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PROJECTED MALAYSIAN LIFETABLE: EVALUATIONS OF THE LEE-CARTER AND POISSON LOG-BILINEAR MODELS

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***Abstract:** There is a continuous improvement in mortality rates globally including in Malaysia. Due to systematic underestimation of mortality rates, many researchers have shown their interest towards mortality study as inaccurate mortality estimates may impact policies and interventions related to health, life insurance and pensions. In this study, two mortality forecasting models were adopted including the Lee-Carter model and its variant, the Poisson log-bilinear regression model. The out-sample forecasts of mortality rates and life expectancy at births from both models were evaluated using Mean Forecast Errors (MFEs) and Mean Absolute Percentage Forecast Errors (MAPFEs). Consequently, using the most accurate model, we forecast future mortality rates and construct Malaysian life tables for males and females. Data of Malaysian mortality rates by age and gender from year 1970 to 2017 were collected from the Department of Statistic Malaysia (DoSM). Results show that the estimation of parameters from both models are approximately similar in trends. The Lee-Carter model provides more accurate out-sample mortality rate and life expectancy at birth forecasts for Malaysian males and females compared to the Poisson log-bilinear model.*

***Keywords:** Mortality Forecasting Model; The Lee-Carter Model, Poisson Log-Bilinear Model; Life Table; Life Expectancy.*

Introduction

The study of mortality models becomes increasingly important for insurance and pension companies in particular accurate estimation of mortality rates is necessary when calculating the costs and reserves of insurance policies and retirement benefits (Wylde, 2015). Underestimation of mortality rates could cause risks to insurance companies in certain ways. For example, low mortality estimates tend to underestimate the insurance premiums and increase the contingent liabilities. These issues may cause insolvency to the company and eventually lead to bankruptcy. Therefore, a mortality model that could accurately estimate mortality rates plays significant roles in insurance industry.

Statistics have shown that Malaysian mortality rates have decreased tremendously over the years leading to an increase in life expectancy at births. See Table 1 for the increasing pattern of Malaysian life expectancy at birth over the past few decades. A continuous decline in mortality together with a decrease in total fertility will lead to population ageing. Malaysia will reach and ageing society status by year 2030 that is when the percentage of old age people age 60 years and above represent fifteen percent of total population (Shair, 2017). The improvement in mortality maybe due to the effectiveness of government policies in providing a good health care system to the people.

Nevertheless, the trend of mortality improvement has been ignored when calculating the costs of insurance, as majority of insurance companies in Malaysia use the M9903 table for pricing and valuations.The Life Insurance Association of Malaysia (LIAM) launched the M9903 life table in year 2007 (LIAM, n.d.). This M9903 table is developed based on mortality experience of live assured from year 1999 to 2003 in which the mortality improvement after year 2003 onwards were not included in valuations. According to Brouhns, Denuit & Vermunt (2002), to provide accurate pricing and reserving, actuaries must use life table that account for mortality improvement of future trends. The life table that captures future mortality improvement is known as projected life tables. This type of life table is usually useful for long term life insurance products such as life annuities, aged care insurance and lifetime sickness insurance. As far as we concern, up to today there is no projected life tables available in Malaysia.

Table 1: The Observed Malaysian Life Expectancy at Births for Males and Females from Year 1966 To 2010. Source: Department of Statistics Malaysia

Year	Male	Female	Year	Male	Female
1966	63.10	66.00	**1990**	68.90	73.50
1970	61.60	65.60	**1995**	69.50	74.30
1975	64.30	68.70	**2000**	70.00	74.70
1980	66.40	60.50	**2005**	71.40	76.20
1985	67.70	72.40	**2010**	71.90	77.00

Following the above-mentioned issue, this research will make an attempt to develop projected life tables for Malaysian males and females. The projected life tables will be developed either based on the Lee-Carter model or its variant, the Poisson log-bilinear model, subject to the accuracy of forecast values from both models. These models have the ability to capture the mortality trends of population. The models consist of mortality index parameter which represent mortality improvement over the years. Although there are several numbers of other mortality models available in the literature, this research focuses on these two models. It is noteworthy that, because mortality data that we obtained is Malaysian population, further adjustment is needed to get better estimates of mortality experience for lives assured. The adjustment method does not include in this paper and it is opened for future work.

Therefore, the main aim of this research is to evaluate the accuracy of the out-sample mortality rate and life expectancy at birth forecasts from the two models--- the Lee Carter model and its extended version, the Poisson log-bilinear model. The most accurate model will be used to develop the projected life tables of Malaysian population.

Literature Review

Mortality Trends in Malaysia

Malaysian population is now living longer than previous generation. The life expectancy at birth of an infant born in 2017 is 74.8 which is 10.3 years longer than those born in year 1966 (Department of Statistics Malaysia, 2017). The increase in life expectancy will increase the demand for aged care, pensions and social benefits. Apart from that, the life expectancy at birth of Malaysian females was reported consistently higher than that of males. Interestingly, the trend of infant mortality rates in Malaysia also showed a decline pattern. This reflects the availability, utilization and effectiveness of health care system, particularly, the post-natal care has improved. Moreover, deaths among Malaysian old-age people have been reducing over the years. The life expectancy of those age 60 increased from 18.25 years in 1970 to 25.29 years in 2017.

The Study of Mortality

In this section, we highlighted the most widely used mortality models in the literature. Although some of them seems outdated, the models are still reliable and have been applied to recent data.

The attempt to find an accurate mortality curve has a long history in demography and actuarial science fields. Age dimension, typically the only factor that was considered when fitting a mortality curve. For instance, Heligman & Pollard (1980) proposed a model that fit a curve to the entire age range. This model however does not take into consideration the time factor. Lee & Carter (1992) proposed an approach that includes both age and time dimensions. Since then, the Lee-Carter model becomes a prominent model and received recognition worldwide. A research work from Ibrahim, Ngataman & Abrisam (2017), applied both models, the Heligman-Pollard and the Lee-Carter, to forecast the mortality of Malaysian population. The results of their paper showed that the Lee-Carter model fitted better than the Heligman-Pollard for females vice-versa for males.

The Lee-Carter model is a well-known stochastic approach that describes the variability of mortality rates with respect to age and time factors (Chavhan & Sinde, 2016). For example, the time-component of the model explains the general level of mortality that changes over time whereas the age-component reflects how rapidly or slowly mortality at each age varies when the general level of mortality changes. The Lee-Carter model has been widely used by actuaries for many purposes such as to forecast mortality reduction factors and to assess adequacy of retirement income. Other applications of Lee-Carter model include population projections and the projection of mortality trends for the oldest-old people.

The Lee-Carter model adopts an extrapolative technique when fitting and forecasting mortality rates which means it does not include the knowledge of medical, behavioural, or social influences on mortality changes. Nevertheless, the Lee-Carter model assumptions may not universally appropriate. Even though the model is succeeded in United States, the Lee-Carter model may not be accurate in some countries (Booth, Tickle & Smith, 2005). According to Ngataman, Ibrahim & Yusuf (2016), although the Lee-Carter model fit Malaysian mortality data quite well, the model underestimated the life expectancy at births.

Due to the above-mentioned reason, there are numbers of researchers have proposed the extended versions of the Lee-Carter model. These Lee-Carter variants made some modifications on the original Lee-Carter to include some additional statistical procedure. Some of the Lee-Carter variants were more proven accurate than that of the original model (Husin, Zainol & Ramli, 2015; Hyndman, Booth & Yasmeen 2014).

The Poisson log-bilinear regression model is one of the Lee-Carter variants proposed by Brouhns et al. (2002). This model improves the original Lee-Carter model by integrating the Poisson regression model which is perfectly suited to forecast age–sex-specific mortality rates. The model improves the original Lee-Carter model which enable us to forecast mortality and projected life table better. Research from Renshaw & Haberman (2003) and Antonio & Bardoutsos (2015) applied this Poisson model in forecasting mortality trends. Since the number of deaths is a counting random variable, thus this Poisson assumption will make it more reasonable and acceptable. The application of the Poisson log-bilinear model using Malaysia data is still lacking. While Sapri, Ramli, Ghani & Zakiyyatussariroh (2016) evaluate the Poisson log-bilinear model using mortality rates as the outcome measure, this study includes both mortality and life expectancy at birth, to ensure the model is well evaluated. Furthermore, our research uses more recent data up to year 2017.

Therefore, this research adopts the Poisson log bilinear model together with the original Lee-Carter model to forecast mortality rates and life expectancy at births of Malaysian males and females. The evaluation of these model is performed and the corresponding out-sample mortality and life expectancy at birth forecasts from both models are illustrated. Subsequently, the most accurate forecast values are applied to develop projected life table for Malaysia population.

Methodology

Data Description

Data that we use include Malaysian age-specific death rates and mid-population estimates by gender, from year 1970 to 2017 (48 years) and for ages between 0 to 75 years old. These mortality data are of excellent quality and have been provided by the Department of Statistics Malaysia (DoSM).

The Lee-Carter Model

In order to estimate out-sample and future mortality rates, first we adopt the Lee-Carter model (Lee & Carter, 1992) which is defined by the following equation:

$$\log[m_{x,t}] = a_x + b_x k_t + \varepsilon_{x,t} \tag{1}$$

where,

$m_{x,t} =$ central death rate at age of a person age x in year t
a_x = average of $\log[m_{x,t}]$ across years
b_x = relative speed of change at each age also known as age-component
k_t = index of the level of mortality at time t also known as time-component
$\varepsilon_{x,t}$ = residual at age x and time t with mean 0 and variance σ_t^2

This model applies two-stage estimation procedures. In the first stage, singular value decomposition (SVD) of $\log[m_{x,t}] - a_x$ is used to obtain estimates of b_x and k_t. These parameters are subject to the constraints of b_x values sum to unity and k_t values sum to zero as follows:

$$\sum_x b_x = 1 \tag{2}$$

$$\sum_t k_t = 0 \tag{3}$$

Then, in the second stage, the time series of k_t is re-estimated by refitting k_t to total observed deaths and the time series model, Autoregressive Integrated Moving Average (ARIMA) is used to forecast k_t

$$\hat{k}_t = k_{t-1} + d + e_t \tag{4}$$

where d is average annual change in k_t and e_t is uncorrelated error. Finally, to forecast age-specific mortality rate for females or males:

$$\log[\hat{m}_{x,t}] = a_x + b_x\hat{k}_t + \varepsilon_{x,t} \tag{6}$$

Poisson Log-bilinear Regression Model

We use the Poisson log-bilinear model as the alternative approach to estimate out-sample and future values of mortality. Because number of deaths is a count data, Brouhns et al. (2002) suggested that Poisson assumption appears to be suitable for this type for mortality data. The Poisson log-bilinear mortality forecasting model consider that

$$D_{x,t} \sim Poisson\ (E_{x,t}, \mu_x(t)) \tag{7}$$

where

$$\mu_x(t) = exp(a_x + b_x k_t)$$

The parameters a_x, b_x and k_t have the same meaning as in the original Lee- Carter model and subject to the same constraints. Instead of using SVD for estimating the parameters, this model's parameters are estimated by maximizing the log-likelihood based on equation (7) as follows:

$$L(a, b, k) = \sum D_{x,t}(a_x + b_x k_t) - E_{x,t} exp(a_x + b_x k_t) + constant \tag{8}$$

We follow Brouhns et al (2002) to use the iterative method to solve the bilinear terms in the equation (8). For this paper, we developed and executed the iterative procedures using R statistical programming. In contrast to the Lee–Carter model, the error applies directly on the number of deaths in the Poisson regression approach. Thus, there is no need for the second-stage procedure. The forecast of mortality index k_t is similar to the Lee–Carter methodology. Finally estimates of a_x and b_x together with forecasted k_t are used to forecast mortality rates and subsequently to generate other life table functions.

Once the mortality rates have been estimated, we use the observed mortality rates and the standard life table approach to estimate the corresponding life expectancy at births for Malaysian population.

Projected Life Table

In order to develop projected life table, the forecasts of mortality and other components described as below are needed. Lopez et al. (2001) described life table as a key summary tool for assessing and comparing mortality conditions in a population. A life table also known as mortality table or actuarial table. It represents the survival rates of people from a certain population. Other ways of explaining it, life table is a mathematical way to measure a populations longevity starting from a person's birth to the day they die. The projected life table consists of a few columns as follows:

i. ***Age***. Age is presented as variable x where x =0,1, 5,10, …, n where n is the maximum age of a person expected to live. The period of life or age interval between two exact ages stated in years can be denoted as $(x, x+n)$.

ii. ***Probability of dying***. This probability is presented as q_x which means the probability of dying between ages x and $x+1$. If the age is in t-year interval, the notation becomes ${}_tq_x$ which means the probability of dying between ages x and $x+t$. This column is the basis of life table where all the subsequent columns are derived from it.

iii. ***Number of surviving***. This variable is presented as l_x which shows the number of persons who survive to the beginning of each age interval. The l_x values are computed from the q_x values, which are successively applied to the remainder of persons still alive at the beginning of each age interval. The starting number of new-borns entered in any life table, l_0 , also known as radix of the life table.

iv. ***Number of dying***. This variable is presented as d_x which shows number of dying in each successive age interval. The number of dying for person age x within a year is $d_x = l_x - l_{x+1}$.

v. ***Person-years lived***. This variable is presented as L_x which shows the number of person-years lived within an age interval $(x, x+1)$. Each figure in this column represents the total time (in years) lived between two indicated birthdays by all those reaching the earlier birthday.

vi. ***Total number of person-years lived***. This variable is presented as T_x which shows the total number of person-years that would be lived after the beginning of the age interval $(x, x+1)$. T_x can be calculated as $Tx = Lx + T_{x+1}$.

vii. ***Expectation of life***. This variable is presented as e_x which shows the average number of years remaining to be lived by those surviving to that age, based on a given set of age-specific rates of dying. It is derived by $e_x = T_x/l_x$.

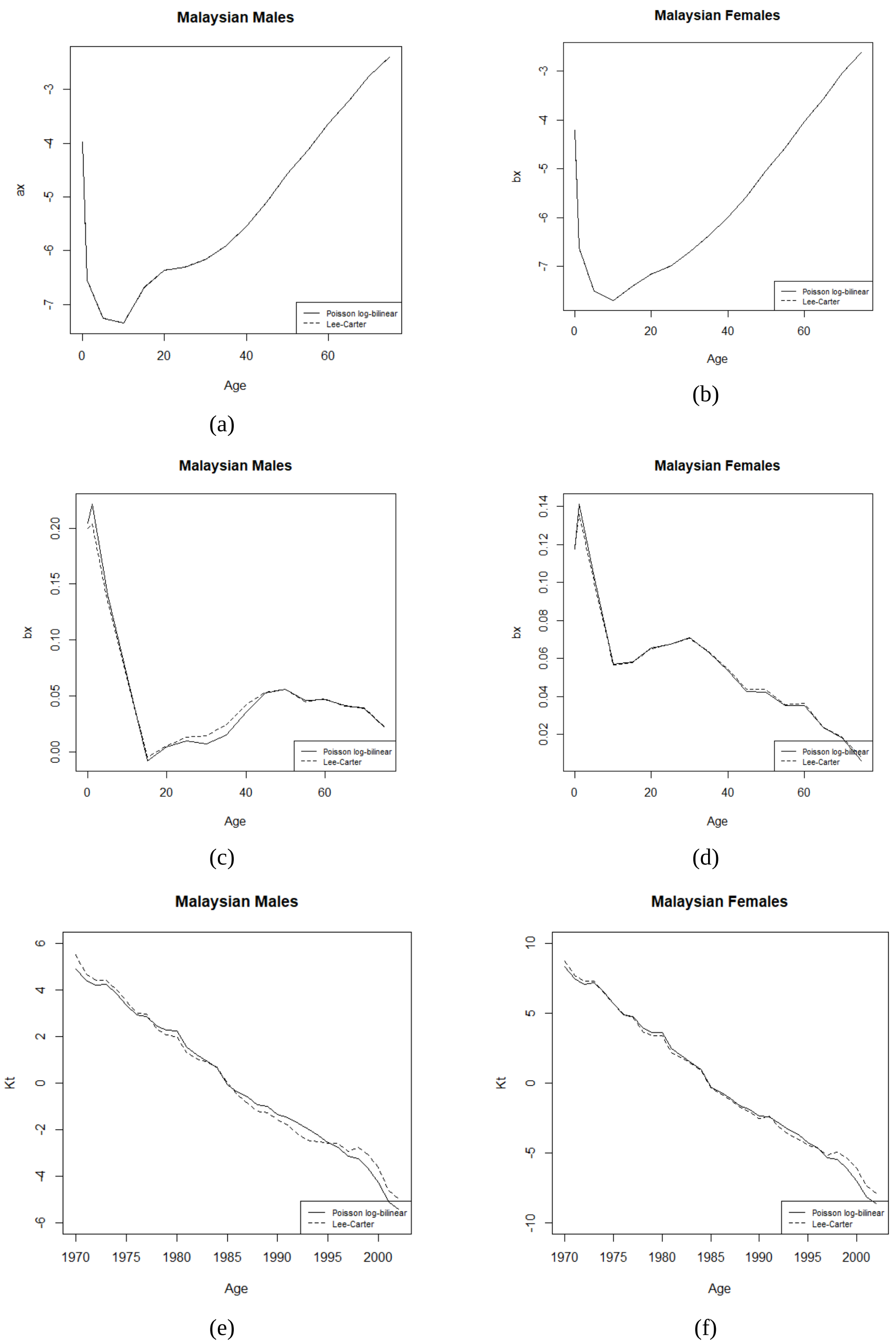


Figure 1: The Estimations Of The Lee-Carter Model (-----) And The Poisson Log-Bilinear (   ) Parameters a_x, b_x And k_t For Malaysian Males And Females.

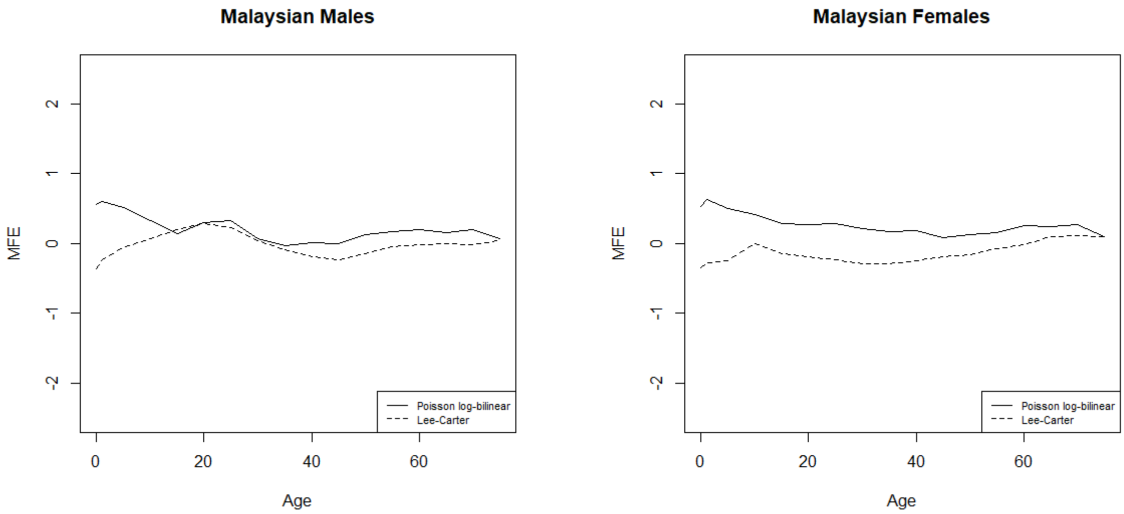
Malaysian Mortality Rate Modelling

Estimation of Parameters

We divide our data from 1970 to 2017 into two parts, which are the 30-year in-sample data from 1970 to 1999 and the 18-year out-sample data from 2000 to 2017. The division of these data into two parts follows the rule suggested by Lazim (2012) in which at least one-quarter of the observed data is enough for evaluation of out-sample forecasts. The in-sample data are then fitted into two different models, which are the Lee-Carter and the Poisson log-bilinear regression model. Once data wrefitted into the models, the parameters of the models will be estimated.

For the comparison purposes, we present the estimated parameters of the Lee-Carter model (dashed lines) and the Poisson log-bilinear model (solid lines) in the Figure 1. The Figure 1 displays the estimated a_x, b_x and k_t from both models for Malaysian males and females. Results show that although different approaches were used to estimate parameters, the patterns of parameters from both methods show almost similar.

The a_x describes the general shape of mortality by different ages in terms of the logarithm of the geometric mean of mortality rates over historical years. The a_x estimates for Malaysian mortality are approximately same between the two models. The b_x term accounts for different effect of time at each age and it explains how the rates decline in response to change in k_t. The k_t explains the mortality change over time. From the Figure 1, we can see that the k_t estimates are linearly decreasing over the years, indicating a consistent improvement in Malaysian mortality rates. Using these estimated a_x and b_x together with forecasted $\hat{k}_t$, the out-sample mortality forecasts are estimated by applying formulas described in the equation 1 and equation 8.



(a) (b)

Figure 2: The Out-Sample Mean Forecast Errors (Mfes) of The Mortality Rates From The Lee-Carter Model (-----) And The Poisson Log-Bilinear ( )

Evaluation of Mortality Models

We plot the mean out-sample forecast errors (MFEs) of Malaysian males and females mortality rates as in the Figure 2. The Figure 2a shows that the mean forecast errors (MFEs) of both models were generally fluctuated around zero for Malaysian males age 30 and above. While the Poisson log-bilinear model overestimates the Malaysian male infants, the Lee-Carter model underestimates the mortality of that group. For females (See Figure 2b), the Poisson log-bilinear model consistently overestimates the mortality of Malaysian females whereas the Lee-Carter model mostly underestimates mortality rates.

The accuracy of the out-sample mortality forecasts from the two models are also evaluated using the Mean Absolute Percentage Forecast Errors (MAPFEs) measure and results are presented in the Table 2. The Table 2 shows that the Lee-Carter model provide more accurate forecast values than that of the Poisson log-bilinear model consistently in majority of age groups including those age 0 to 25 years old and older age group between 55 to 75 years old. These lead to the Lee-Carter model out-performs the Poisson log-bilinear model for males and females in terms of overall (average is taken over age groups). The Poisson log-bilinear model substantially provide higher errors than the Lee-Carter model, for children ages 1 to 10 years old and for elderly age between 55 to 70 years. These high errors led to the Poisson log-bilinear model become less accurate than the Lee-Carter model in overall. Our results consistent with Sapri et al. (2016) that proved the extended version of the Lee-Carter model which is the Poisson log-bilinear model does not improve the forecast accuracy of the original Lee-Carter model for Malaysian mortality data.

Table 2: Mean Absolute Percentage Forecast Errors (Mapfes) of Log Mortality Rates by Age Groups. Mean is Taken Over Years

	Poisson log-bilinear model		**Lee-Carter model**	
Age	**Male (%)**	**Female (%)**	**Male (%)**	**Female (%)**
0	10.91	10.50	**8.41**	**7.99**
1	7.70	7.87	**3.33**	**4.21**
5	6.23	5.90	**1.67**	**2.87**
10	4.10	4.94	**1.38**	**0.86**
15	2.01	3.53	**2.92**	**1.76**
20	4.37	3.63	**4.18**	**2.38**
25	4.96	3.86	**3.30**	**3.01**
30	1.68	3.70	**1.57**	4.04
35	0.61	3.33	1.55	4.18
40	1.19	3.64	3.39	3.92
45	1.35	2.04	4.41	3.27
50	2.73	2.82	2.95	3.08
55	3.86	3.47	**1.43**	**1.56**
60	5.20	5.76	**0.88**	**0.81**
65	4.36	6.20	**1.21**	**2.71**
70	6.44	7.83	**1.44**	**3.24**
75	2.82	3.56	**2.09**	**3.37**
Overall	4.15	4.86	**2.71**	**3.13**

Next, we evaluate the two mortality models using different outcome measure which is the life expectancy at births. Table 3 shows that the Lee-Carter model provide smaller out-sample MFEs and MAPFEs of life expectancy at births for Malaysian females compared to the Poisson log-bilinear, where the mean is taken over the years. For males, although the Lee-Carter model is less accurate than the Poisson log-bilinear model when using MFEs, the model is superior than the Poisson log-bilinear model when using MAPFEs, leading to the Lee-Carter model works better than its improved version in terms of overall. Thus, the outcomes of this research provide evidence that the Lee-Carter model is more accurate than that of the Poisson log-bilinear to forecast Malaysian mortality rates and life expectancy at births.

Hence, using the most accurate method which is the Lee-Carter model, we construct the Malaysian projected life table for future years. We estimate the projected life table up to year 2030 that is when Malaysia is expected to become an ageing nation. Table 4 and Table 5 illustrate the 2030 projected life tables for Malaysian males and females respectively. The estimated life expectancy at birth from the projected life tables show that the life expectancy of a newborn is 76.22 for males and 82.23 for females. These values are 6% and 7% higher than the respective life expectancy at births in year 2010. This shows that the mortality improvement trend will continue to occur in the future hence it is crucial to incorporate the mortality improvement when pricing policies with long term benefits. Countries like USA has already included the mortality improvement (which estimated from the Lee-Carter model) in their insurance pricing (Wylde 2015). Hence, it is not too late for Malaysia to follow suit.

Table 3: Mean Forecast Errors (Mfes) And Mean Absolute Percentage Errors (Mapfes) of Life Expectancy at Births. Mean is Taken Over Years

	Poisson log-bilinear model		**Lee-Carter model**	
	Male	**Female**	**Male**	**Female**
MFEs	-0.0569	1.0624	-0.159	**0.7857**
MAPFEs	0.59	1.29	**0.57**	**1.00**

Conclusions

This paper evaluates the out-sample forecast accuracy of the Lee-Carter model and its revised version, the Poisson log-bilinear model, using two different outcomes---mortality rates and life expectancy at births. The out-sample forecast errors showed that the Lee-Carter model remained valid and consistently provided more accurate forecast values than that of the Poisson log-bilinear model for Malaysian mortality rates and life expectancy at births. The application of the most accurate model which is the Lee-Carter model was extended to develop the projected Malaysian life tables up to year 2030. The life expectancy at birth will increase as a result from a continues mortality improvement over the future years. For future works, the development of methods to adjust Malaysian population projected life table to fit the mortality experience of lives assured would provide a great contribution to insurance field.

Table 4: Projected Malaysian Males Life Table 2030

x	m_x	q_x	l_x	d_x	L_x	T_x	e_x
0	0.0035	0.0034	1.000	0.0034	1.00	76.26	76.26
1	0.0002	0.0009	0.9966	0.0009	3.98	75.27	75.53
5	0.0002	0.0010	0.9956	0.0010	4.98	71.28	71.59
10	0.0003	0.0016	0.9947	0.0016	4.97	66.31	66.66
15	0.0011	0.0054	0.9931	0.0053	4.95	61.34	61.76
20	0.0012	0.0062	0.9878	0.0061	4.92	56.38	57.08
25	0.0013	0.0064	0.9817	0.0063	4.89	51.46	52.42
30	0.0017	0.0087	0.9754	0.0085	4.86	46.57	47.74
35	0.0023	0.0114	0.9669	0.0110	4.81	41.71	43.14
40	0.0031	0.0152	0.9559	0.0145	4.74	36.90	38.61
45	0.0044	0.0217	0.9413	0.0204	4.66	32.16	34.16
50	0.0067	0.0328	0.9209	0.0302	4.53	27.50	29.86
55	0.0107	0.0523	0.8907	0.0466	4.34	22.97	25.79
60	0.0167	0.0804	0.8441	0.0678	4.06	18.63	22.07
65	0.0266	0.1250	0.7763	0.0970	3.65	14.57	18.77
70	0.0435	0.1970	0.6792	0.1338	3.08	10.92	16.08
75	0.0695	1.0000	0.5454	0.5454	7.85	7.85	14.39

Table 5: Projected Malaysian Females Life Table 2030

x	m_x	q_x	l_x	d_x	L_x	T_x	e_x
0	0.0030	0.0030	1.000	0.0030	1.00	82.83	82.83
1	0.0002	0.0008	0.9970	0.0008	3.99	81.83	82.08
5	0.0001	0.0007	0.9962	0.0007	4.98	77.85	78.15
10	0.0002	0.0009	0.9955	0.0009	4.98	72.87	73.20

15	0.0003	0.0014	0.9946	0.0014	4.97	67.89	68.26
20	0.0003	0.0016	0.9932	0.0016	4.96	62.92	63.35
25	0.0004	0.0019	0.9916	0.0019	4.95	57.96	58.45
30	0.0005	0.0026	0.9897	0.0026	4.94	53.01	53.56
35	0.0008	0.0040	0.9871	0.0040	4.93	48.07	48.69
40	0.0013	0.0065	0.9831	0.0064	4.90	43.14	43.88
45	0.0023	0.0112	0.9767	0.0110	4.86	38.24	39.15
50	0.0037	0.0184	0.9657	0.0178	4.79	33.38	34.58
55	0.0062	0.0307	0.9479	0.0291	4.67	28.60	30.17
60	0.0101	0.0494	0.9188	0.0454	4.49	23.93	26.04
65	0.0176	0.0846	0.8734	0.0739	4.19	19.44	22.26
70	0.0320	0.1486	0.7995	0.1188	3.71	15.25	19.08
75	0.0590	1.0000	0.6807	0.6807	11.54	11.54	16.95

References

Antonio, K., & Bardoutsos, K. (2015). Bayesian Poisson log-bilinear models for mortality projections with multiple populations. *European Actuarial Journal*, *5*(2), 245-281.

Booth, H., Tickle, L., & Smith, L. (2005), Evaluation of the variants of Lee-Carter method of forecasting mortality: a multi-country comparison. *New Zealand Population Review 31(1)*, 13 34

Brouhns, N., Denuit, M., & Vermunt, J. K. (2002). A Poisson log-bilinear regression approach to the construction of projected lifetables. *Insurance: Mathematics and Economics*, *31 (2002)*, 373–393.

Chavhan, R.N., & Shinde, R.L. (2016). Modelling and forecasting mortality using the Lee-Carter model for Indian population based on decade-wise data. *Sri Lankan Journal of Applied Statistics*, 17-1.

Department of Statistics Malaysia (2017), *Abridged Life Tables, Malaysia, 2015-2017* Retrieved from: https://www.dosm.gov.my/v1/index.php?r=column/pdfPrev&id

Heligman, L., & Pollard, J. H. (1980). The age pattern of mortality. *Journal of the Institute of Actuaries*, *107*(1), 49-80.

Husin, W. Z. W., Zainol, M. S., & Ramli, N. M. (2015). Stochastic models in forecasting Malaysian mortality: The lee-carter model and its extension. *Advanced Science Letters*, *21*(6), 1850-1853.

Hyndman, R.J., Booth, H., & Yasmeen, F. (2013). Coherent mortality forecasting: the product-ratio method with functional time series model. *Demography*, *50*(1), 261-283.

Ibrahim, R.I., Ngataman, N., & Abrisam, W.N.A. (2017). Forecasting the mortality rates using Lee-Carter model and Heligman-Pollard model. *Journalof Physics: Conference Series, 890* 012128.

Lazim, M. A. (2012), Introductory Business Forecasting: a practical approach, third edn, *Evaluating the models* (p.309-340), UiTM Press.

Lee, R. D., & Carter, L. R. (1992), Modelling and forecasting U.S mortality, *Journal of the American Statistical Association 87(419)*, 659-671.

Life Insurance Association of Malaysia. (n.d.). *Briefing on new mortality table 1999 to 2003*. Retrieved from: https://www.liam.org.my/index.php/newsmedia-room/e-magazine/657

Lopez, A. D, Salomon, J. A, Ahmad, O. B., Christopher J. L, & Mafat, Doris (2001). *Life tables for 191 countries: data, methods and results.* Geneva: World Health Organization.

Ngataman, N., Ibrahim, R. I., & Yusuf, M. M. (2016). Forecasting the Mortality Rates of Malaysian Population Using Lee-Carter Method. *American Institute of Physics, 1750(1).*

Renshaw, A., & Haberman, S. (2003), Lee-Carter mortality forecasting: a parallel generalized linear modelling approach for England and Wales mortality projection, *Journal of the Royal Statistical Society 52*, 119-137.

Sapri,N.N.F.F., Ramli,N.M., Ghani,N.A.M., & Zakiyyatussariroh,W.H.W (2016). Projected Malaysia mortalit rates based on the Lee-Carter and Poisson log-bilinear models, *Advanced Science Letter 22*(12), 4065-4068.

Shair, S.N. (2017). *Three essays on Malaysian population ageing* (Doctoral thesis). Available from Australasian Digital Theses database:Available at: http://hdl.handle.net/1959.14/1261296.

Wylde, D. (2015). US mortality improvement: analysis and methodology. Retrieved from SCOR website: http://www.scorgloballifeamericas.com/en-us/knowledgecenter.