MATHEMATICAL MODELING OF COLLECTIVE VALUE AT RISK (CVAR) AND COLLECTIVE MODIFIED VALUE AT RISK (CMVAR) IN LIFE INSURANCE COLLECTION FOR SOME COMPOUND DISTRIBUTION

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A thesis submitted in

fulfilment of the requirement for the award of the

Doctor of Philosophy

Faculty of Technology Management and Business

Universiti Tun Hussein Onn Malaysia

JANUARY 2023

I dedicate this to my father and my late mother,

(Haji Ismail bin Mohd and Allahyarhamah Hajah Yultri Ernelly binti Sarim),

My wife,

(Tuti Hudayah)

My daughter,

(Annisa Tantiana Zahra)

&

My siblings

(Siti Irma Fadhilah, Siti Altaf Deviyati, Muhammad Anas Danial &

Muhammad Badrul Hisham)

ACKNOWLEDGMENT

In the name of Allah, The Most Gracious, The Most Merciful. Alhamdulillah, praise to Allah SWT the Almighty for giving me an opportunity, granting me strength to complete my study. Sholawat and salam to our Prophet Muhammad SAW.

I would like to express my appreciation to my supervisor Prof. Dr. Abdul Talib bin Bon and my co-supervisors Prof. Dr. Sukono from Padjajaran University, Bandung, Indonesia and Dr. Adhitya Ronnie Effendie from Gadjah Mada University, Yogyakarta, Indonesia for their guidance and assistance in conducting the needed work during my studies and this thesis. Without their support, guidance, supervision, and motivation, it will be impossible for me to complete my studies.

Besides, I would like to thank the examination committee members for their insightful comments during this process of evaluation.

Most importantly my special thanks to my beloved father Haji Ismail bin Mohd for the love, moral support and motivation for me, my lovely wife who will always be the queen of my heart Tuti Hudayah for all your support and sacrifice for me and always stay beside me in whatever situation. To my lovely daughter my beautiful princess Annisa Tantiana Zahra for always make life cheerful. To my siblings, Siti Irma Fadhilah, Siti Altaf Deviyati, Muhammad Anas Danial and Muhammad Badrul Hisham with all your moral support and material assistance. And not forgotten I dedicate to my late mother Allahyarhamah Hajah Yultri Ernelly binti Sarim may Allah SWT bless and granted to the highest Jannah.

ABSTRACT

It is known that life insurance claims involve large sums of money, so it is very important for the actuarial company of the insurance company to make risk analysis of the claim. In general, the risks associated with life insurance claims are measured using standard deviation and variance. However, standard deviation and variance could not accommodate all claim of risk occurrence. Thus, the question remains at how the standard deviation or variance to calculate individual risk parameters and collective risk in life insurance for some models related to the distribution of claims numbers and claim amount should be used. In this study, two models called Collective Value at Risk (CVaR) and Collective Modified Value at Risk (CMVaR) model were developed as two modification models to measure value on collective risk or risk. The main objective of this research is to achieve two models of collective value. In this collective risk model, the proposed method was performed for two models of distribution of claim number and claim amount. The collective results from the development of the Modified Value at Risk model are expected to meet each claim for risk events when given a certain level of significance. Data provided by Bank Negara Malaysia (BNM) have been used to identify the use and effectiveness of the CVaR model and CMVaR in this study. In the implementation of the CVaR model and the CMVaR models, the actual data from BNM was transformed by using Minitab 16 software. The next analysis is to use Microsoft Excel to build graphs, histograms and analysed the model being developed. In this analysis, the significance level chosen is from $\alpha = 0.5\%$ to $\alpha = 4.0\%$ for the two models being developed. Results show that both proposed method CVaR and CMVaR models acquired the required scores on Collective Risk. This indicates that the advantages were proven by comparing Collective Risk with CVaR and CMVaR, thus the objectives of this study have been achieved. In addition, results indicate that CMVaR has higher risk than CVaR.

ABSTRAK

Diketahui bahawa tuntutan insurans nyawa melibatkan penggunaan wang yang besar, maka adalah sangat penting pihak aktuari syarikat insurans membuat analisis risiko terhadap tuntutan tersebut. Secara am, risiko yang berkaitan dengan tuntutan insurans hayat diukur menggunakan parameter sisihan piawai atau varians. Akan tetapi, sisihan piawai atau varians tidak dapat menampung keseluruhan tuntutan kejadian risiko. Oleh itu, bagaimana sisihan piawai atau varians dapat digunakan untuk mengira parameter risiko individu dan risiko kolektif dalam insurans hayat untuk beberapa model yang berkaitan dengan pengagihan bilangan dan nilai tuntutan. Maka, dalam kajian ini, dikembangkan dua model yang dinamai model *Collective Value-at-Risk (CVaR)* dan model *Collective Modified Value-at-Risk (CMVaR)* sebagai dua buah model pengubahsuaian untuk mengukur nilai pada risiko atau risiko kolektif. Dua model nilai kolektif itu ialah objektif yang perlu dicapai. Dalam model risiko kolektif ini, kaedah yang disodorkan akan dilakukan untuk dua model pengagihan bilangan tuntutan dan nilai tuntutan. Hasil kolektif dari pengembangan model *Modified Value-at-Risk* diharapkan dapat menampung setiap tuntutan bagi peristiwa risiko apabila diberikan paras keertian tertentu. Bagi melihat penggunaan dan keberkesanan model *CVaR* dan model *CMVaR* itu, dalam kajian ini telah digunakan data sebenar yang dibekalkan oleh Bank Negara Malaysia (BNM). Dalam pelaksanaan model *CVaR* dan *CMVaR*, data sebenar dari pihak BNM harus diubah dengan menggunakan pengisian Minitab 16. Analisis seterusnya ialah menggunakan Microsoft Excel untuk membina graf, histogram dan menganalisis model yang sedang dikembangkan itu. Dalam analisis ini, paras keertian yang dipilih ialah dari $\alpha = 0.5\%$ hingga $\alpha = 4.0\%$ untuk kedua-dua model yang sedang dikembangkan itu. Hasilnya menunjukkan bahawa kedua-dua model *CVaR* dan *CMVaR* yang dicadangkan itu mendapat skor yang cukup baik terhadap Risiko Kolektif. Dengan demikian, keunggulan yang telah dibuktikan dengan perbandingan Risiko Kolektif dengan *CVaR* dan *CMVaR* menunjukkan objektif kajian ini telah dicapai. Sementara di antara kedua *CVaR* dan *CMVaR* menunjukkan bahawa *CMVaR* mempunyai risiko lebih tinggi daripada *CVaR*.

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LIST OF ABBREVIATIONS

BNM	Bank Negara Malaysia
CA	Claim Amount
CN	Claim Number
CMVaR	Collective Modified Value at Risk
CVaR	Collective Value at Risk
MVaR	Modified Value at Risk
VaR	Value at Risk

CHAPTER 1

RESEARCH OVERVIEW

1.1 Research Background

A community is always trying to get security and welfare for themselves and for the people who depend on the community itself. Unforeseen things that may occur in life, such as accidents, natural disasters or deaths resulted from the risk of financial loss affects the welfare and security of the community (Magfidar, 2017).

One reliable way to minimize or to handle this risk is insurance. Insurance can be used to reduce losses that will be caused by unexpected events such as death or certain events that occur but are uncertain when they occur; old age or events that are certain to occur and can be predicted but uncertain of how long the duration is; and accidents or events that are not certain to happen but not impossible to happen. Therefore, the insured must choose the type of insurance that suits their needs and pay close attention to the contract (Magfidar, 2017)..

Insurance designed to reduce the risk of financial loss due to unforeseen consequences related to the death of the insured is called life insurance. In life insurance, the insurer provides a number of death benefits as a claim when the insured suffered death. Insurance is one of the techniques to manage risk, which is quite widely used. Insurance

can be viewed as a tool in which an individual can transfer the risk to another party, in which the insurance company to accumulate funds from individuals to meet the financial needs related to damages (Dickson, 2016; Djuric, 2013 and Sidi *et al*, 2018). Essentially, insurance means collecting funds which can be used to offer compensation to the person who is the one experiencing the loss. Insurance is a business of taking over the risk from customer to the insurance company until the customer feels comfortable to follow the insurance program. Insurance must be reliable to handle the risk in order for the business to be profitable, which in turn makes the customer feels comfortable to follow the offered program. In insurance, experience about risk is the occurrence of insured claim.

Insurance can be seen from two points of view. First, as protection for the finances provided by the insurer and second, as a risk pooling tool of two or more persons or companies through promised donations to establish funds to pay claims (Dionne, 2013). Insurance is a means of risk transfer, requiring collective (aggregate) risk, such as an insurer combining risks from many insured.

There are two standard approaches for distribution claim modelling during the insurance period, which are the collective risk modelling and individual risk modelling (Liu & Wang, 2017). In the collective risk modelling, claims that appear when every risk occurs are called the individual claim, and the accumulation of individual claims during the period of insurance claims is referred as aggregation (Kahn, 1992; Dickson, 2016). A distribution model can be formed from the aggregation of claims of the models and number of individual claims. Thus, before modelling the distribution for the aggregation, claims must first be determined besides the model of distribution of the individual claim amount (Heckman & Meyers, 1983; Bowers *et al*., 1997).

1.2 Problem Statement

Risk is generally measured by variance and standard deviation. The role of variance and standard deviation in measuring is explained in Chapter 5. It should be highlighted that variance and standard deviations measure the average risk size and do not accommodate all of the risks, thus, there is a need to find an alternative measure. Therefore, the idea emerged to quantify the risk carried by quintile or better known as Value-at-Risk (VaR).

One alternative to measuring risk is using Value at Risk (VAR). This is a way to resolve the issue by measuring the risk probability experienced by a claim. VaR assesses the worst loss that can happen to an insurance company, whether as an individual or aggregate (collective) at a time, and at level chance set. In VaR, probability of loss calculated is the worst from a set of percentages. VaR is a quantile measurement which assumes that function probability follows the normal distribution. The question is what if the function probability does not follow normal distribution. Then, there is a need to have a modification from the Value at Risk known as Modified Value at Risk (MVaR).The MVaR is applied in AlternativeSoft's platform. The skewness and the kurtosis effect is high if VaR is computed at 99%. In an insurance system, the risk is the event when an insured party puts forward a claim. Claim is the compensation for a risk loss. Individual claim of one period insurance is called aggregation claim, while aggregation claim is collective risk (Dickson, 2016).

Therefore, to address the problems mentioned above , this study developed a model of collective risk measure, called the Collective Value-at-Risk (CVaR) and Collective Modified Value-at-Risk (CMVaR). Development of this model is based on the collective risk model as stated by Dickson (2016) and Khan (1992) in which CVaR and CMVaR are not only for modification but also knowledgeable that can be beneficial. The goal is to formulate a model as an alternative for measuring the collective risk. CVaR and CMVaR as a result of this development is expected to accommodate any event collective risk when given a certain level of significance. As a results, CVaR and CMVaR models have been used to analyze the data from Bank Negara Malaysia (BNM) that have the risk characteristics of incurred claims.

Zuanetti *et al*. (2006) in their study on a simulation data using Poisson distribution for claim number and Lognormal distribution for claim amount which they had concluded that both Poisson and Lognormal distribution were well distributed. Omari *et al*. (2018) mention that Antonio *et al*. (2010) had presented the Poisson distribution as the modelling archetype of claim number. It is stated that Lognormal distribution is among the most applied distributions for modelling claim amount and concluded that Lognormal is selected as reasonably good distribution for modelling claims amount. They implement their research on a sample of automobile portfolio datasets obtained from the insurance Data package in R with variables; Auto Collision, data Car, and data Ohlsson. Although they have concluded that Negative Binomial and Geometric distributions are selected as the most appropriate for claim number but still, they had suggested to use Poisson distribution for further research. Euphasio and Carvalho (2020) implement their research on the simulation stated that the claim numbers was adjusted by a Poisson distribution as well as the claim amount. Although the claim number was modelled by Negative Binomial, the case generated claims observations exceedingly greater than real numbers. Therefore, it was decided running simulations as a compound Poisson process. They also show that Lognormal was the most chosen distribution. Bolance and Vernic (2020) on their study using data from a Spanish portfolio used Poisson and Negative Binomial distribution claim numbers and the Gamma and Lognormal for claim amount. Although they concluded that Negative Binomial provided the best for claim numbers, still Poisson was considered to as counting distributions while Lognormal provided the best for claim amount.

One benefit of Poisson is by using the Taylor Series where Taylor Series is an important role by finding moment. Therefore, in this research, Poisson distributions for claim numbers and Lognormal distributions for claim amount in this research were selected.

1.3 Research Questions

The research addresses several issues as listed follows:

1. How to estimate parameters of individual risk and collective risk in life insurance, for some models related to the distribution of the number and the value of the claim?
2. How to develop of CVaR and CMVaR in life insurance, for a number of claims distribution model and value of the claim?
3. How to evaluate results of calculations from Collective Risk, CVaR, and CMVaR in the simulation data and value of the number of claims in life insurance claims?

1.4 Research Objectives

The objectives of this study are as follows:

1. To estimate model parameters for individual and collective risk in life insurance.
2. To develop models of CVaR and CMVaR in risk life insurance, for a number of claims and the distribution of the value of the claim.
3. To compare and analyse the calculations of Collective Risk, CVaR, and CMVaR of the simulation data and value of the number of claims life insurance claims.

1.6 Research Significance

The significance of this research in terms of theory is that it brings new knowledge or a development model which will be useful in the future. This can be an application to implement in insurance industry. In general, the proposed method developed can be used as a tool to accommodate all event risks.

1.7 Operational Definition

For the propose of this study, model Value at Risk and Modified Value at Risk as foundation will be defined as VaR and MVaR. Both developed models Collective Value at Risk and Collective Modified Value at Risk will be defined as CVaR and CMVaR.can be used as a tool to accommodate all event risks. Bank Negara Malaysia as the organization which the data is used in this study will be defined as BNM.

1.8 Structure of the Thesis

The following subsections describe the organization of the thesis. Chapter 1 introduces the study through a general description of the study which consists of a discussion on insurance and the development of risk model methods in recent years. This is followed by a presentation of the research background included the focus of this research, problem statement, research questions, objectives of the study and a brief description of the methodology.

Chapter 2 provides a review of previous works from which this research is drawn. It is a review of the problems and issues related to the collective risk model. It discusses the various types of collective risk models in life insurance.

Chapter 3 discusses the works which formed the procedure to be carried out to achieve the objectives of the study listed in Chapter 1. The objective of this chapter is to describe the procedure and steps involved in the construction of methods to overcome problems related to collective value at risk. Discussion includes the building blocks on which the foundation of the desired methods is based. It continues with a discussion on developing the CVaR to become CMVaR. The discussion concludes with a description of the simulations to generate data used to investigate the proposed models in comparison to the existing models.

Chapter 4 contains the discussion concerning the development of a risk size model for insurance claims. The discussion covers the characteristics of insurance claims data, Collective Risk model, and the developments of CVaR general models, CMVaR models, specific models of CVaR, and CMVaR.

Chapter 5 presents the simulation studies which discuss the results of the proposed model, CVaR and CMVaR developed in the current study. Finally, chapter 6 presents the conclusion of the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents the literature review of the study. It covers the previous study about risk measurments by previous reserchers. The chapter commences with an overview of Collective Risk, Value at Risk and Modified Value at Risk.

2.1.1 Insurance

2.1.1.1 Definition of Insurance

Insurance can be defined as undertaking of risks by an insurance company which agrees to indemnify the insured or the risk transferor for specified losses upon their occurrence, subject to the payment of insurance premiums by the insured.

Insurance is one of the methods of managing risks, in particular, one of the methods of risk transfer. Some people loosely say that insurance is paying one dollar for one hundred dollars. What this means is that the insured only has to pay a relatively small, predetermined amount, to have a peace of mind by not having to worry about an even more substantial loss in the event that an insured peril occurs.

The owner of an insurance policy is called the policyholder, while the subject matter or person who is to be protected under the insurance is called the insured. For example, a husband may purchase a medical insurance policy for his wife. In this case, the husband is the policyholder and the wife is the insured.

2.1.1.2 Basic Features of Insurance

There are **FOUR (4)** basic features of insurance as the following:

1. Pooling risks

   Pooling risks means insurance companies combine the expected losses of a group of people so that risks spread out and the average losses will be close to the actual loss. By having a large group of subjects that are exposed to similar risks, insurance companies are able to predict actual losses with higher degree of accuracy. By pooling losses, insurers reduce the probability of an occurrence of large loss.

2. Transfer of risks

   Transfer or risks means transferring an insurable risk from the insured to the insurer via an insurance policy contract. Pure risks that are usually transferred by an insured to an insurer are the risks of death, disability, longevity, poor health, property loss due to five or other perils, and personal liability risks.

3. Payment of fortuitous losses

   A fortuitous loss refers to loss that occurs by accident or by chance, for example a loss that occurs unintentionally and unexpectedly. For example, fire that is caused by a leakage in a gas pipe would result in fortuitous loss. However, fire that is intentionally ignited by someone with malicious intentions of claiming from the insurance company does not result in fortuitous loss.

4. Indemnification of losses

   Indemnification of losses means that the insured is compensated by insurer by an amount that reinstates his position to the original situation prior to the incidence of loss. The insurer cannot gain or profit after claiming from the insurer.

2.1.1.3 Types of Insurance

Insurance can be categorized into two types:

i. Life insurance

ii. General insurance.

Each insurance type has its own mathematical modelling. In this research the mathematical modelling is for life insurance. Therefore, only life insurance is discussed in this section.

2.1.1.4 Life insurance

Life insurance is basically a type of insurance that pays out a certain amount of compensation to the beneficiary in the occurrence of insured's death. The main objective of life insurance is to create a fund that will be available to the next beneficiary in the event that the insured passes away. Hence, the proceeds act to protect the beneficiaries from the financial impact which results from the insured's death.

A life insurance contract is created when a large number of individuals mutually contribute towards a common pool fund which is managed by the life insurance company. Upon death or any other contingency dependent on human life, the life insurance company will pay lump sum or the face amount of the policy which is guaranteed at the contract's inception to the insured's beneficiary.

2.1.1.5 Types of Life Insurance

According to Shahnaz and Boey (2015), basic types or definition of life insurance are as follows:

1. Term Insurance

   This is the most basic form of life insurance. It usually refers to temporary insurance or a fixed insurance whereby the insured is covered for a fix level of face amount over a specified period, example one year, five years or ten years.

2. Whole Life Insurance

   This is an insurance plan that provides protection for the duration of the insurers' lifetime but this is usually limited to client or customer age until 100 years old.

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VITA

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