer failure event) belongs to the expected loss area (EL) because it has high frequency (27 times in 9 years) and low losses (180 thousand DZD during the same period).

- The second risk factor (embezzlement event) belongs to the area of unexpected loss (UL) because it has a low frequency (4 times in 10 years) and high losses (1824.5 million DZD during the same period).

From this, we conclude that the two previous risk factors need to be quantitatively modeled and thus enable an estimate of the value at risk for both.

Estimating The Value At Risk of A Computer Failure Event Using Monte Carlo
The VaR of a PC failure event is estimated through the following stages:

Modeling The Frequency Distribution f (n)
Since the frequency of an event is an intermittent variable, to calculate the probability of recurrence we use the probability law of Poisson's distribution, which is expressed by the following equation:

$$\mathbf{n} \sim \mathbf{p}(\boldsymbol{\lambda} = \mathbf{3}) \quad ; \ \mathbf{f}(\mathbf{n}) = \mathbf{e}^{-\boldsymbol{\lambda}}.\boldsymbol{\lambda}^{\mathbf{n}}/\boldsymbol{n}! \qquad \textbf{(1)}$$

where: **n:** the frequency (number) of events in a year. **f(n):** the probability that **n** events will occur in a year.

$\boldsymbol{\lambda}$**:** Average, where: $\boldsymbol{\lambda} = \sum \boldsymbol{n_i}/\boldsymbol{N} = \mathbf{27/9 = 3}$

The results are shown in Table 04:

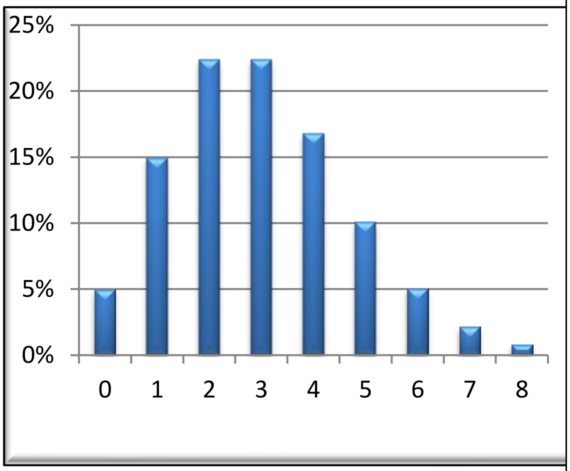


Figure 05 : Frequency distribution of computercrash events per year

Source: Prepared by the two researchers using Excel, values of Table 02.

Table 04: Frequency distribution of computer crash events per year

Frequency n	Probability f(n)
0	0,0498
1	1494
2	2240
3	2240
4	1680
5	1008
6	0504
7	0,0216
8	0081

Source: Prepared by th Based on the two Researchers using Excel based on the values of table 04.

Based on the table data, the graphical representation of the distribution of the frequency of the computer failure event, shown in Figure 05, is prepared through the previous table and figure. We note that the highest possible probability is that the failure event will be repeated 2 and 3 times.

Modelling The Severity Distribution

The severity of the severity $g(V|n = 1)$ is a function of the density of the loss conditioned by a single event (i.e. the loss per event), and since it is a continuous variable, this means that to calculate the probability, the probability law of the normal distribution, which is expressed by the following equation, must be used:

$$\mathbf{V} \sim \mathbf{N}(\boldsymbol{\mu}, \boldsymbol{\sigma}) \quad ; \quad \mathbf{g}(\mathbf{V}) = \frac{\mathbf{1}}{\sqrt{\mathbf{2\pi\sigma^2}}}\mathbf{e}^{-\frac{(\mathbf{V}-\boldsymbol{\mu})^2}{\mathbf{2\sigma^2}}} \qquad \textbf{(2)}$$

Where: **V: The** value of the loss per occurrence per year.

g(V): The probability that a loss V **will occur** in a year.

$\boldsymbol{\mu}$**:** Average, where: $\boldsymbol{\mu} = \sum \boldsymbol{V_i}/\boldsymbol{N} = \mathbf{180/9 = 20}$

Standard deviation, where :

$$\sigma = \sqrt{\sum_{i=1}^{n} \frac{1}{N} (V_i - \mu)^2 \sigma}$$

As a first stage, we calculate the standard deviation of loss values, and the following table shows this:

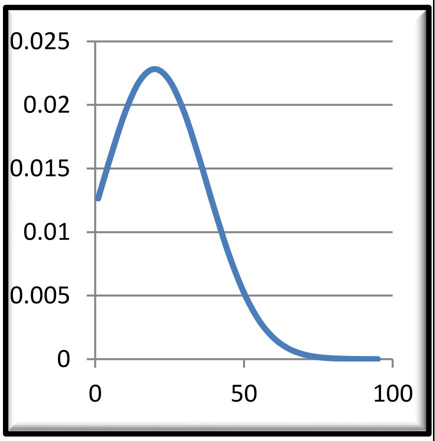
Table 05: Calculation of Average and Standard Deviation of Loss Values (Thousand DZD)

	Loss Value V_i	$V_i - \mu$	$1/N(V_i - \mu)^2$
V_1	50	30,00	900
V_2	4	(16, 00)	256
V_3	12	(8, 00)	64
V_4	44	24,00	576
V_5	2	(18:00)	324
V_6	36	16,00	256
V_7	11	(9, 00)	81
V_8	18	$\leq$ 2.00	4
V_9	3	(17, 00)	289
Total	**180**	-	2 750,00
μ	**20**	**σ^2**	**305**
		Σ	**17.48**

Source: Prepared by the two researchers using Excel, based on the values of Table 02.

Through the previous table, we find that the value of the loss on average is 20 thousand DZD with a standard deviation of 17.48 thousand DZD, that is, $V \sim N(20;\ 17.48)$. Based on the previous values and the normal distribution equation, we obtain the severity distribution shown in the following table and figure:

Table 06: Severity Distribution



Source: Prepared by the two researchers using Excel, based on the Table 06.

Probability	Loss values (thousand DZD)	Probability	Loss values (thousand DZD)
0,0082073	**45**	0,01264199	**1**
0,0052332	**50**	0,01343105	**2**
0,00307469	**55**	0,01501188	**4**
0,00166457	**60**	0,01579304	**5**
0,00083037	**65**	0,01937754	**10**
0.00038169	**70**	0,02190778	**15**
0,00016166	**75**	0,02282259	**20**
6,3092E-05	**80**	0,02190778	**25**
2,2689E-05	**85**	0,01937754	**30**
7,5182E-06	**90**	0,01579304	**35**
2,2955E-06	**95**	0,0118604	**40**

Figure 06: Severity distribution per year

Source: Prepared by the two researchers using Excel, based on the values of Table 05.

The loss values shown in the previous table are hypothetical in order to determine the probable distribution of the severity of the loss.

5.3.3 Deriving The Allocation of Loss and Determining The Value at Risk

In order to derive the loss distribution, we use the convolution process to combine f(n) and $g(V|n = 1)$, this can be done using either the scheduling method or the Monte Carlo method, and since the iterations may reach 5 or 6 times, the scheduling method becomes a little long and time-consuming, and therefore it is better to rely on the Monte Carlo method to generate random numbers, to systematically record some possible random switches in the severity of each n, and the following table shows the probability distribution of loss based on the frequency and intensity distributions according to the Monte Carlo method:

Table 07: Probable Distribution of Loss using Monte Carlo

Frequency	Possible Loss Values (Thousand DZD)						Total loss values in the year (thousand DZD)	Probability
	L1	L2	L3	L4.	L5	L6		
4	8	27	22 meters	3			60	2,0577 E-08
2	36	48					84	2,1276E-05
4	11	48	35	7			101	5,8082E-09
3	8	31	11				50	4,535E-06
1	40						40	0,00177194
5	35	4	43	50	33		165	2,0788E-11
6	25	39	27	24	9	36	160	1,8373E-12
2	18	31					49	9,5092E-05
5	44	47	7	37	38		173	2,0518E-11
3	12	21	35				68	1,6567E-06
3	11	21	44				76	9,0725E-07
2	9	34					43	6,9454E-05
2	24	9					33	9,3243E-05
3	34	34	9				77	1,1502E-06
1	41						41	0,00165696
4	26	28	10	12			76	2,9591 E-08
1	19						19	0,00340412
3	11	46	40				97	4,0096E-07
4	41	19	15	35			110	1,4689 E-08
3	1	19	25				45	6,3106E-06
4	15	30	44	47			136	4,3906E-09

Source: Prepared by the two researchers using Excel, based on the values of Table 04.

We note from the previous table that for each random repetition random loss values were set according to the number of repetitions and then we added the loss values together. As for the probability, the probability of each loss value as well as the probability of repetition is multiplied. For example, we take the first line from the previous table, which contains the repetition 4 and the folloing loss values: 8, 27, 22 , 3 thousand DZD, from which the common probability is calculated based on the Poisson distribution of repetitions and the normal distribution of loss values as follows:

$$0.168 \times 0.0180314 \times 0.021064 \times 0.022673 \times 0.0142227 = 2{,}0577 \text{ E-08}$$

After arranging the total loss values in ascending order, the graph of the distribution of loss values shown in the following figure is drawn:

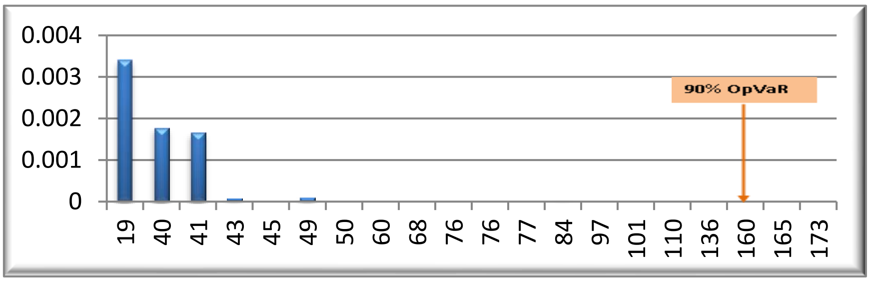


Figure 07: Probable Distribution of Loss

Source: Prepared by the two researchers using Excel, based on the values of Table 07

It is noted through the previous figure that the horizontal axis is not measured uniformly, it is clear that it has a long tail, and therefore the graphical representation of the loss distribution is abnormal , and therefore the value exposed to the operational risk of the computer failure event can be calculated from the loss distribution in the previous table and using the ionization scale (Percentile) depending on the Excel, from which we obtain the values shown in the following table at different confidence levels:

Table 08: Value at Operational Risk for Computer Hardware Failure Event (Thousand DZD)

(1-α)%	90%	95%	99%	99.9 %
$OpVaR_1$	160	165	171	848

Source: Prepared by the two researchers using Excel, based on the values of Table 07.

The maximum loss that the bank can suffer due to computer crashes in the coming year is estimated at 160.5 thousand DZD at a level of confidence 90%.

Estimating the Value at Risk of the Embezzlement Event Using the Scheduling Process:

The value at risk of an embezzlement event is estimated using the scheduling process through the following stages:

Modeling The Frequency Distribution f (n):

In the same way as before, in a computer crash, we calculate the probability of recurrence using the Poisson distribution probability law, so we get the results shown in the following table and figure, as the average is estimated as: $\boldsymbol{\lambda = 4/10 = 0.4}$.

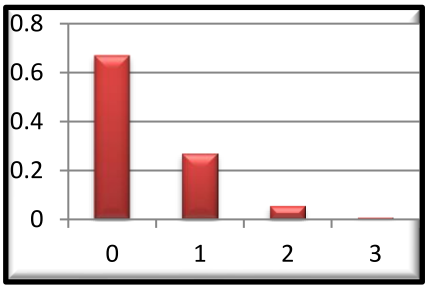


Figure 08: Distribution of frequency of embezzlement event

Source: Prepared by the two researchers using Excel, Based on the values of Table 03

Table 09: Distribution of frequency of embezzlement event

Frequency n	Probability f(n)
0	0,67032005
1	0,26812802
2	0,0536256
3	0,00715008

Source : Prepared by the two researchers using Excel, based on the source values of Table 09.

Through the previous table and figure, we note that the highest possible probability is that embezzlement does not occur with a probability of 67.03%, followed by it being repeated once with a probability of 26.81%.

5.4.2. Modelling The Severity Distribution:

As in the first example, we calculate probability using the probability law of normal distribution, where the following table shows the calculation of the mean and standard deviation of loss values:

Table 10: Calculation of the average and standard deviation of loss values (million DZD)

	Loss Value V_i	$V_i - \mu$	$1/N(V_i - \mu)^2$
V-D1	4.5	(625)	203965,141
V_2	20	436	190205,016
V_3	500	875	1925,01563
V_4	1300	843	712125,016
Total	**1824**	-	1108220,19
μ	**456**	**Σ**	**277055,047**
		Σ	**526,360187**

Source: Prepared by the two researchers using Excel, based on the values of Table 03.

Through the previous table, we find that the average loss value is 456.125 million DZD with a standard deviation of 526.36 million DZD, i.e.$V \sim N(456.125;\ 526.36)$. Based on the previous values and the normal distribution equation, we obtain the severity distribution shown in the following table:

Table 11: Severity Distribution

Loss values (million DZD)	**Probability**	**Loss values** (million DZD)	**Probability**
1	0,00052153	**1,000**	0,00044441
2	0.00052238	**1100**	0.00035867
3	0,00052324	**1200**	0,00027921
4.5	0,00052452	**1300**	0,00020965
10	0.00052922	**1400**	0.00015183
20	0,00053771	**1500**	0,00010607
50	0.0005628	**1600**	7,1467E-05
100	0.00060287	**1700**	4,6447E-05
200	0,0006733	**1800**	2,9117E-05
300	0.00072531	**1900**	1,7605E-05
400	0,00075363	**2000**	1,0268E-05
500	0.0007553	**2100**	5,776E-06
600	0.00073013	**2200**	3,1341E-06
700	0,00068079	**23**	1, 6402E-06
800	0,00061227	**2400**	8,2801E-07
900	0,00053113	**2500**	4,0317E-07

Source: Prepared by the two researchers using Excel, based on the values of Table 10.

Loss values are hypothetical values in order to determine the probable distribution of severity. To illustrate further, we show the following figure:

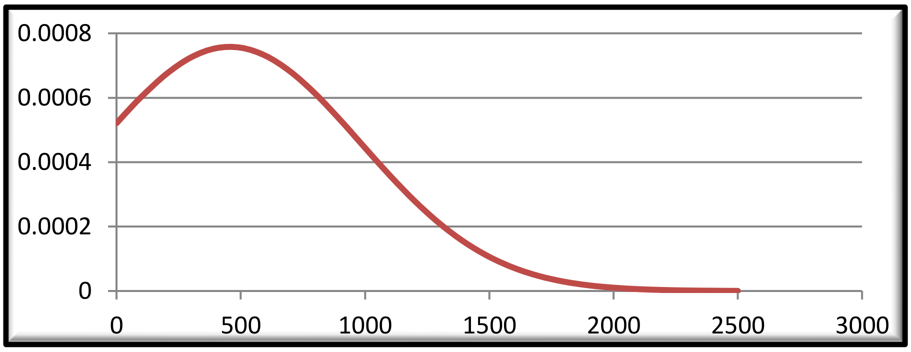


Figure 09: Severity distribution per year

Source: Prepared by the two researchers using Excel, based on the values of Table 11.

5.4.3. Deriving The Allocation of Loss And Determining The Value at Risk:

Since the frequency of the event is between 0-3, the loss distribution can be derived in a simplified manner by a convolutional process using scheduling, which is to systematically record all possible switches in severity for each n, and the following table shows this:

Table 12: Probable Distribution of Loss Using Scheduling

Frequency	Possible Loss Values (Million DZD)			Total loss values in the year (million DZD)	Probability
	L1	L2	L3		
0				0	0,670320046
1	4.5			4.5	0,00014064
1	20			20	0,000144176
1	500			500	0,000202517
1	1300			1300	5,62118E-05
2	4.5	4.5		9	1,47538 E-08
2	4.5	20		24.5	1,51247 E-08
2	4.5	500		504	2,1245 E-08
2	4.5	1300		1304	5,89689E-09
2	20	4.5		24.5	1,51247 E-08
2	20	20		40	1,5505 E-08
2	20	500		520	2,17791 E-08
2	20	1300		1320	6,04516E-09
2	500	4.5		504	2,1245 E-08
2	500	20		520	2,17791 E-08
2	500	500		1,000	3,05921 E-08
2	500	1300		1800	8,49133E-09
2	1300	4.5		1304	5,89689E-09
2	1300	20		1320	6,04516E-09
2	1300	500		1800	8,49133E-09
2	1300	1300		2600	2,35691E-09
3	4.5	4.5	4.5	13.5	1,03183E-12
3	4.5	4.5	20	29	1,05777E-12
3	4.5	4.5	500	509	1,4858E-12
3	4.5	4.5	1300	1309	4,12408E-13
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
3	1300	1300	1300	3900	6,5882E-14

Source: Prepared by the two researchers using Excel, based on the values of Table 03.

For example for n = 2, there are (4^2) =16 ways to get two events while giving four possible risk values, for each toggle the total loss is the sum of the losses for these two events, the probabilities can simply be read from the previous table, for example for the seventh line the combined probability of repetition2, loss 4.5 and loss 20 is:

$$(0.053626 \times 0.0001406 \times 0.0001442) = 1{,}51247\text{ E-08}.$$

For more clarity, we present the following figure, which shows the probable distribution of loss:

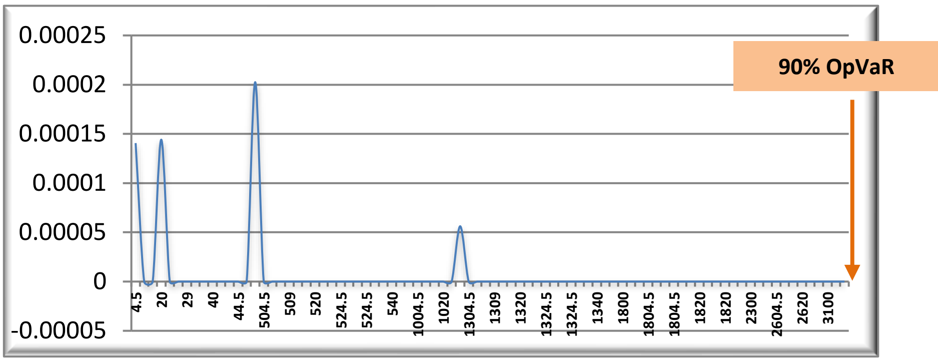


Figure 09: Severity distribution per year

Source: Prepared by the two researchers using Excel , based on the values of Table 12.

The horizontal axis of the previous figure is not measured uniformly, and therefore the graphical representation of the loss distribution is abnormal and constitutes a long-tail distribution, and therefore the value exposed to the operational risk of the embezzlement event can be calculated from the loss distribution in the previous table and using the ionization scale (Percentile) depending on the Excel, from which we obtain the values shown in the following table at different confidence levels:

Table 13: Value at Operational Risk of Embezzlement Event (Million DZD)

(1-α)%	90%	95%	99%	99.9 %
OpVaR2	2604	2620	3228	8

Source: Prepared by the two researchers using Excel, based on the values of Table 12.

Through the previous table, we find that the maximum loss that the bank can suffer due to embezzlement incidents in the coming year is estimated at 2604.5 million DZD at a confidence level of 90%.

5.5. Total Operational Risk Exposure Value (Opvars)

Since each of the risk factor network cells constitutes a risk factor independent of others, the OpVaRs are simply the product of combining OpVaR for each risk factor without regard to correlation, and the following table illustrates this:

Table 14: Total Operational Risk Exposed Value at Different Confidence Levels (10^3 DZD)

(1-α)%	90%	95%	99%	99.9 %
$OpVaR_1$	160	165	171	848
OpVaR2	2604500	2620000	3228000	3832800
$OpVaR_S$	**2604660,5**	**2620165,4**	**3228171,48**	**3832972,848**

Source: Prepared by the two researchers using Excel, based on the values of Tables No. 08 and 13.

Through the previous table, we find that the maximum loss that the bank can suffer due to total operational risks in the coming year is estimated at 2604660500 DZD at a confidence level of 90%, while the total OpVaR used to determine the capital requirements to cover operational risks is estimated at 3832972848 DZD over a one-year horizon and at a confidence level of 99.9.%

CONCLUSION

Results Of The Study

Through this study, a number of results were reached as follows:

- The value-at-risk method provides accurate and summarized information in one easy-to-interpret number about the maximum loss that can be incurred at a certain confidence level, this individual number can be translated into the capital requirements necessary to cover the risk.

- Value-at-risk is one of the most advanced methods for measuring operational risks, but it is difficult to apply on the ground. In addition to requiring the need to provide time series for realized losses that extend to five years, we find the problem of merging and relying simultaneously on internal and external data that are difficult to synthesize together. Moreover, relying only on the value-at-risk approach as a measurement and analysis standard is insufficient to give accurate estimates of expected losses.

- The application of the var method to measure operational risk is more complex than its application to market risk, since the data used in the calculation process rely more on the autonomy of users, and therefore the expert opinion is very important because he is familiar with predicting the occurrence of operational risk.

- The application of VaR models is one of the activities with high intensity of work, which requires a distinguished quality of human competencies, whether in the mathematical and statistical aspect, or in the technical aspect and control of software, which was not available in the bank under study.

- The proper application of value at risk in the Algerian External Bank requires increasing the level of investment in modern banking technology, and relying on modern programs that increase the speed and efficiency of risk assessment**.**

- To estimate the OpVaR of the EBA bank , a network of risk factors was formed consisting of the computer failure event and the embezzlement event, where the Monte Carlo method was used for the computer failure event, while the scheduling process was used in the case of the embezzlement event.

- The application of the value at risk to estimate the operational risks in the Algerian External Bank gave satisfactory results - based on the data obtained from the bank (which are estimated data based on the experience of the bank's manager) - which can be relied upon in determining the capital requirements necessary to cover those risks, as it is estimated at 3228.17 million DZD, which represents the maximum loss that a bank can suffer at a level of confidence of 99%.

Hypothesis Testing

This study was based on two main partial hypotheses, as follows:

- The first partial hypothesis: "The nature of the operational risk data makes it more difficult to estimate the value at risk for it", which is a correct hypothesis and this has been proven based on results No. 02 and 03.

- The second partial hypothesis: "The application of the value-at-risk method is useful in providing accurate estimates of the capital requirements necessary to cover the risks", which is a correct hypothesis and this has been proven based on results No. 01 and 07.

From the above, it was concluded to prove the validity of the main hypothesis that "the proper application of the value-at-risk method to estimate the operational risks in the Algerian External bank requires the existence of some basic requirements that are not available in the bank under study", which is a correct hypothesis based on results Nos. 02, 04, 05, and 07.

Recommendations

By studying the various aspects of the topic, a number of suggestions can be made, as follows:

- The value-at-risk approach should be given greater importance academically and practically in order to provide the human competencies required to control its models.

The need to provide a huge database related to all the operational events of the bank, and this is achieved by intensifying efforts, as all business units of the bank must create statistical tables of the events that occurred as well as determine the losses resulting from them.

- The Bank shall have an independent operational risk management activity, which shall be responsible for the design and implementation of the operational risk management framework, and shall be responsible for the development of strategies for the diagnosis, measurement, follow-up, control and mitigation of operational risks.

- The internal operational risk measurement system should be closely linked and integrated with the Bank's day-to-day risk management processes and provide regular reports on risk exposures.

- Clarify the reason for selecting each risk factor as one of the causes of operational risks on the basis of experience and practice, as well as introducing the personal judgment of those with experience in the aspects of the activities that have suffered losses, and the risk factor must be convertible into quantitative measures as much as possible.

- The Bank must rely in its estimates of operational risks on relevant internal and external data and analysis of scenarios and factors that reflect the environment of activity and internal control systems. The risk measurement system must have credibility,transparency,good documentation and demonstrability, complemented by consistency in application.

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