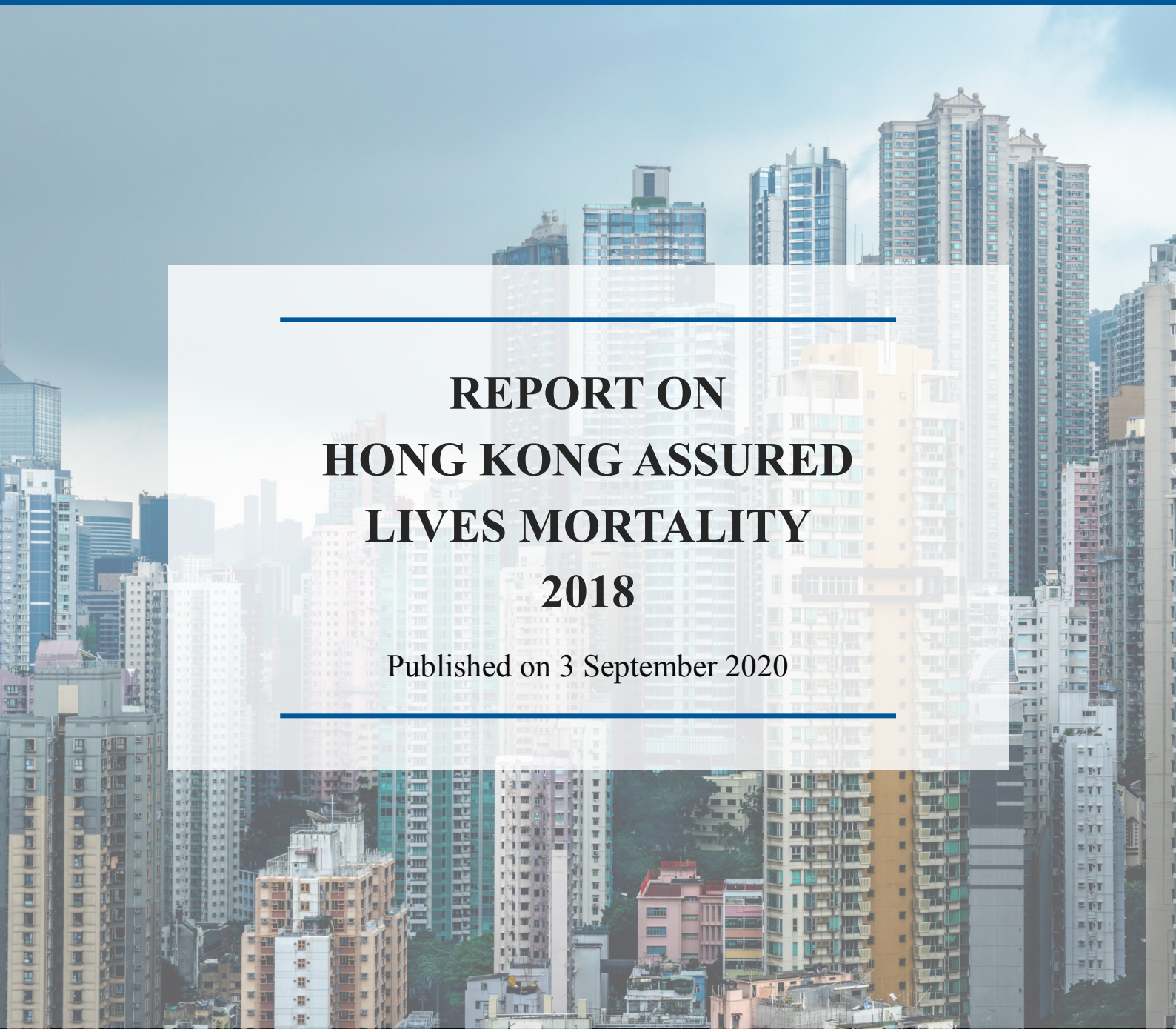

REPORT ON HONG KONG ASSURED LIVES MORTALITY 2018

Published on 3 September 2020

ACTUARIAL SOCIETY of HONG KONG
香港精算學會

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Table of Contents

1 Introduction

The Actuarial Society of Hong Kong Council has great pleasure presenting its latest full report on the mortality of assured lives in Hong Kong. This new mortality table is named as Hong Kong Assured Lives Mortality 2018 (HKA18). It aims to serve as a better indication for industry on both pricing and valuation purpose.

This report provides an overview of the assured lives experience in Hong Kong for the period from 2010 to 2017. It based on data collected from seventeen Hong Kong life insurance companies that represent the majority of industry from business volume perspective. This report examines the mortality experience under standard fully underwritten individual life insurance. It excludes group policies and substandard cases as a fair proxy for individual mortality rates.

Given that most of the resources have been devoted to come up this new mortality table, we focus our analysis on the fully underwritten individual life insurance in this study. For other underwriting approaches like simplified underwritten or guaranteed issued products, we will proceed this as an area of improvement in the future analysis.

Taking this valuable opportunity, the Council would like to express its sincere gratitude to all participating companies who have made considerable contributions leading to the success of this work. We would also like to acknowledge the contribution of the Life Committee of the Actuarial Society of Hong Kong for their review of this report. Their contribution is very much appreciated. The participating companies are listed below.

1. AIA International Limited
2. AXA China Region Insurance Company Limited
3. BEA Life Limited
4. Blue Insurance Limited
5. BOC Group Life Assurance Company Limited
6. Chubb Life Insurance Company Ltd.
7. Fubon Life Insurance (Hong Kong) Company Limited
8. Hang Seng Insurance Company Limited
9. HSBC Life (International) Limited
10. Manulife (International) Limited
11. Prudential Hong Kong Limited
12. Standard Life (Asia) Limited
13. Sun Life Hong Kong Limited
14. Tahoe Life Insurance Company Limited
15. Transamerica Life (Bermuda) Ltd
16. YF Life Insurance International Ltd
17. Zurich Life Insurance (Hong Kong)

This report is available in electronic format from the Actuarial Society of Hong Kong's website http://www.actuaries.org.hk. Should there be any inquiries on the study of this report, please contact us via info@actuaries.org.hk.

Simon Lam
ASHK Life Committee
September 2020

2 Executive summary

This report is based on the insured experience collected by the Actuarial Society of Hong Kong (ASHK) for Hong Kong insurance market, with an observation period from 2010 to 2017. Seventeen representative companies participated and provided the relevant data of their life insurance products. According to the statistics published by the Insurance Authority, these seventeen participating companies represented 86% of the individual life policies in-force in Hong Kong at the end of 2017. The majority of this coverage demonstrates credibility of this study.

We have completed extensive validation of the data although ultimately we are reliant on the contributing companies for the accuracy of the survey results.

The key output of this report is the new mortality table for Hong Kong market, which is closer to more recent industrial experience. We decided to name this new mortality table as Hong Kong Assured Life Mortality 2018 (HKA18). We hope that this new mortality table could serve as an updated reference for actuarial exercises particularly under the coming Risk-Based Capital framework.

In this report, a comparison between HKA18 and Hong Kong Assured Life Mortality 2001 (HKA01) was conducted. The major findings are summarised as below:

- The expectation of life at birth increased from 78.6 and 83.2 to 82.5 and 86.8, for males and females respectively compared to HKA01.
- The observation of cause of claims are summarised as below:
  - The proportion of deaths due to accidents decreased for all age bands;
  - For the age group “under 25 years old”, the proportion of deaths caused by cancer increases notably;
  - For age groups between 25 and 45 years old, the cardiovascular diseases account for a larger share for male, compared with prior studies;
  - For age groups over 45 years old, there is a significant increase in the proportion of diseases of the respiratory system.

Other than the derivation of the new mortality table and the analysis of causes of death claims, we included the experience comparison by a variety of dimensions such as mortality differentiation between smoker and non-smoker, selection effect and etc.

The limitation of the new mortality table is listed in section 7 – Use of this Report. Particularly, this new mortality table is formulated based on the whole industrial mortality experience which could be significantly different from the mortality experience of particular insurer. Actuaries using these tables should therefore consider the need of any adjustment so that the mortality used is appropriate for the purpose.

3 Data

3.1 Overview of Data

3.1.1 Scope of Data

The study of this report covers eight (8) years' period from 1 January 2010 to 31 December 2017. The scope of data includes all policies under individual life policies with standard underwritten class which provides pure mortality coverage without other accelerated benefits, e.g. accelerated critical illness benefit that will reduce the sum assured of death benefit after the claim payment. Given that not many insurance companies could provide an indicator to separate data between Hong Kong and non-Hong Kong residents, this study scope covered both Hong Kong and non-Hong Kong residents based on the existing business mix. Simultaneously, these policies have been in-forced during the study period, including:

- Issued before and still in-forced at the beginning of study period, which may be surrendered, lapsed, matured, claimed during the study period, or still in-forced at the end of the study period; and
- Issued during the study period.

Particularly, it excludes group life policies and any substandard individual life policies to derive the pure mortality rates for standard individual life policies.

3.1.2 Required Data Input

The mortality study period is from 1 January 2010 to 31 December 2017. The mid-point of the mortality study is the end of the year 2013. In this new mortality study, below key information of all individual life policies (joint life excluded) was requested on a per-policy basis:

- Age – 0 to 100 under Age Last Basis
- Gender – male or female
- Smoking status – smoker, non-smoker or aggregate
- Duration – 0, 1 and 2+; defined as curtate duration since policy inception
- Cause of death

Data were collected in 2018 to capture incurred death claims reported after the end of the study period. Incurred But Not Reported (IBNR) claims were considered and included in the mortality table derivation based on the claims lag observed from the actual data and the data cut-off dates of individual companies. Please refer to Section 4.1 for details of IBNR calculation.

3.2 Overview of Data Gathered

3.2.1 Penetration of Survey

Seventeen companies delivered data for this survey. According to the statistics published by the Insurance Authority, these seventeen participating companies represented 86% of the individual life policies in-force in Hong Kong at the end of 2017. The majority of this coverage demonstrates credibility of this study.

Total in-force policies of 17 participating companies according to the Insurance Authority report 2017 (1)	Total in-force policies in Hong Kong according to the Insurance Authority report 2017 (2)	HKA18 study Penetration (3) = (1) / (2)
10,781,453	12,549,354	86%

Table 3.2.1 – Penetration of HKA18 Study

3.2.2 Data by Company

The majority of the participating companies provided data for the full period in the specific format requested. It allowed a large proportion of the data collected to be used as the basis for this report. However, not all companies provide the cause of claims. All participating companies provided the in-force data on per-policy basis.

Out of these seventeen participating companies, one company could only provide the in-force data and claim records of the period from 2016 to 2017 with no duration 2+ policies. The relevant data were not used in the derivation of this new mortality table. However, these policies were taken into account when we performed the analysis of the impact on mortality rates by a variety of dimensions. All other companies provided policies and claims with duration 2+ from 2010 to 2017.

3.2.3 Comparison of Data with HKA01

Compared with data collected for HKA01 mortality study, both the number of exposure and the number of claims increased significantly, where exposure size is 177% more than that in HKA01 mortality study. Although only 8 years of data were collected compared to 10 years for HKA01, the credibility of this study is higher than that of last study.

Gender	Duration	In-force Exposure		Deaths Claims	
		HKA18	HKA01	HKA18	HKA01
Male	0	1,537,563	1,692,291	958	850
	1	1,354,494	1,385,409	1,187	898
	2+	19,410,281	6,718,224	40,403	7,319
Female	0	1,940,041	1,487,363	850	361
	1	1,759,241	1,200,410	1,213	383
	2+	21,933,406	4,851,170	31,758	3,006
Total		47,935,026	17,334,867	76,369	12,817

Table 3.2.3 – Comparison of exposures and claims between HKA01 and HKA18

3.3 Analysis of In-Force

3.3.1 In-force by gender

Among all exposures with duration 2+, 47% are male, and the rest 53% are female. Compared with the 58% of males and 42% of females observed in HKA01 mortality study, there was a significant decrease in male proportion while the female proportion rose notably.

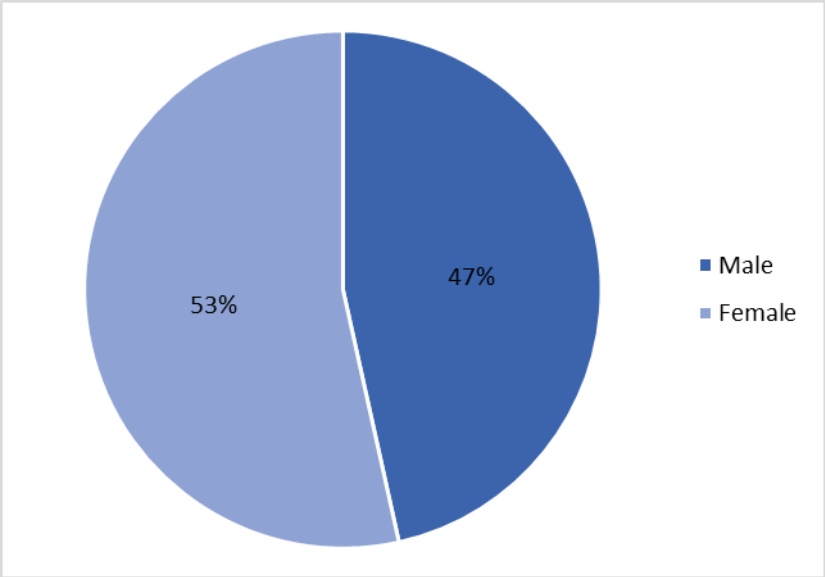

Figure 3.3.1 - Breakdown of duration 2+ lives by gender

3.3.2 In-force Age Distribution

Similar to the distribution observed in HKA01 study, the exposure amount with duration 2+ peaks at the middle ages and the shape of both genders are quite close. However, the peak ages increased for both males and females, and the peak age is 51 for males and 49 for females in the HKA18 study, while the number of exposures peaked at age 36 for males and age 34 for females in HKA01 study. Moreover, the shape for ages 5 to 20 is considerably different from the prior study. For this age range from 5 to 20, the curve goes up in HKA18 study, while it went down in the prior HKA01 study.

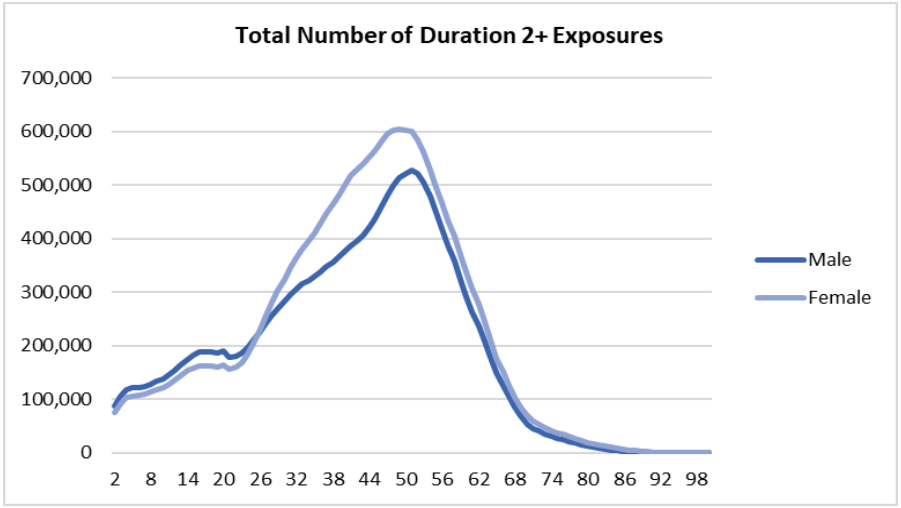

Figure 3.3.2 - Age distribution of duration 2+ policies during 2010 to 2017

With the significant increase in peak age as per the above graph, it should be attributed to the difference of study period between these two studies. The mid-point of HKA01's data is at year end of

1995 while mid-point of HKA18's data is at year end of 2013. The difference in the study period of eighteen (18) years should roughly account for the difference in their peak age.

Regarding the age distribution of the new business written during the period from 2010 to 2017, the proportion of policies issued by insureds aged 40 to 60 significantly increased. This might be attributed to the more friendly underwriting rules with higher maximum issue age. Meanwhile, saving plans and unit-link products make up a remarkable portion of all life insurance products, and these kinds of products require a more stable and higher income, which is one of the characters of the insured aged 40 to 60. That could be one of reasons to explain for this observation.

3.4 Age Distribution of Death Claims

Below graph indicates that a greater proportion of life claims were from males, which is consistent with the observation in the ASHK01 study. The median age of the claims increased to 60 for both male and female insured, while 42 and 39 for males and females respectively in HKA01 study. This notable change is consistent with the trend of the exposure's age distribution.

The following graph also shows the scarcity of claim data of insured aged 25 below and aged 90 above.

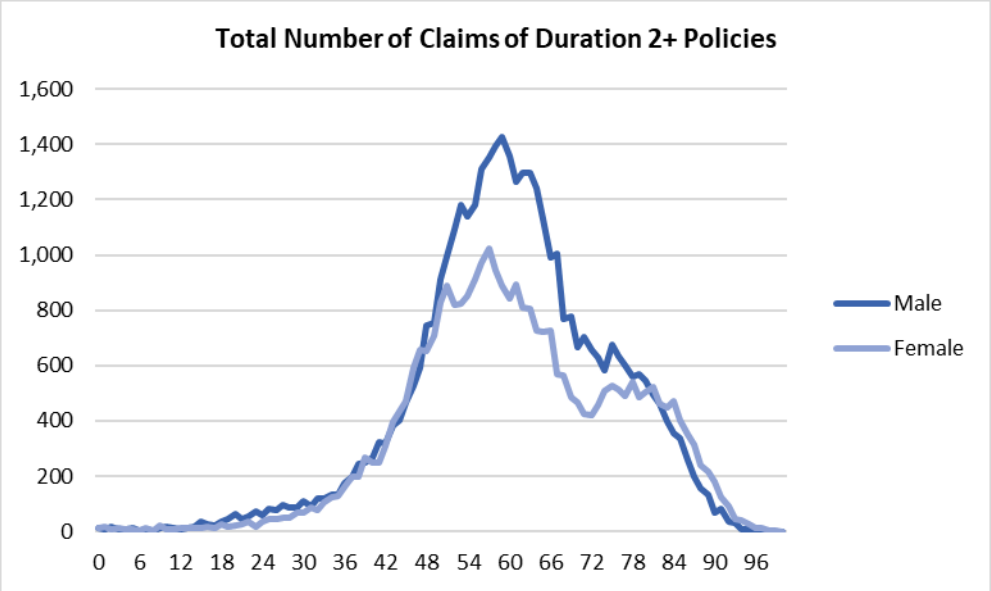

Figure 3.4 - Age distribution of claims during 2010 to 2017

3.5 Data Validation

We performed the checking and standardized all data fields according to our prescribed data template, including but not limited to the followings:

- <Issue age> is within 0 - 100
- <Premium Payment Mode> falls into A / H / Q / M / S
- <Smoking status> falls into NS / S / A / U
- <Policy status> falls into IF / L / S / M / D

After the standardization of data fields are completed, we performed additional checking based on the meaning of the data fields, including but not limited to the followings:

- Exclude joint life policies
- Exclude plans which only provide accident death benefit coverage
- Check the consistency of data fields between exposure and claim database
- Check all records with <Policy status> = "D" (I.e. Death) in the exposure database could be found with the corresponding claim records in the claim database, and vice versa
- Check <Death Claim Incurred Date> is before <Death Claim Reported Date> and <Death Claim Reported Date> is before <Death Claim Payment Date>

4 Methodology for New Industrial Mortality Table

To derive new industrial mortality table HKA18, the data we used met below criteria:

- **Only standard risks were used**: Over 98.4% of policies provided by all participating companies are standard lives.
- **Policies with duration 2+ were adopted only**: For duration 2+ policies, the selection effect from underwriting at the date of inception should be minimal. Therefore, they are more suitable for pricing and reserving for long-term business.
- **Experience of full underwritten policies was considered only**: As the majority of the inforce policies were full underwritten in Hong Kong market, we apply the full underwritten policies to derive HKA18. For the avoidance of doubt, full underwritten policies refer to those policies underwritten through the full underwriting form. It includes both classes of insureds which are underwritten with and without medical check-up.
- **Data provided by all participating companies for the period from 2010 to 2017 was used**: The full data set is used to maximize the credibility.

4.1 Volatility Adjustment

The crude mortality rates were calculated by using the experience of standard risks with duration 2+ only. The IBNR was also included in the calculation, where IBNR was calculated based on the time lag between Death Claim Incurred Date and Death Claim Reported Date for each company. Chain Ladder Method was adopted. The number of IBNR distributes around 1% of total incurred death claims. Since we collected 2017 year end's data at the end of 2018, the claim has almost run off after the collection period.

To avoid any potential under-pricing or under-valuation due to statistical fluctuation in crude rates, we applied volatility adjustment to address this concern. The detailed methodology is described as follows.

According to the Central Limit Theorems, the distribution of the sample means will be approximately normally distributed when sufficiently large random samples are available. Thus, the distribution of the crude rate at age x is approximately normally distributed with mean q_x and variance $\frac{q_x \times (1-q_x)}{E_x}$, where q_x is the crude rate at age x and E_x is the exposure count at age x. Considering the volatility risk of the crude rates, we used the upper limit of the 70%[1] confidence interval of the crude rates for all ages for the next graduation step to avoid any potential under-pricing or under-valuation due to statistical fluctuation. The rates before graduation were capped at 115%[2] of crude rates, i.e., we used

[1] We tested seven (7) confidence levels ranged from 70% to 98% and finally choose 70% confidence interval due to the more reasonable volatility adjustments on crude rates.

[2] To avoid the high volatility caused by small sample size, we proposed to cap the rates at 115% of crude rates in this study. For most of the ages between 2 to 85, the volatility is within 15%.

$q_x + Min\left(z_{\frac{\alpha}{2}}\sqrt{\frac{q_x \times (1-q_x)}{E_x}}, 0.15q_x\right)$ in the next graduation step. The volatility adjustments were applied to all ages and the adjustment level was based on the sample size of each age (I.e. The higher the sample size of the specific age, the lower the adjustment, and vice versa).

4.2 Graduated and Crude Mortality Rates (for ages 2 to 85)

Graduation is the process to obtain smoothed mortality rates from crude mortality rates by using certain models. As compared to HKA01 report, where age 2 - 70 are chosen as the crude mortality rate for graduation, we observed that the number of claims for elder age up to age 85 demonstrated reasonable credibility. Therefore, we decided to choose the crude mortality rate from age 2 up to age 85 for graduation. Below table shows claim count (duration 2+, full underwritten) for ages 71 to 85 in HKA18 versus HKA01 report for your easy reference.

	HKA18		HKA01	
Age	M	F	M	F
71 – 75	2,475	1,518	258	197
76 – 80	2,322	1,897	125	112
81 – 85	1,700	1,892	65	20
Total	6,497	5,307	448	329

Table 4.2 – Number of Claims (duration 2+, full underwritten) for ages 71 to 85 in HKA18 versus HKA01

In this study, we have applied the natural cubic spline graduation with variable knots for ages 2 to 85. The graduation method is described in appendix 8.4.

To illustrate the smoothness and fitness for the graduated rates, below please find the comparison between graduated rates and crude rates. The statistic of log of 1000 * qx is used for the purpose of visualization.

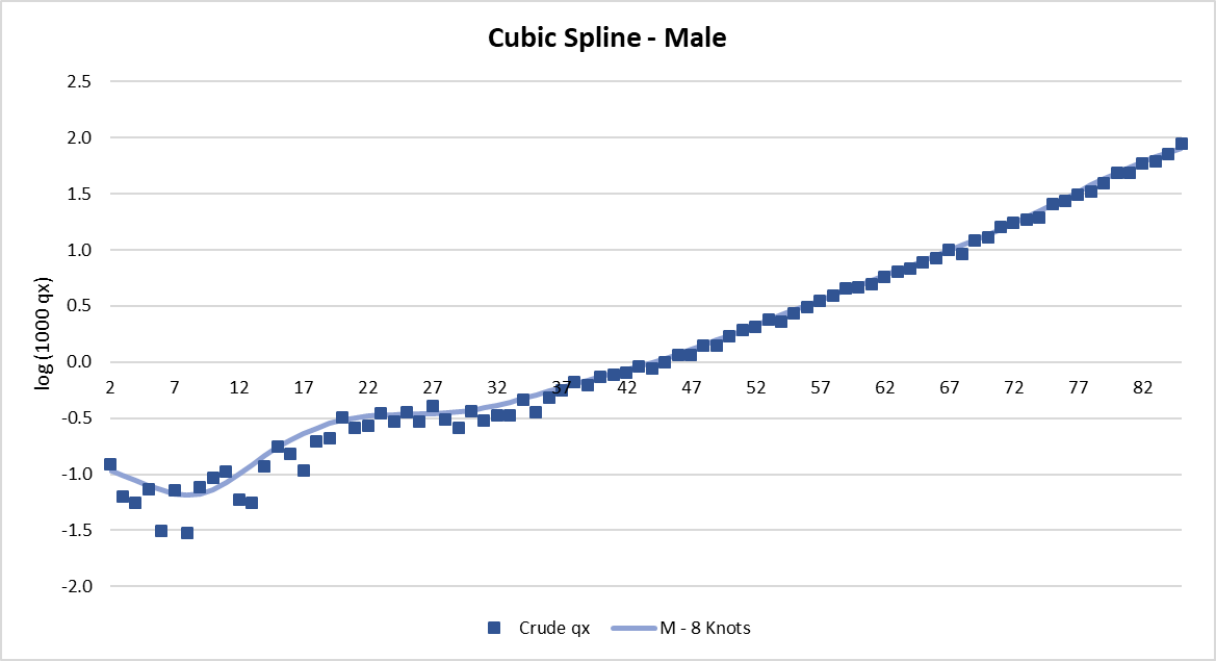

Figure 4.2.1 - Comparison between the graduated rates and the crude rates for males

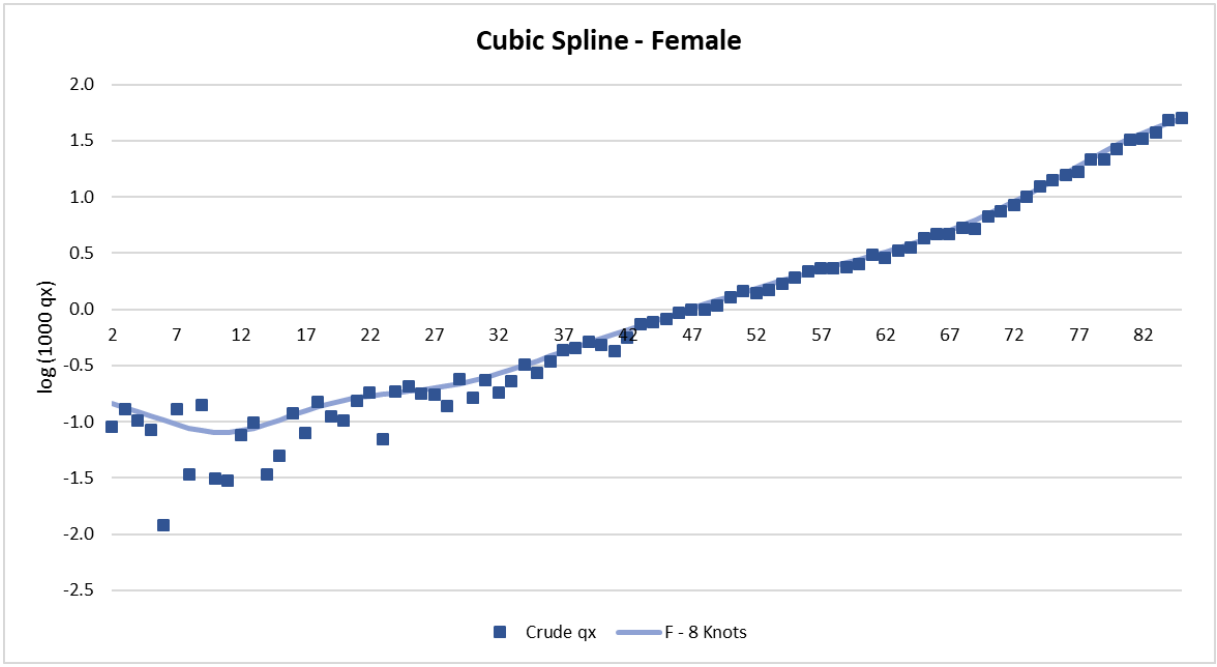

Figure 4.2.2 - Comparison between the graduated rates and the crude rates for females

4.3 Low and high ages (ages below 2 and above 85)

The actual deaths for the ages 0 and 1 were far below the expected. Thus, we referred to the population infant mortality rates from the Hong Kong Annual Digest of Statistics 2018 edition issued by Census and Statistics Department of Hong Kong SAR while determining the rate level, which aligned with the methodology used by HKA01 report. The final assumption for age 0 mortality rate was set as the average late-neonatal plus post-neonatal (7 days - under 1 year) mortality rate from 2010 to 2017. The expected number of claims per one hundred thousand under the new mortality table is as below.

	Expected Claim based on HKA01		Expected Claim based on HKA18	
Age	M	F	M	F
0	100	100	93	80
1	26	33	20	32

Table 4.3.1 - Expected number of claims per one hundred thousand for insureds aged below 2

Due to the sparse data observed for the elder aged above 85, the graduation method could not be extended further. Below table shows exposures (duration 2+, standard risk, full underwritten) in the cleaned databases of HKA18 for ages above 85 for your easy reference.

Gender	Age 85+	Percentage of Total Exposure (duration 2+, standard risk, full underwritten)
M	7,994	0.06%
F	18,339	0.13%

Table 4.3.2 - Number of exposures (duration 2+, standard risk, full underwritten) for insureds aged above 85

Similar to HKA01 report, extrapolation was performed for high-age mortality rates. As we received the relatively suitable amount of data until age 85, we decided to extrapolate the mortality rate starting from ages 85 to age 100. To calibrate the extrapolation, crude rates for ages from 60 to 85 were applied. Ultimately, Gompertz model was selected for both male and female extrapolation. For the rationale to

select Gompertz model, please refer to section 8.4 - Graduation methodology. Please find the charts comparing the crude rates and the extrapolated mortality rates for these high ages for your reference.

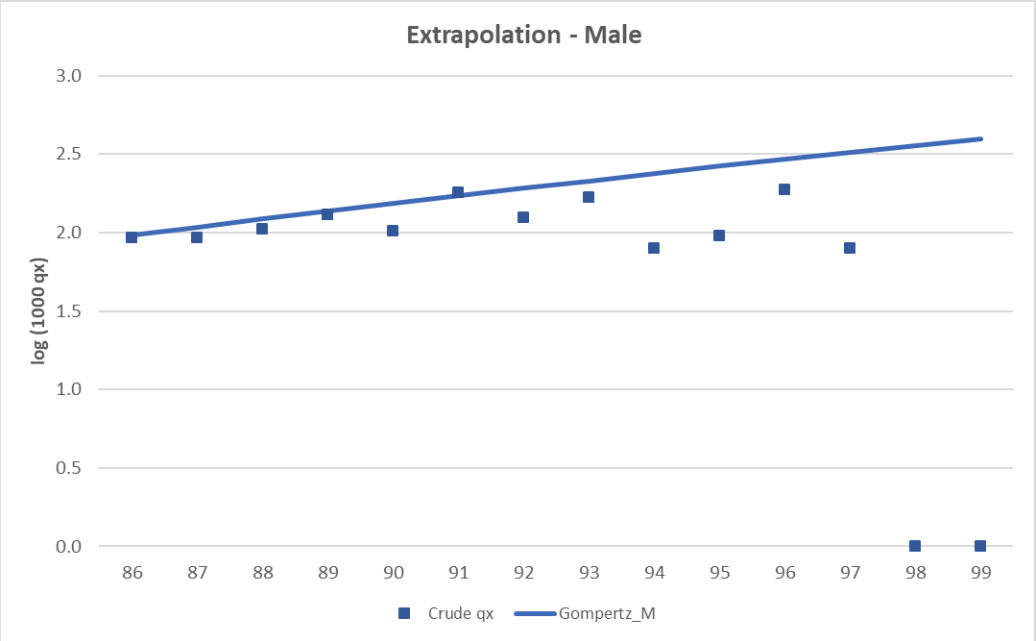

Figure 4.3.1 – Comparison between the crude rates and extrapolated rates for males

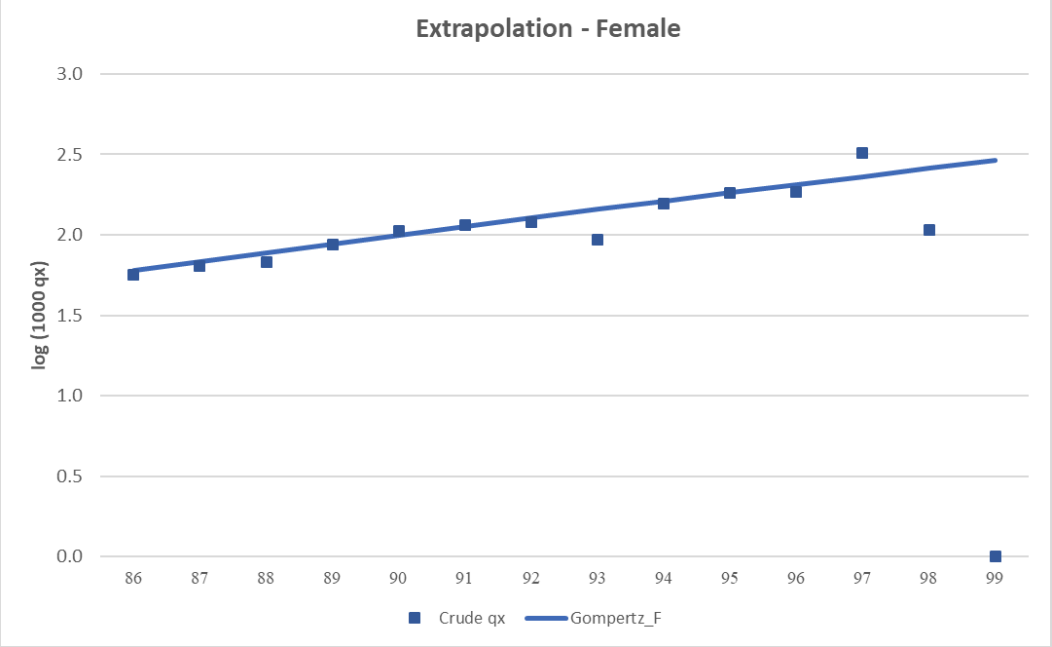

Figure 4.3.2 – Comparison between the crude rates and extrapolated rates for females

4.4 Comparison between mortality rates from HKA18 and HKA01

Compared with HKA01, the mortality rates decreased around 36% and 30% for insureds aged between 20 and 85 for males and females respectively. We illustrate the comparison between HKA18 and HKA01 for this key age range since they are more credible from statistical perspective.

Gender	Male	Female
Age Band	HKA18 / HKA01	HKA18 / HKA01
20 - 24	62.1%	83.1%
25 - 29	74.8%	79.6%
30 - 34	75.1%	78.0%
35 - 39	70.5%	79.5%
40 - 44	63.2%	79.3%
45 - 49	60.9%	78.8%
50 - 54	62.0%	78.6%
55 - 59	62.0%	76.6%
60 - 64	61.3%	71.0%
65 - 69	62.8%	60.3%
70 - 74	63.1%	55.5%
75 - 79	67.7%	62.5%
80 - 85	69.4%	65.4%
20 - 85	63.4%	70.0%

Table 4.4 - Mortality Rate Comparison between HKA18 and HKA01

To clearly present the difference between HKA18 and HKA01, we present this in two different graphs for both ages from 20 to 70 and ages from 71 to 85.

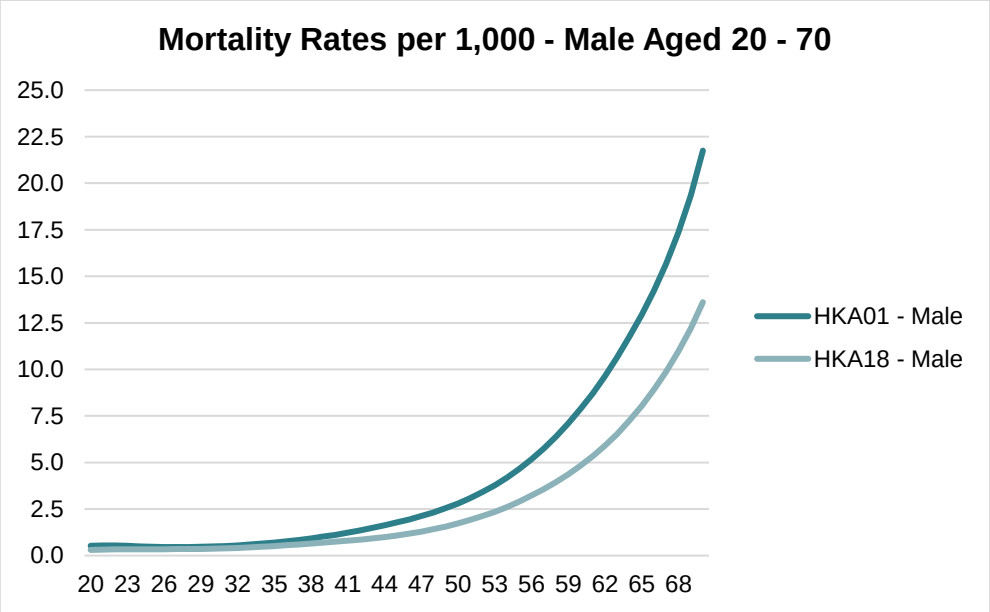

Figure 4.4.1 - Mortality rates comparison for male aged from 20 to 70

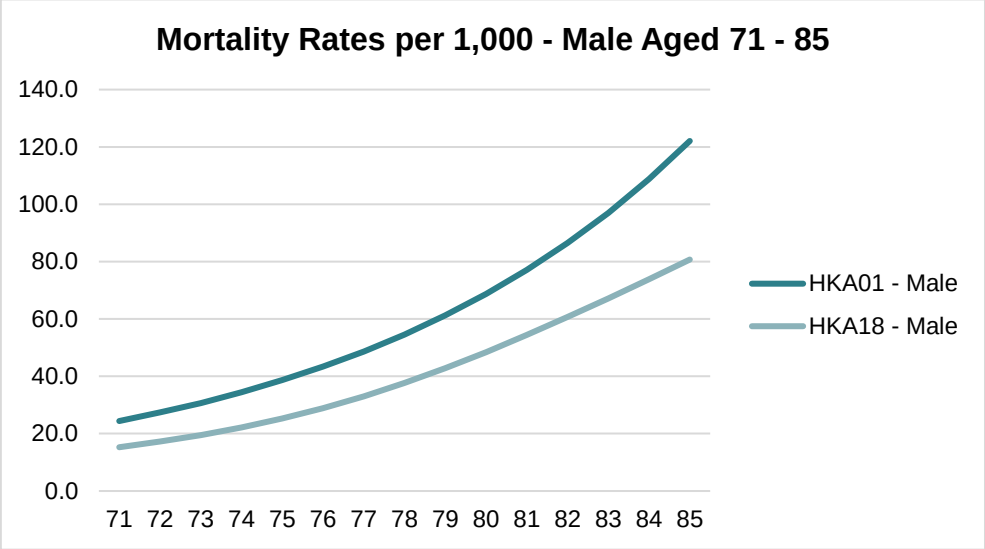

Figure 4.4.2 - Mortality rates comparison for male aged from 71 to 85

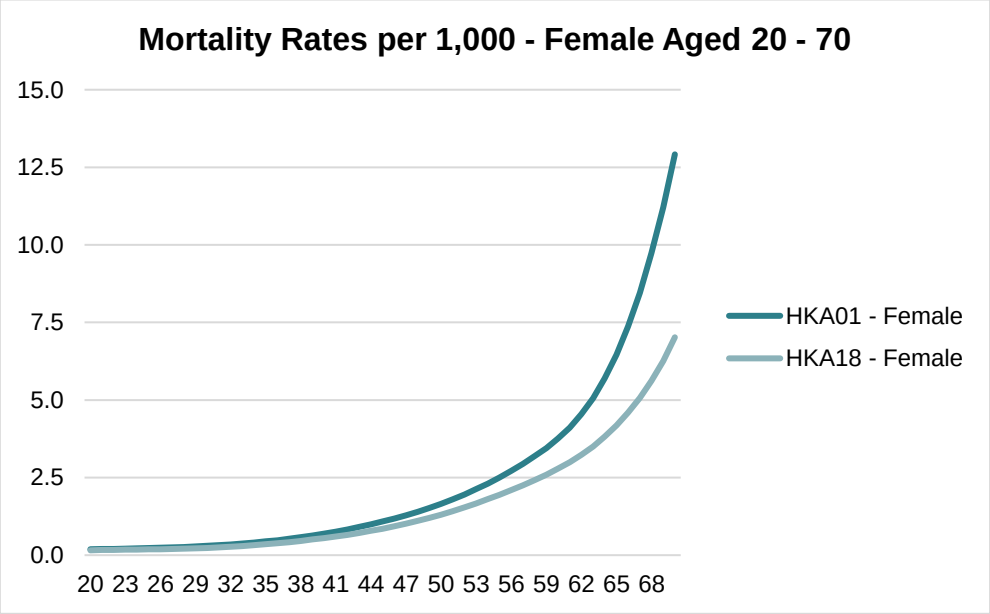

Figure 4.4.3 - Mortality rates comparison for female aged from 20 to 70

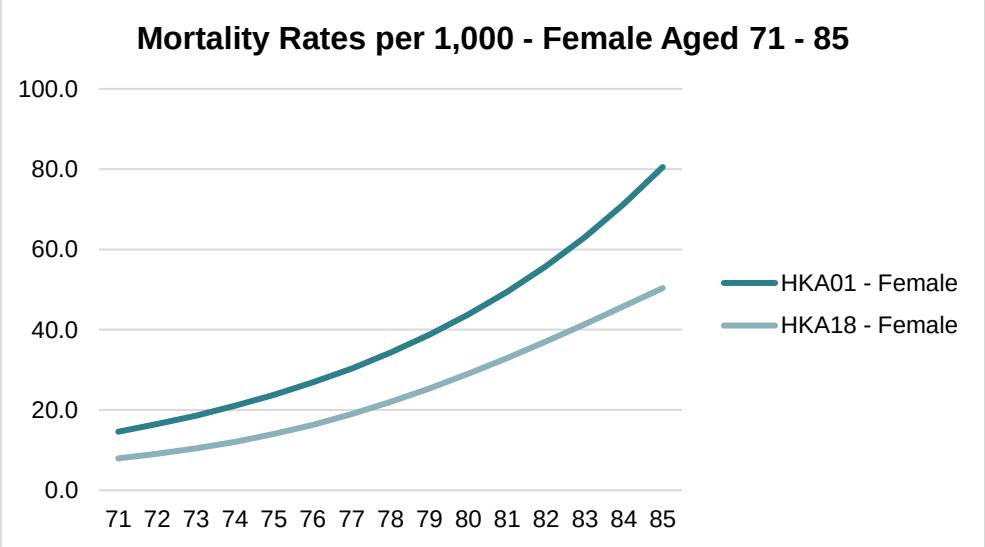

Figure 4.4.4 - Mortality rates comparison for female aged from 71 to 85

4.5 Life Expectancy

In this study, the life expectancy for Hong Kong insureds increased significantly compared with life expectancy in HKA01. According to HKA01, the expectation of assured life at birth are 78.6 and 83.2 years for males and females respectively. Based on HKA18, the life expectancy has increased significantly to 82.5 and 86.8 years for males and females respectively. The rising expectation of life reflected the decrease in the mortality rates. The following tables illustrate the difference among the life expectancy for key ages of HKA18, HKA01 and the Hong Kong Life Table 2013 (population statistics).

Expectation of Life (Male):

Age Last Birthday	HKA18 (2010-2017)	HKA01 (1991-2000)	Hong Kong Life Table 2013
0	82.5	78.6	81.1
10	72.6	68.8	71.4
20	62.7	58.9	61.5
30	52.9	49.2	51.7
40	43.2	39.5	42.0
50	33.6	30.1	32.6
60	24.4	21.3	23.8
70	15.9	13.4	15.8

Table 4.5.1 – Comparison of Life Expectancy for Key Ages (Male)

Expectation of Life (Female):

Age Last Birthday	HKA18 (2010-2017)	HKA01 (1991-2000)	Hong Kong Life Table 2013
0	86.8	83.2	86.7
10	77.0	73.4	76.9
20	67.1	63.5	67.0
30	57.2	53.6	57.1
40	47.4	43.8	47.3
50	37.7	34.2	37.7
60	28.3	25.0	28.4
70	19.3	16.3	19.6

Table 4.5.2 - Comparison of Life Expectancy for Key Ages (Female)

5 Mortality Results from various perspectives

This section illustrates the impact on mortality rates from various perspectives like smoking differentials, gender mix and duration.

5.1 Smoking Differentials

The following table shows the experience breakdown by smoking status (non-smokers and smokers), with actual claims compared to expected claims under HKA18. In this study, there are 46% of the policy data provided with specific smoking status while others were sold on an aggregate basis or marked as unknown.

We compared the experience of policies with specific smoking status with the overall experience of all valid policies. These results illustrate the impact on mortality rates from smoking habit. Unsurprisingly, non-smokers have lower mortality rates for all ages. The ratio of smokers' mortality rate experience over that of non-smokers is 169%, which is not far away from the difference by smoker status (178%) shown in Hong Kong Assured Lives Mortality and Critical Illness Experience Study 2002 – 2006 study (ASHK08).

	Experience for Non-Smokers, All Durations					Experience for Smokers, All Durations				
Age Group	Exposure	Actual Claim	Expected Claim	A/E Lives	NS / Avg	Exposure	Actual Claim	Expected Claim	A/E Lives	S / Avg
15 – 19	823,017	101	149	68%	98%	223,195	33	40	82%	119%
20 – 24	1,001,061	158	248	64%	84%	215,911	63	56	113%	149%
25 – 29	1,492,757	288	399	72%	90%	256,002	101	75	135%	168%
30 – 34	1,890,299	417	631	66%	86%	304,689	146	112	131%	170%
35 – 39	2,163,315	749	1,065	70%	82%	324,486	223	176	126%	148%
40 – 44	2,458,733	1,392	1,812	77%	89%	307,784	285	248	115%	133%
45 – 49	2,818,000	2,647	3,183	83%	92%	286,227	496	355	140%	154%
50 – 54	2,883,767	3,878	5,077	76%	86%	259,175	708	523	136%	153%
55 – 59	2,263,005	4,591	6,141	75%	84%	193,526	905	645	140%	157%
60 – 64	1,482,848	4,440	6,131	72%	84%	122,916	836	672	124%	145%
65 – 69	705,832	3,226	4,655	69%	81%	59,845	733	540	136%	159%
70 – 74	281,020	2,386	3,291	72%	84%	26,141	565	411	137%	158%
75 – 79	138,384	2,382	3,207	74%	85%	15,439	509	452	113%	129%
80 – 84	53,836	1,808	2,320	78%	86%	7,724	459	396	116%	127%
85+	19,230	1,370	1,622	84%	92%	4,000	388	420	92%	101%
Age 15+	20,475,103	29,832	39,931	75%	85%	2,607,061	6,450	5,121	126%	144%

Table 5.1 - Experience of all policies for all durations by smoking status

5.2 Smoking Differentials together with Gender Mix

The proportion of smokers is 19% and 6% for males and females respectively, which is similar to the smoking status distribution observed in Hong Kong Assured Lives Mortality and Critical Illness Experience Study 2002 – 2006 study (ASHK08) (21% for males and 6% for females).

Below tables illustrate the impact from smoking status for different genders.

Experience of non-smokers for male / female:

	Experience for Male Non-Smokers, All Durations					Experience for Female Non-Smokers, All Durations				
Age Group	Exposure	Actual Claim	Expected Claim	A/E Lives	NS / Avg	Exposure	Actual Claim	Expected Claim	A/E Lives	NS / Avg
15 - 19	435,005	65	100	65%	96%	388,011	36	49	73%	103%
20 - 24	493,692	100	161	62%	80%	507,369	58	86	67%	92%
25 - 29	662,387	165	232	71%	88%	830,369	123	168	73%	93%
30 - 34	779,125	211	327	64%	85%	1,111,174	207	305	68%	87%
35 - 39	826,042	323	495	65%	77%	1,337,273	426	570	75%	86%
40 - 44	883,866	572	764	75%	84%	1,574,867	820	1,048	78%	94%
45 - 49	1,020,907	981	1,340	73%	81%	1,797,093	1,666	1,843	90%	100%
50 - 54	1,063,472	1,658	2,270	73%	80%	1,820,295	2,220	2,807	79%	93%
55 - 59	817,903	1,979	2,899	68%	75%	1,445,102	2,612	3,242	81%	93%
60 - 64	522,784	2,064	3,049	68%	77%	960,064	2,376	3,082	77%	93%
65 - 69	248,343	1,467	2,388	61%	72%	457,489	1,759	2,267	78%	90%
70 - 74	97,141	1,099	1,645	67%	76%	183,879	1,287	1,646	78%	91%
75 - 79	48,142	1,102	1,547	71%	81%	90,242	1,280	1,659	77%	89%
80 - 84	17,894	784	1,037	76%	84%	35,941	1,024	1,283	80%	87%
85+	5,189	455	583	78%	89%	14,041	915	1,038	88%	93%
Age 15+	7,921,894	13,024	18,837	69%	78%	12,553,209	16,808	21,093	80%	92%

Table 5.2.1 - Experience of all policies for all durations by gender (Non-smokers)

Experience of smokers for male / female:

	Experience for Male Smokers, All Durations					Experience for Female Smokers, All Durations				
Age Group	Exposure	Actual Claim	Expected Claim	A/E Lives	S / Avg	Exposure	Actual Claim	Expected Claim	A/E Lives	S / Avg
15 - 19	119,369	21	27	77%	113%	103,826	12	13	93%	131%
20 - 24	123,370	37	40	92%	119%	92,541	26	16	166%	229%
25 - 29	156,843	70	55	129%	160%	99,159	30	20	151%	191%
30 - 34	194,040	98	81	120%	158%	110,649	49	30	161%	205%
35 - 39	222,116	158	133	119%	141%	102,371	65	43	150%	173%
40 - 44	225,941	223	195	115%	129%	81,844	62	54	115%	139%
45 - 49	223,666	413	292	142%	157%	62,562	82	63	130%	143%
50 - 54	209,875	632	447	141%	155%	49,301	77	76	101%	119%
55 - 59	161,553	827	574	144%	158%	31,973	78	71	109%	126%
60 - 64	105,530	776	616	126%	143%	17,385	59	56	107%	130%
65 - 69	51,919	672	500	134%	158%	7,926	61	39	156%	181%
70 - 74	21,854	502	372	135%	154%	4,287	62	39	159%	186%
75 - 79	11,847	432	384	113%	129%	3,592	77	69	112%	129%
80 - 84	5,207	323	304	106%	118%	2,517	136	92	148%	162%
85+	2,161	228	264	86%	98%	1,838	161	156	103%	108%
Age 15+	1,835,291	5,413	4,285	126%	143%	771,770	1,037	836	124%	143%

Table 5.2.2 - Experience of all policies for all durations by gender (Smokers)

5.3 Smoking Differentials together with Duration

Below tables show the smoking habit impact by in-force duration.

Experience of duration 0 policies for non-smokers / smokers:

	Experience for Non-Smokers, Duration 0					Experience for Smokers, Duration 0				
Age Group	Exposure	Actual Claim	Expected Claim	A/E Lives	NS / Avg	Exposure	Actual Claim	Expected Claim	A/E Lives	S / Avg
15 - 19	87,545	4	16	25%	36%	5,583	0	1	0%	0%
20 - 24	180,599	12	44	27%	36%	21,891	6	6	98%	130%
25 - 29	201,807	20	54	38%	47%	31,446	9	10	94%	118%
30 - 34	188,065	25	63	40%	52%	32,410	10	12	83%	108%
35 - 39	186,336	46	92	51%	59%	28,578	18	16	115%	134%
40 - 44	190,189	75	140	54%	63%	23,108	15	19	81%	94%
45 - 49	208,779	105	233	45%	50%	17,867	15	22	68%	75%
50 - 54	197,846	182	341	54%	60%	12,780	22	26	86%	97%
55 - 59	158,368	208	416	50%	56%	7,976	34	27	129%	144%
60 - 64	111,490	222	446	50%	58%	4,033	19	22	87%	101%
65 - 69	54,286	170	347	49%	57%	1,501	18	14	135%	157%
70 - 74	19,426	107	221	48%	56%	399	5	6	80%	92%
75 - 79	4,934	44	107	41%	47%	90	2	3	78%	89%
80 - 84	334	7	14	50%	55%	5	0	0	0%	0%
85+	13	0	1	0%	0%	0	0	0	N/A	N/A
Age 15+	1,790,019	1,228	2,534	48%	55%	187,668	175	183	95%	109%

Table 5.3.1 - Experience of all duration 0 policies by smoking status

Experience of duration 1 policies for non-smokers / smokers:

	Experience for Non-Smokers, Duration 1					Experience for Smokers, Duration 1				
Age Group	Exposure	Actual Claim	Expected Claim	A/E Lives	NS / Avg	Exposure	Actual Claim	Expected Claim	A/E Lives	S / Avg
15 - 19	66,238	7	12	57%	83%	5,481	1	1	105%	153%
20 - 24	142,800	22	35	63%	83%	15,031	8	4	191%	251%
25 - 29	187,046	26	50	53%	67%	26,654	14	8	175%	219%
30 - 34	173,834	28	58	49%	63%	28,991	18	11	168%	218%
35 - 39	170,619	53	84	63%	73%	26,137	17	14	120%	140%
40 - 44	177,080	89	130	69%	80%	21,086	16	17	95%	110%
45 - 49	195,948	159	219	73%	80%	16,623	27	21	133%	147%
50 - 54	193,324	201	332	61%	68%	12,228	31	25	128%	144%
55 - 59	157,153	241	411	59%	66%	7,857	26	26	100%	112%
60 - 64	113,268	273	451	60%	70%	4,288	26	23	112%	131%
65 - 69	59,777	216	380	57%	66%	1,743	23	16	149%	175%
70 - 74	23,261	169	260	65%	75%	534	4	8	49%	56%
75 - 79	7,888	107	168	63%	73%	135	2	4	52%	60%
80 - 84	896	14	37	39%	42%	14	0	1	0%	0%
85+	48	1	4	26%	28%	1	0	0	0%	0%
Age 15+	1,669,181	1,606	2,630	61%	70%	166,803	215	179	120%	138%

Table 5.3.2 - Experience of all duration 1 policies by smoking status

Experience of duration 2+ policies for non-smokers / smokers:

	Experience for Non-Smokers, Duration 2+					Experience for Smokers, Duration 2+				
Age Group	Exposure	Actual Claim	Expected Claim	A/E Lives	NS / Avg	Exposure	Actual Claim	Expected Claim	A/E Lives	S / Avg
15 - 19	669,233	90	121	75%	108%	212,132	32	38	84%	122%
20 - 24	677,662	124	169	73%	97%	178,988	49	46	107%	142%
25 - 29	1,103,903	241	296	81%	102%	197,902	78	57	136%	170%
30 - 34	1,528,400	364	511	71%	92%	243,288	118	89	133%	172%
35 - 39	1,806,359	650	889	73%	85%	269,772	188	146	128%	150%
40 - 44	2,091,464	1,227	1,543	80%	93%	263,590	253	212	119%	139%
45 - 49	2,413,273	2,383	2,730	87%	97%	251,737	453	313	145%	160%
50 - 54	2,492,597	3,495	4,404	79%	90%	234,167	655	472	139%	157%
55 - 59	1,947,484	4,142	5,314	78%	87%	177,693	844	592	143%	160%
60 - 64	1,258,090	3,945	5,234	75%	88%	114,596	790	626	126%	147%
65 - 69	591,768	2,840	3,928	72%	85%	56,600	692	510	136%	159%
70 - 74	238,333	2,110	2,810	75%	87%	25,207	556	397	140%	161%
75 - 79	125,562	2,231	2,932	76%	87%	15,214	505	446	113%	130%
80 - 84	52,606	1,787	2,269	79%	86%	7,705	459	395	116%	128%
85+	19,169	1,369	1,617	85%	92%	3,999	388	420	92%	101%
Age 15+	17,015,902	26,998	34,766	78%	89%	2,252,590	6,060	4,760	127%	145%

Table 5.3.3 - Experience of all duration 2+ policies by smoking status

6 Cause of death study

6.1 Cause of Death Summary (2010 – 2017)

6.2 Similar to the distribution of causes of deaths in previous studies, accidents were the major cause of deaths for the younger-aged insureds, while cancers resulted in most of the deaths for elder-aged insureds. **Cause of death breakdown**

Below graphs show the proportion of claims caused by different incidents. The proportion of deaths due to AIDS was still minimal for insureds in the Hong Kong market. For the exact figures, please refer to section 6.3.

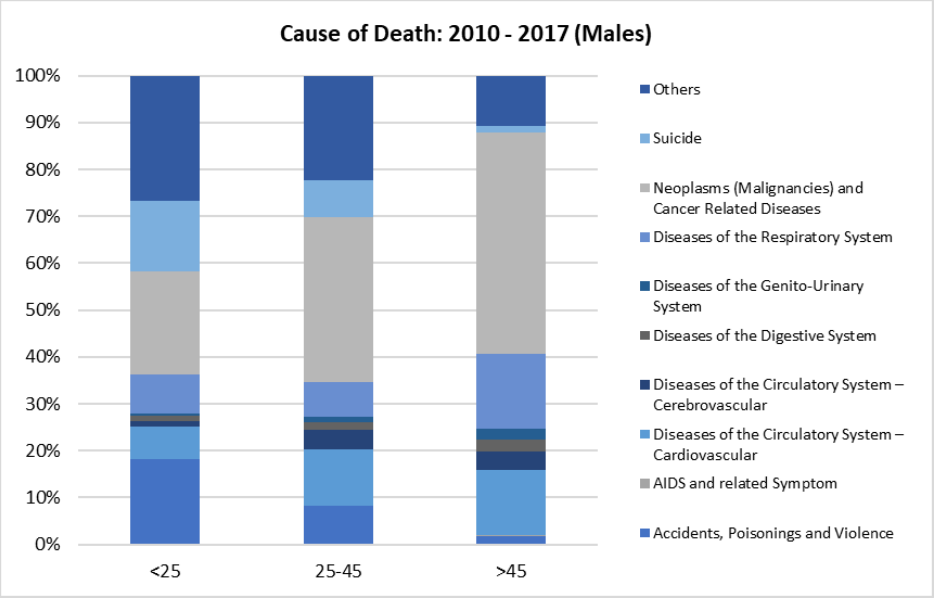

Figure 6.2.1 - Distribution of causes of death claims (Male)

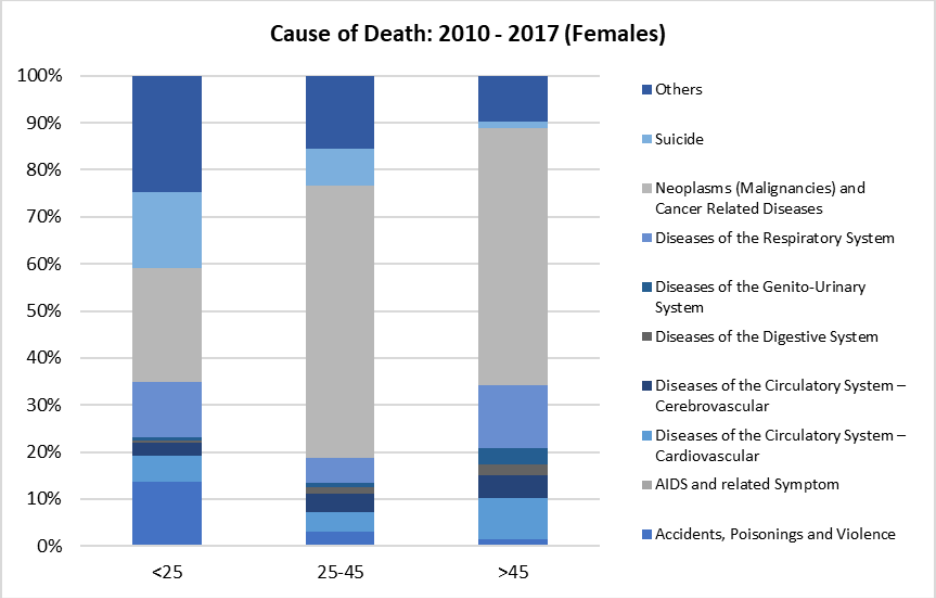

Figure 6.2.2 - Distribution of causes of death claims (Female)

6.3 Comparison with the previous studies

For all age bands, the proportion of deaths due to accidents decreased significantly. For females, deaths due to cancer-related diseases increased for all age bands, especially for ages 0 - 24. For males aged 0 - 24, cancer-related diseases make up a more significant part comparing to prior studies. However, the increasing pattern of cancer-related diseases was not that obvious for males aged 25 or above.

The proportion of cardiovascular disease increased from 7% to 12% for males, and 3% to 4% for females aged 25 to 45. For insureds aged 45 above, the risk of cardiovascular disease increased from 12% to 14% for males while keeps at a similar level for females.

The deaths caused by diseases of the respiratory system accounted for a higher share for all age bands, compared with historical experience, especially for the age groups over 45 years old.

Age group - under 25 years old:

	Male under 25 years old				Female under 25 years old			
Cause of Deaths	HKA01	ASHK03	ASHK08	HKA18	HKA01	ASHK03	ASHK08	HKA18
Accidents, Poisonings and Violence	38%	36%	33%	18%	38%	18%	23%	14%
AIDS and related Symptom	0%	0%	0%	0%	0%	0%	0%	0%
Diseases of the Circulatory System – Cardiovascular	7%	8%	4%	7%	7%	9%	7%	6%
Diseases of the Circulatory System – Cerebrovascular	2%	4%	2%	1%	2%	3%	5%	3%
Diseases of the Digestive System	2%	0%	1%	1%	2%	2%	1%	0%
Diseases of the Genito-Urinary System	0%	0%	1%	1%	0%	2%	1%	1%
Diseases of the Respiratory System	6%	6%	4%	8%	6%	5%	4%	12%
Neoplasms (Malignancies) and Cancer Related Diseases	15%	17%	15%	22%	15%	21%	15%	24%
Suicide	9%	15%	20%	15%	9%	22%	20%	16%
Others	22%	13%	20%	27%	22%	18%	24%	25%

Table 6.3.1 – Distribution of causes of death claimants aged under 25 years old by gender

Age group - between 25 and 45 years old:

	Male between 25 and 45 years old				Female between 25 and 45 years old			
Cause of Deaths	HKA01	ASHK03	ASHK08	HKA18	HKA01	ASHK03	ASHK08	HKA18
Accidents, Poisonings and Violence	18%	15%	16%	8%	10%	7%	10%	3%
AIDS and related Symptom	0%	0%	0%	0%	0%	0%	0%	0%
Diseases of the Circulatory System – Cardiovascular	8%	8%	7%	12%	6%	3%	3%	4%
Diseases of the Circulatory System – Cerebrovascular	4%	4%	3%	4%	3%	3%	4%	4%
Diseases of the Digestive System	4%	2%	2%	2%	2%	1%	1%	1%
Diseases of the Genito-Urinary System	1%	1%	2%	1%	1%	1%	1%	1%
Diseases of the Respiratory System	3%	3%	4%	7%	4%	4%	4%	5%
Neoplasms (Malignancies) and Cancer Related Diseases	41%	42%	36%	35%	47%	59%	50%	58%
Suicide	8%	15%	14%	8%	13%	15%	14%	8%
Others	14%	9%	15%	22%	14%	9%	13%	15%

Table 6.3.2 - Distribution of causes of death claimants aged between 25 and 45 years old by gender

Age group - over 45 years old:

	Male over 45 years old				Female over 45 years old			
Cause of Deaths	HKA01	ASHK03	ASHK08	HKA18	HKA01	ASHK03	ASHK08	HKA18
Accidents, Poisonings and Violence	5%	3%	4%	2%	2%	3%	3%	1%
AIDS and related Symptom	0%	0%	0%	0%	0%	0%	0%	0%
Diseases of the Circulatory System – Cardiovascular	14%	13%	12%	14%	12%	9%	9%	9%
Diseases of the Circulatory System – Cerebrovascular	5%	5%	5%	4%	7%	8%	7%	5%
Diseases of the Digestive System	4%	4%	3%	2%	3%	2%	3%	2%
Diseases of the Genito-Urinary System	1%	2%	3%	2%	3%	3%	4%	4%
Diseases of the Respiratory System	9%	7%	10%	16%	8%	7%	8%	13%
Neoplasms (Malignancies) and Cancer Related Diseases	53%	53%	49%	47%	55%	57%	53%	55%
Suicide	3%	3%	3%	1%	3%	4%	4%	1%
Others	7%	8%	10%	11%	8%	7%	10%	10%

Table 6.3.3 - Distribution of causes of death claimants aged over 45 years old by gender

7 Use of This Report

7.1 Use of HKA18

Below points should be noted when applying this mortality rate table for pricing, valuation, or any other purposes. Appropriate adjustments are required according to different purposes.

- the data is based on predominantly permanent assurance experience;
- the data excludes the first two years of policy duration;
- despite the 177% increase in exposure compared to HKA01, the tables are based on a relatively small amount of data, especially for very young and old ages;
- the tables shall be applied to individual basic life products only;
- the data excludes policies issued by simplified underwriting or guaranteed issues;
- the tables pool data across eight (8) calendar years from 2010 to 2017. Since the mid-point of this mortality study is the end of the year 2013, appropriate adjustments are required when this mortality study is used for different time period;
- the tables pool data across all participating companies and considerable variations in experience between companies should be considered.

7.2 Disclaimer

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8 Appendices

8.1 HKA18 mortality table

Hong Kong Assured Lives Mortality Table 2018 (Males) – HKA18(M)

Age Last Birthday	Probability of dying between exact age x and age x+1	Number of survivors at exact age x	Number of deaths between exact age x and age x+1	Number of person-years lived between exact age x and age x+1	Total person-years lived after exact age x	Expectation of life at exact age x
x	*q(x)*	*l(x)*	*d(x)*	*L(x)*	*T(x)*	*e(x)*
0	0.000929	1,000,000	929	999,210	82,466,061	82.47
1	0.000203	999,071	203	998,969	81,466,851	81.54
2	0.000110	998,868	109	998,813	80,467,882	80.56
3	0.000099	998,758	99	998,709	79,469,069	79.57
4	0.000088	998,660	88	998,616	78,470,360	78.58
5	0.000079	998,571	79	998,532	77,471,745	77.58
6	0.000072	998,492	72	998,456	76,473,213	76.59
7	0.000067	998,420	67	998,387	75,474,756	75.59
8	0.000065	998,353	65	998,321	74,476,369	74.60
9	0.000067	998,288	67	998,255	73,478,049	73.60
10	0.000073	998,221	73	998,185	72,479,794	72.61
11	0.000084	998,148	84	998,106	71,481,609	71.61
12	0.000101	998,064	100	998,014	70,483,503	70.62
13	0.000122	997,964	122	997,903	69,485,489	69.63
14	0.000147	997,842	146	997,769	68,487,587	68.64
15	0.000174	997,696	174	997,609	67,489,818	67.65
16	0.000202	997,522	202	997,421	66,492,209	66.66
17	0.000231	997,320	230	997,205	65,494,788	65.67
18	0.000258	997,090	257	996,962	64,497,582	64.69
19	0.000283	996,833	282	996,692	63,500,621	63.70
20	0.000303	996,551	302	996,400	62,503,929	62.72
21	0.000319	996,249	318	996,090	61,507,529	61.74
22	0.000330	995,931	329	995,766	60,511,439	60.76
23	0.000337	995,602	335	995,434	59,515,673	59.78
24	0.000341	995,266	339	995,097	58,520,239	58.80
25	0.000343	994,927	341	994,757	57,525,142	57.82
26	0.000345	994,586	343	994,415	56,530,385	56.84
27	0.000347	994,244	345	994,071	55,535,970	55.86
28	0.000352	993,898	350	993,724	54,541,899	54.88
29	0.000360	993,549	357	993,370	53,548,175	53.90
30	0.000372	993,192	370	993,007	52,554,805	52.92
31	0.000390	992,822	387	992,629	51,561,798	51.93
32	0.000413	992,435	410	992,230	50,569,170	50.95
33	0.000442	992,025	438	991,806	49,576,940	49.98
34	0.000474	991,587	470	991,352	48,585,134	49.00
35	0.000511	991,116	507	990,863	47,593,783	48.02
36	0.000552	990,610	546	990,337	46,602,919	47.04
37	0.000595	990,063	589	989,769	45,612,583	46.07
38	0.000642	989,474	635	989,157	44,622,814	45.10
39	0.000691	988,839	683	988,497	43,633,657	44.13
40	0.000742	988,156	733	987,789	42,645,160	43.16
41	0.000796	987,423	786	987,030	41,657,371	42.19
42	0.000855	986,637	844	986,215	40,670,341	41.22
43	0.000921	985,793	908	985,339	39,684,126	40.26
44	0.000995	984,885	980	984,395	38,698,787	39.29
45	0.001080	983,905	1,063	983,373	37,714,393	38.33
46	0.001177	982,842	1,157	982,263	36,731,019	37.37
47	0.001289	981,685	1,265	981,052	35,748,756	36.42
48	0.001416	980,420	1,388	979,725	34,767,704	35.46
49	0.001561	979,031	1,528	978,267	33,787,979	34.51
50	0.001726	977,503	1,687	976,660	32,809,711	33.56

Note: $L_0 = l_0 - 0.85 \times d_0$

Age Last Birthday	Probability of dying between exact age x and age x+1	Number of survivors at exact age x	Number of deaths between exact age x and age x+1	Number of person-years lived between exact age x and age x+1	Total person-years lived after exact age x	Expectation of life at exact age x
x	*q(x)*	*l(x)*	*d(x)*	*L(x)*	*T(x)*	*e(x)*
51	0.001911	975,816	1,865	974,884	31,833,052	32.62
52	0.002120	973,951	2,065	972,919	30,858,168	31.68
53	0.002354	971,886	2,287	970,742	29,885,249	30.75
54	0.002613	969,599	2,534	968,332	28,914,507	29.82
55	0.002901	967,065	2,805	965,662	27,946,176	28.90
56	0.003218	964,259	3,103	962,708	26,980,514	27.98
57	0.003566	961,157	3,428	959,443	26,017,806	27.07
58	0.003947	957,729	3,781	955,839	25,058,363	26.16
59	0.004364	953,948	4,163	951,867	24,102,524	25.27
60	0.004823	949,785	4,581	947,494	23,150,658	24.37
61	0.005333	945,204	5,041	942,684	22,203,163	23.49
62	0.005901	940,163	5,547	937,389	21,260,480	22.61
63	0.006534	934,616	6,107	931,562	20,323,090	21.74
64	0.007242	928,509	6,724	925,147	19,391,528	20.88
65	0.008031	921,785	7,403	918,083	18,466,381	20.03
66	0.008910	914,382	8,147	910,308	17,548,298	19.19
67	0.009887	906,234	8,960	901,754	16,637,990	18.36
68	0.010971	897,274	9,844	892,353	15,736,236	17.54
69	0.012196	887,431	10,823	882,019	14,843,883	16.73
70	0.013612	876,608	11,932	870,641	13,961,864	15.93
71	0.015268	864,675	13,202	858,074	13,091,223	15.14
72	0.017213	851,474	14,657	844,145	12,233,148	14.37
73	0.019498	836,817	16,316	828,659	11,389,003	13.61
74	0.022172	820,501	18,192	811,405	10,560,344	12.87
75	0.025283	802,309	20,285	792,166	9,748,939	12.15
76	0.028883	782,024	22,587	770,731	8,956,773	11.45
77	0.033019	759,437	25,076	746,899	8,186,042	10.78
78	0.037699	734,361	27,685	720,519	7,439,143	10.13
79	0.042869	706,677	30,294	691,530	6,718,624	9.51
80	0.048466	676,382	32,781	659,992	6,027,095	8.91
81	0.054430	643,601	35,031	626,086	5,367,103	8.34
82	0.060699	608,570	36,940	590,100	4,741,017	7.79
83	0.067213	571,631	38,421	552,420	4,150,917	7.26
84	0.073910	533,210	39,409	513,505	3,598,497	6.75
85	0.080729	493,800	39,864	473,868	3,084,992	6.25
86	0.096627	453,936	43,863	432,005	2,611,123	5.75
87	0.108558	410,074	44,517	387,815	2,179,118	5.31
88	0.121860	365,557	44,547	343,284	1,791,303	4.90
89	0.136663	321,010	43,870	299,075	1,448,019	4.51
90	0.153102	277,140	42,431	255,925	1,148,944	4.15
91	0.171316	234,709	40,209	214,605	893,019	3.80
92	0.191440	194,500	37,235	175,882	678,414	3.49
93	0.213610	157,265	33,593	140,468	502,532	3.20
94	0.237948	123,672	29,427	108,958	362,063	2.93
95	0.264564	94,244	24,934	81,777	253,106	2.69
96	0.293544	69,311	20,346	59,138	171,328	2.47
97	0.324942	48,965	15,911	41,009	112,190	2.29
98	0.358770	33,054	11,859	27,125	71,181	2.15
99	0.394986	21,195	8,372	17,009	44,056	2.08
100+	1.000000	12,823	12,823	27,047	27,047	2.11

Note: $L_0 = l_0 - 0.85 \times d_0$

Hong Kong Assured Lives Mortality Table 2018 (Females) – HKA18(F)

Age Last Birthday	Probability of dying between exact age x and age x+1	Number of survivors at exact age x	Number of deaths between exact age x and age x+1	Number of person-years lived between exact age x and age x+1	Total person-years lived after exact age x	Expectation of life at exact age x
x	*q(x)*	*l(x)*	*d(x)*	*L(x)*	*T(x)*	*e(x)*
0	0.000805	1,000,000	805	999,316	86,823,501	86.82
1	0.000320	999,195	320	999,035	85,824,185	85.89
2	0.000146	998,875	145	998,803	84,825,150	84.92
3	0.000134	998,730	134	998,663	83,826,347	83.93
4	0.000123	998,596	123	998,535	82,827,684	82.94
5	0.000113	998,473	112	998,417	81,829,150	81.95
6	0.000103	998,361	103	998,309	80,830,733	80.96
7	0.000095	998,258	95	998,211	79,832,423	79.97
8	0.000088	998,163	88	998,120	78,834,212	78.98
9	0.000083	998,076	83	998,034	77,836,093	77.99
10	0.000080	997,993	80	997,952	76,838,059	76.99
11	0.000080	997,912	80	997,872	75,840,106	76.00
12	0.000083	997,832	83	997,791	74,842,234	75.00
13	0.000088	997,749	88	997,705	73,844,443	74.01
14	0.000095	997,661	95	997,614	72,846,738	73.02
15	0.000104	997,566	104	997,514	71,849,124	72.02
16	0.000114	997,462	114	997,405	70,851,610	71.03
17	0.000125	997,348	125	997,286	69,854,205	70.04
18	0.000136	997,223	135	997,156	68,856,919	69.05
19	0.000146	997,088	146	997,015	67,859,764	68.06
20	0.000156	996,942	155	996,865	66,862,748	67.07
21	0.000164	996,787	163	996,706	65,865,884	66.08
22	0.000170	996,624	170	996,539	64,869,178	65.09
23	0.000176	996,454	175	996,367	63,872,639	64.10
24	0.000181	996,279	180	996,189	62,876,272	63.11
25	0.000186	996,099	186	996,006	61,880,084	62.12
26	0.000192	995,913	191	995,817	60,884,078	61.13
27	0.000199	995,721	198	995,622	59,888,261	60.15
28	0.000208	995,523	207	995,420	58,892,638	59.16
29	0.000219	995,316	218	995,207	57,897,219	58.17
30	0.000232	995,098	231	994,983	56,902,011	57.18
31	0.000249	994,867	248	994,743	55,907,029	56.20
32	0.000269	994,620	268	994,486	54,912,285	55.21
33	0.000292	994,352	291	994,206	53,917,799	54.22
34	0.000319	994,061	317	993,902	52,923,593	53.24
35	0.000349	993,744	347	993,570	51,929,691	52.26
36	0.000383	993,397	380	993,206	50,936,120	51.27
37	0.000420	993,016	417	992,808	49,942,914	50.29
38	0.000460	992,600	457	992,371	48,950,106	49.32
39	0.000504	992,143	500	991,893	47,957,735	48.34
40	0.000551	991,643	547	991,369	46,965,842	47.36
41	0.000603	991,096	597	990,798	45,974,472	46.39
42	0.000658	990,499	652	990,173	44,983,675	45.42
43	0.000718	989,847	711	989,492	43,993,502	44.44
44	0.000783	989,136	775	988,749	43,004,010	43.48
45	0.000854	988,361	844	987,939	42,015,261	42.51
46	0.000931	987,517	920	987,057	41,027,322	41.55
47	0.001014	986,598	1,001	986,097	40,040,265	40.58
48	0.001105	985,597	1,089	985,052	39,054,168	39.62
49	0.001202	984,508	1,184	983,916	38,069,115	38.67
50	0.001307	983,324	1,286	982,682	37,085,199	37.71

Note: $L_0 = l_0 - 0.85 \times d_0$

Age Last Birthday	Probability of dying between exact age x and age x+1	Number of survivors at exact age x	Number of deaths between exact age x and age x+1	Number of person-years lived between exact age x and age x+1	Total person-years lived after exact age x	Expectation of life at exact age x
x	*q(x)*	*l(x)*	*d(x)*	*L(x)*	*T(x)*	*e(x)*
51	0.001420	982,039	1,395	981,342	36,102,518	36.76
52	0.001540	980,644	1,511	979,889	35,121,176	35.81
53	0.001668	979,134	1,634	978,317	34,141,287	34.87
54	0.001804	977,500	1,763	976,619	33,162,970	33.93
55	0.001947	975,737	1,900	974,787	32,186,351	32.99
56	0.002098	973,837	2,043	972,816	31,211,564	32.05
57	0.002256	971,795	2,192	970,698	30,238,748	31.12
58	0.002422	969,602	2,348	968,428	29,268,050	30.19
59	0.002596	967,254	2,511	965,999	28,299,621	29.26
60	0.002785	964,743	2,687	963,400	27,333,623	28.33
61	0.002995	962,057	2,881	960,616	26,370,223	27.41
62	0.003232	959,176	3,100	957,626	25,409,607	26.49
63	0.003504	956,076	3,350	954,401	24,451,981	25.58
64	0.003816	952,726	3,636	950,908	23,497,580	24.66
65	0.004177	949,090	3,964	947,108	22,546,672	23.76
66	0.004592	945,126	4,340	942,956	21,599,564	22.85
67	0.005068	940,786	4,768	938,402	20,656,608	21.96
68	0.005614	936,017	5,255	933,390	19,718,206	21.07
69	0.006253	930,763	5,820	927,852	18,784,817	20.18
70	0.007022	924,942	6,495	921,695	17,856,964	19.31
71	0.007954	918,448	7,305	914,795	16,935,269	18.44
72	0.009084	911,143	8,277	907,004	16,020,474	17.58
73	0.010450	902,865	9,435	898,148	15,113,470	16.74
74	0.012084	893,431	10,796	888,033	14,215,322	15.91
75	0.014023	882,635	12,377	876,446	13,327,289	15.10
76	0.016301	870,258	14,186	863,165	12,450,843	14.31
77	0.018954	856,072	16,226	847,959	11,587,679	13.54
78	0.021986	839,846	18,465	830,613	10,739,720	12.79
79	0.025360	821,381	20,830	810,966	9,909,106	12.06
80	0.029033	800,551	23,242	788,930	9,098,140	11.36
81	0.032961	777,309	25,621	764,498	8,309,211	10.69
82	0.037103	751,688	27,890	737,743	7,544,713	10.04
83	0.041415	723,798	29,976	708,810	6,806,970	9.40
84	0.045855	693,822	31,815	677,914	6,098,160	8.79
85	0.050381	662,007	33,352	645,330	5,420,245	8.19
86	0.060304	628,654	37,911	609,699	4,774,915	7.60
87	0.068444	590,744	40,433	570,527	4,165,216	7.05
88	0.077635	550,311	42,723	528,949	3,594,689	6.53
89	0.088002	507,588	44,669	485,253	3,065,739	6.04
90	0.099676	462,919	46,142	439,848	2,580,486	5.57
91	0.112801	416,777	47,013	393,271	2,140,638	5.14
92	0.127528	369,764	47,155	346,187	1,747,367	4.73
93	0.144018	322,609	46,461	299,378	1,401,180	4.34
94	0.162433	276,148	44,856	253,720	1,101,802	3.99
95	0.182942	231,292	42,313	210,135	848,082	3.67
96	0.205707	188,979	38,874	169,542	637,947	3.38
97	0.230884	150,105	34,657	132,776	468,405	3.12
98	0.258610	115,448	29,856	100,520	335,629	2.91
99	0.288997	85,592	24,736	73,224	235,109	2.75
100+	1.000000	60,856	60,856	161,885	161,885	2.66

Note: $L_0 = l_0 - 0.85 \times d_0$

8.2 Actual and expected deaths

Actual and expected (HKA18) deaths – male lives duration 2+, full underwritten

Age Last Birthday	Exposure	Crude q_x	Graduated q_x	Actual deaths	Expected deaths	Actual / Expected
0	66,451	0.000122	0.000929	8	62	13%
1	65,852	0.000122	0.000203	8	13	60%
2	65,349	0.000124	0.000110	8	7	113%
3	80,120	0.000064	0.000099	5	8	65%
4	91,046	0.000056	0.000088	5	8	63%
5	94,819	0.000074	0.000079	7	8	94%
6	95,896	0.000031	0.000072	3	7	44%
7	98,094	0.000072	0.000067	7	7	107%
8	101,153	0.000030	0.000065	3	7	46%
9	105,317	0.000076	0.000067	8	7	114%
10	108,820	0.000092	0.000073	10	8	126%
11	113,653	0.000107	0.000084	12	10	126%
12	120,027	0.000059	0.000101	7	12	59%
13	127,614	0.000056	0.000122	7	16	46%
14	135,886	0.000118	0.000147	16	20	80%
15	141,963	0.000177	0.000174	25	25	102%
16	146,262	0.000151	0.000202	22	30	75%
17	147,705	0.000109	0.000231	16	34	47%
18	148,014	0.000197	0.000258	29	38	76%
19	147,907	0.000210	0.000283	31	42	74%
20	148,428	0.000319	0.000303	47	45	105%
21	145,908	0.000261	0.000319	38	47	82%
22	144,246	0.000273	0.000330	39	48	83%
23	144,750	0.000347	0.000337	50	49	103%
24	147,406	0.000295	0.000341	43	50	87%
25	151,559	0.000354	0.000343	54	52	103%
26	158,497	0.000292	0.000345	46	55	85%
27	166,338	0.000405	0.000347	67	58	117%
28	173,188	0.000308	0.000352	53	61	88%
29	180,140	0.000257	0.000360	46	65	71%
30	189,075	0.000366	0.000372	69	70	98%
31	198,442	0.000304	0.000390	60	77	78%
32	207,321	0.000334	0.000413	69	86	81%
33	215,360	0.000336	0.000442	72	95	76%
34	223,095	0.000460	0.000474	103	106	97%
35	230,900	0.000356	0.000511	82	118	70%
36	239,724	0.000484	0.000552	116	132	88%
37	249,127	0.000561	0.000595	140	148	94%
38	257,813	0.000665	0.000642	171	165	104%
39	266,977	0.000624	0.000691	167	184	90%
40	276,527	0.000737	0.000742	204	205	99%
41	287,061	0.000773	0.000796	222	229	97%
42	296,981	0.000809	0.000855	240	254	95%
43	306,379	0.000912	0.000921	279	282	99%
44	319,178	0.000876	0.000995	280	318	88%
45	334,216	0.001004	0.001080	336	361	93%
46	353,050	0.001153	0.001177	407	416	98%
47	370,257	0.001166	0.001289	432	477	90%
48	384,512	0.001404	0.001416	540	544	99%
49	395,004	0.001395	0.001561	551	617	89%
50	401,497	0.001701	0.001726	683	693	99%

Note: For age 0, duration 0 data is shown and for age 1, duration 1 data is shown

Actual and expected (HKA18) deaths – male lives duration 2+, full underwritten – continued

Age Last Birthday	Exposure	Crude q_x	Graduated q_x	Actual deaths	Expected deaths	Actual / Expected
51	404,794	0.001926	0.001911	779	774	101%
52	399,871	0.002040	0.002120	816	848	96%
53	387,387	0.002367	0.002354	917	912	101%
54	367,067	0.002279	0.002613	837	959	87%
55	343,801	0.002710	0.002901	932	997	93%
56	319,425	0.003093	0.003218	988	1,028	96%
57	294,653	0.003542	0.003566	1,044	1,051	99%
58	270,972	0.003915	0.003947	1,061	1,070	99%
59	244,655	0.004532	0.004364	1,109	1,068	104%
60	218,525	0.004677	0.004823	1,022	1,054	97%
61	196,315	0.004906	0.005333	963	1,047	92%
62	175,243	0.005781	0.005901	1,013	1,034	98%
63	154,068	0.006332	0.006534	975	1,007	97%
64	131,781	0.006810	0.007242	897	954	94%
65	110,578	0.007750	0.008031	857	888	96%
66	93,314	0.008474	0.008910	791	831	95%
67	77,075	0.009988	0.009887	770	762	101%
68	62,754	0.009127	0.010971	573	688	83%
69	50,691	0.012148	0.012196	616	618	100%
70	39,568	0.012953	0.013612	513	539	95%
71	33,367	0.016162	0.015268	539	509	106%
72	29,243	0.017288	0.017213	506	503	100%
73	25,499	0.018768	0.019498	479	497	96%
74	22,504	0.019418	0.022172	437	499	88%
75	20,049	0.025613	0.025283	514	507	101%
76	17,790	0.027498	0.028883	489	514	95%
77	15,525	0.030965	0.033019	481	513	94%
78	13,394	0.032810	0.037699	439	505	87%
79	11,386	0.039647	0.042869	451	488	92%
80	9,557	0.048357	0.048466	462	463	100%
81	8,027	0.048265	0.054430	387	437	89%
82	6,667	0.058350	0.060699	389	405	96%
83	5,378	0.060911	0.067213	328	361	91%
84	4,256	0.071071	0.073910	303	315	96%
85	3,322	0.088206	0.080729	293	268	109%
86	2,472	0.093428	0.096627	231	239	97%
87	1,772	0.093084	0.108558	165	192	86%
88	1,271	0.105759	0.121860	134	155	87%
89	883	0.130255	0.136663	115	121	95%
90	586	0.102091	0.153102	60	90	67%
91	401	0.180812	0.171316	73	69	106%
92	239	0.125987	0.191440	30	46	66%
93	150	0.167856	0.213610	25	32	79%
94	88	0.080230	0.237948	7	21	34%
95	53	0.095088	0.264564	5	14	36%
96	34	0.189534	0.293544	6	10	65%
97	25	0.079720	0.324942	2	8	25%
98	16	0.000000	0.358770	0	6	0%
99	4	0.000000	0.394986	0	1	0%
100	0	N/A	1.000000	0	0	N/A

Note: For age 0, duration 0 data is shown and for age 1, duration 1 data is shown

Actual and expected (HKA18) deaths – female lives duration 2+, full underwritten

Age Last Birthday	Exposure	Crude q_x	Graduated q_x	Actual deaths	Expected deaths	Actual / Expected
0	57,129	0.000141	0.000805	8	46	18%
1	56,854	0.000124	0.000320	7	18	39%
2	56,587	0.000090	0.000146	5	8	62%
3	69,709	0.000130	0.000134	9	9	97%
4	78,971	0.000103	0.000123	8	10	84%
5	82,496	0.000085	0.000113	7	9	75%
6	83,847	0.000012	0.000103	1	9	12%
7	86,281	0.000128	0.000095	11	8	135%
8	89,292	0.000034	0.000088	3	8	39%
9	92,920	0.000141	0.000083	13	8	169%
10	96,028	0.000031	0.000080	3	8	39%
11	100,302	0.000030	0.000080	3	8	37%
12	105,495	0.000076	0.000083	8	9	92%
13	111,846	0.000099	0.000088	11	10	112%
14	118,741	0.000034	0.000095	4	11	36%
15	123,313	0.000049	0.000104	6	13	47%
16	126,544	0.000119	0.000114	15	14	104%
17	127,249	0.000079	0.000125	10	16	63%
18	126,709	0.000151	0.000136	19	17	111%
19	126,412	0.000111	0.000146	14	18	76%
20	127,047	0.000103	0.000156	13	20	66%
21	125,620	0.000152	0.000164	19	21	93%
22	126,281	0.000183	0.000170	23	22	107%
23	129,464	0.000070	0.000176	9	23	40%
24	136,110	0.000184	0.000181	25	25	102%
25	145,343	0.000207	0.000186	30	27	111%
26	158,369	0.000178	0.000192	28	30	93%
27	173,155	0.000175	0.000199	30	34	88%
28	186,619	0.000139	0.000208	26	39	67%
29	199,730	0.000237	0.000219	47	44	108%
30	213,370	0.000165	0.000232	35	50	71%
31	227,590	0.000233	0.000249	53	57	94%
32	240,284	0.000180	0.000269	43	65	67%
33	252,123	0.000227	0.000292	57	74	78%
34	263,741	0.000324	0.000319	86	84	102%
35	275,480	0.000273	0.000349	75	96	78%
36	288,489	0.000346	0.000383	100	110	90%
37	303,080	0.000434	0.000420	132	127	103%
38	315,999	0.000451	0.000460	142	145	98%
39	328,262	0.000512	0.000504	168	165	102%
40	340,700	0.000487	0.000551	166	188	88%
41	353,156	0.000428	0.000603	151	213	71%
42	362,259	0.000554	0.000658	201	238	84%
43	369,016	0.000742	0.000718	274	265	103%
44	376,827	0.000777	0.000783	293	295	99%
45	385,075	0.000824	0.000854	317	329	97%
46	395,693	0.000923	0.000931	365	368	99%
47	402,042	0.001002	0.001014	403	408	99%
48	403,234	0.000989	0.001105	399	445	90%
49	400,324	0.001078	0.001202	432	481	90%
50	394,673	0.001278	0.001307	505	516	98%

Note: For age 0, duration 0 data is shown and for age 1, duration 1 data is shown

Actual and expected (HKA18) deaths – female lives duration 2+, full underwritten – continued

Age Last Birthday	Exposure	Crude q_x	Graduated q_x	Actual deaths	Expected deaths	Actual / Expected
51	387,029	0.001449	0.001420	561	550	102%
52	372,836	0.001383	0.001540	515	574	90%
53	354,025	0.001492	0.001668	528	591	89%
54	329,940	0.001671	0.001804	551	595	93%
55	306,526	0.001899	0.001947	582	597	98%
56	285,105	0.002158	0.002098	615	598	103%
57	263,425	0.002315	0.002256	610	594	103%
58	242,930	0.002326	0.002422	565	588	96%
59	220,609	0.002361	0.002596	521	573	91%
60	199,704	0.002508	0.002785	501	556	90%
61	180,868	0.003062	0.002995	554	542	102%
62	162,978	0.002857	0.003232	466	527	88%
63	144,082	0.003323	0.003504	479	505	95%
64	124,401	0.003535	0.003816	440	475	93%
65	105,960	0.004265	0.004177	452	443	102%
66	90,849	0.004692	0.004592	426	417	102%
67	76,339	0.004638	0.005068	354	387	92%
68	63,099	0.005333	0.005614	336	354	95%
69	51,675	0.005164	0.006253	267	323	83%
70	42,063	0.006652	0.007022	280	295	95%
71	36,356	0.007472	0.007954	272	289	94%
72	32,543	0.008491	0.009084	276	296	93%
73	29,250	0.009973	0.010450	292	306	95%
74	26,623	0.012504	0.012084	333	322	103%
75	24,662	0.014006	0.014023	345	346	100%
76	22,926	0.015694	0.016301	360	374	96%
77	21,143	0.016790	0.018954	355	401	89%
78	19,190	0.021590	0.021986	414	422	98%
79	17,036	0.021557	0.025360	367	432	85%
80	15,008	0.026731	0.029033	401	436	92%
81	13,178	0.032327	0.032961	426	434	98%
82	11,479	0.032776	0.037103	376	426	88%
83	9,793	0.037546	0.041415	368	406	91%
84	8,128	0.048413	0.045855	393	373	106%
85	6,558	0.050190	0.050381	329	330	100%
86	5,180	0.056373	0.060304	292	312	93%
87	4,010	0.064020	0.068444	257	274	94%
88	3,028	0.067992	0.077635	206	235	88%
89	2,177	0.087221	0.088002	190	192	99%
90	1,494	0.106060	0.099676	158	149	106%
91	980	0.115605	0.112801	113	111	102%
92	621	0.119559	0.127528	74	79	94%
93	380	0.092661	0.144018	35	55	64%
94	239	0.155865	0.162433	37	39	96%
95	127	0.183243	0.182942	23	23	100%
96	60	0.185381	0.205707	11	12	90%
97	31	0.321862	0.230884	10	7	139%
98	9	0.106581	0.258610	1	2	41%
99	2	0.000000	0.288997	0	1	0%
100	1	0.000000	1.000000	0	1	0%

Note: For age 0, duration 0 data is shown and for age 1, duration 1 data is shown

8.3 Comparison among HKA18, HKA01 and Hong Kong Life Table 2013

Male lives

Age	HKA18 q_x	HKA01 q_x	HKLT13 q_x	HKA18 / HKA01	HKA18 / HKTL13
0	0.000929	0.001000	0.002050	93%	45%
1	0.000203	0.000257	0.000296	79%	69%
2	0.000110	0.000161	0.000256	68%	43%
3	0.000099	0.000147	0.000222	67%	44%
4	0.000088	0.000133	0.000192	66%	46%
5	0.000079	0.000120	0.000167	66%	47%
6	0.000072	0.000110	0.000147	65%	49%
7	0.000067	0.000102	0.000131	66%	51%
8	0.000065	0.000098	0.000119	67%	55%
9	0.000067	0.000098	0.000112	69%	60%
10	0.000073	0.000103	0.000108	71%	68%
11	0.000084	0.000113	0.000107	75%	79%
12	0.000101	0.000130	0.000109	77%	92%
13	0.000122	0.000153	0.000114	80%	107%
14	0.000147	0.000184	0.000121	80%	121%
15	0.000174	0.000224	0.000132	78%	132%
16	0.000202	0.000272	0.000146	74%	138%
17	0.000231	0.000330	0.000165	70%	140%
18	0.000258	0.000399	0.000188	65%	137%
19	0.000283	0.000476	0.000214	59%	132%
20	0.000303	0.000528	0.000242	57%	125%
21	0.000319	0.000546	0.000270	59%	118%
22	0.000330	0.000539	0.000297	61%	111%
23	0.000337	0.000518	0.000324	65%	104%
24	0.000341	0.000495	0.000349	69%	97%
25	0.000343	0.000476	0.000376	72%	91%
26	0.000345	0.000465	0.000404	74%	85%
27	0.000347	0.000460	0.000436	75%	80%
28	0.000352	0.000463	0.000473	76%	74%
29	0.000360	0.000473	0.000513	76%	70%
30	0.000372	0.000490	0.000558	76%	67%
31	0.000390	0.000515	0.000608	76%	64%
32	0.000413	0.000548	0.000660	75%	63%
33	0.000442	0.000590	0.000714	75%	62%
34	0.000474	0.000639	0.000769	74%	62%
35	0.000511	0.000697	0.000821	73%	62%
36	0.000552	0.000763	0.000867	72%	64%
37	0.000595	0.000838	0.000910	71%	65%
38	0.000642	0.000923	0.000950	70%	68%
39	0.000691	0.001016	0.000993	68%	70%
40	0.000742	0.001118	0.001046	66%	71%
41	0.000796	0.001230	0.001115	65%	71%
42	0.000855	0.001352	0.001205	63%	71%
43	0.000921	0.001484	0.001319	62%	70%
44	0.000995	0.001625	0.001457	61%	68%
45	0.001080	0.001777	0.001613	61%	67%
46	0.001177	0.001941	0.001779	61%	66%
47	0.001289	0.002121	0.001950	61%	66%
48	0.001416	0.002322	0.002130	61%	66%
49	0.001561	0.002548	0.002322	61%	67%
50	0.001726	0.002803	0.002535	62%	68%

Male lives – continued

Age	HKA18 q_x	HKA01 q_x	HKLT13 q_x	HKA18 / HKA01	HKA18 / HKTL13
51	0.001911	0.003090	0.002779	62%	69%
52	0.002120	0.003415	0.003063	62%	69%
53	0.002354	0.003782	0.003394	62%	69%
54	0.002613	0.004194	0.003774	62%	69%
55	0.002901	0.004656	0.004201	62%	69%
56	0.003218	0.005172	0.004672	62%	69%
57	0.003566	0.005747	0.005180	62%	69%
58	0.003947	0.006384	0.005724	62%	69%
59	0.004364	0.007088	0.006308	62%	69%
60	0.004823	0.007862	0.006909	61%	70%
61	0.005333	0.008712	0.007523	61%	71%
62	0.005901	0.009641	0.008165	61%	72%
63	0.006534	0.010653	0.008857	61%	74%
64	0.007242	0.011754	0.009628	62%	75%
65	0.008031	0.012945	0.010520	62%	76%
66	0.008910	0.014236	0.011567	63%	77%
67	0.009887	0.015673	0.012799	63%	77%
68	0.010971	0.017345	0.014239	63%	77%
69	0.012196	0.019341	0.015898	63%	77%
70	0.013612	0.021752	0.017723	63%	77%
71	0.015268	0.024403	0.019681	63%	78%
72	0.017213	0.027377	0.021759	63%	79%
73	0.019498	0.030714	0.023992	63%	81%
74	0.022172	0.034457	0.026436	64%	84%
75	0.025283	0.038657	0.029168	65%	87%
76	0.028883	0.043368	0.032259	67%	90%
77	0.033019	0.048653	0.035769	68%	92%
78	0.037699	0.054583	0.039754	69%	95%
79	0.042869	0.061235	0.044245	70%	97%
80	0.048466	0.068698	0.049256	71%	98%
81	0.054430	0.077070	0.054792	71%	99%
82	0.060699	0.086463	0.060848	70%	100%
83	0.067213	0.097001	0.067414	69%	100%
84	0.073910	0.108822	0.074479	68%	99%
85	0.080729	0.122085	0.082217	66%	98%
86	0.096627	0.136964	0.090681	71%	107%
87	0.108558	0.153656	0.099927	71%	109%
88	0.121860	0.172383	0.110014	71%	111%
89	0.136663	0.193392	0.121002	71%	113%
90	0.153102	0.216961	0.132954	71%	115%
91	0.171316	0.243403	0.145932	70%	117%
92	0.191440	0.273067	0.160000	70%	120%
93	0.213610	0.306347	0.175223	70%	122%
94	0.237948	0.343682	0.191664	69%	124%
95	0.264564	0.385568	0.209385	69%	126%
96	0.293544	0.432559	0.228443	68%	128%
97	0.324942	0.485276	0.248895	67%	131%
98	0.358770	0.544418	0.270791	66%	132%
99	0.394986	0.610768	0.294173	65%	134%
100	1.000000	0.685205	1.000000	146%	100%

Female lives

Age	HKA18 q_x	HKA01 q_x	HKLT13 q_x	HKA18 / HKA01	HKA18 / HKTL13
0	0.000805	0.001000	0.001243	80%	65%
1	0.000320	0.000333	0.000241	96%	133%
2	0.000146	0.000093	0.000211	157%	69%
3	0.000134	0.000090	0.000183	149%	73%
4	0.000123	0.000088	0.000159	140%	77%
5	0.000113	0.000086	0.000138	131%	82%
6	0.000103	0.000085	0.000120	121%	86%
7	0.000095	0.000086	0.000105	110%	91%
8	0.000088	0.000088	0.000093	100%	95%
9	0.000083	0.000092	0.000085	90%	98%
10	0.000080	0.000099	0.000080	81%	100%
11	0.000080	0.000108	0.000079	74%	101%
12	0.000083	0.000120	0.000082	69%	102%
13	0.000088	0.000134	0.000087	66%	101%
14	0.000095	0.000146	0.000095	65%	101%
15	0.000104	0.000156	0.000103	67%	101%
16	0.000114	0.000164	0.000113	70%	101%
17	0.000125	0.000172	0.000122	73%	102%
18	0.000136	0.000179	0.000131	76%	104%
19	0.000146	0.000185	0.000139	79%	105%
20	0.000156	0.000191	0.000147	81%	106%
21	0.000164	0.000197	0.000155	83%	106%
22	0.000170	0.000203	0.000164	84%	104%
23	0.000176	0.000210	0.000174	84%	101%
24	0.000181	0.000218	0.000186	83%	98%
25	0.000186	0.000227	0.000198	82%	94%
26	0.000192	0.000238	0.000211	81%	91%
27	0.000199	0.000250	0.000223	80%	89%
28	0.000208	0.000264	0.000236	79%	88%
29	0.000219	0.000280	0.000249	78%	88%
30	0.000232	0.000299	0.000262	78%	89%
31	0.000249	0.000321	0.000276	78%	90%
32	0.000269	0.000346	0.000290	78%	93%
33	0.000292	0.000374	0.000306	78%	96%
34	0.000319	0.000407	0.000325	78%	98%
35	0.000349	0.000443	0.000349	79%	100%
36	0.000383	0.000483	0.000380	79%	101%
37	0.000420	0.000528	0.000417	79%	101%
38	0.000460	0.000577	0.000462	80%	100%
39	0.000504	0.000632	0.000514	80%	98%
40	0.000551	0.000692	0.000573	80%	96%
41	0.000603	0.000758	0.000637	79%	95%
42	0.000658	0.000830	0.000704	79%	93%
43	0.000718	0.000908	0.000776	79%	93%
44	0.000783	0.000992	0.000851	79%	92%
45	0.000854	0.001083	0.000931	79%	92%
46	0.000931	0.001182	0.001014	79%	92%
47	0.001014	0.001287	0.001104	79%	92%
48	0.001105	0.001401	0.001203	79%	92%
49	0.001202	0.001524	0.001312	79%	92%
50	0.001307	0.001657	0.001437	79%	91%

Female lives – continued

Age	HKA18 q_x	HKA01 q_x	HKLT13 q_x	HKA18 / HKA01	HKA18 / HKTL13
51	0.001420	0.001801	0.001579	79%	90%
52	0.001540	0.001956	0.001740	79%	89%
53	0.001668	0.002124	0.001918	79%	87%
54	0.001804	0.002306	0.002113	78%	85%
55	0.001947	0.002502	0.002315	78%	84%
56	0.002098	0.002714	0.002520	77%	83%
57	0.002256	0.002942	0.002725	77%	83%
58	0.002422	0.003187	0.002932	76%	83%
59	0.002596	0.003453	0.003145	75%	83%
60	0.002785	0.003754	0.003363	74%	83%
61	0.002995	0.004109	0.003591	73%	83%
62	0.003232	0.004538	0.003844	71%	84%
63	0.003504	0.005060	0.004134	69%	85%
64	0.003816	0.005694	0.004476	67%	85%
65	0.004177	0.006458	0.004874	65%	86%
66	0.004592	0.007373	0.005334	62%	86%
67	0.005068	0.008457	0.005868	60%	86%
68	0.005614	0.009730	0.006491	58%	86%
69	0.006253	0.011210	0.007223	56%	87%
70	0.007022	0.012917	0.008035	54%	87%
71	0.007954	0.014593	0.008926	55%	89%
72	0.009084	0.016486	0.009917	55%	92%
73	0.010450	0.018626	0.011054	56%	95%
74	0.012084	0.021042	0.012395	57%	97%
75	0.014023	0.023773	0.014003	59%	100%
76	0.016301	0.026857	0.015938	61%	102%
77	0.018954	0.030342	0.018245	62%	104%
78	0.021986	0.034279	0.020964	64%	105%
79	0.025360	0.038727	0.024118	65%	105%
80	0.029033	0.043752	0.027721	66%	105%
81	0.032961	0.049429	0.031774	67%	104%
82	0.037103	0.055843	0.036275	66%	102%
83	0.041415	0.063089	0.041219	66%	100%
84	0.045855	0.071275	0.046597	64%	98%
85	0.050381	0.080523	0.052586	63%	96%
86	0.060304	0.090971	0.059239	66%	102%
87	0.068444	0.102775	0.066614	67%	103%
88	0.077635	0.116110	0.074769	67%	104%
89	0.088002	0.131176	0.083764	67%	105%
90	0.099676	0.148197	0.093663	67%	106%
91	0.112801	0.167426	0.104526	67%	108%
92	0.127528	0.189150	0.116417	67%	110%
93	0.144018	0.213693	0.129396	67%	111%
94	0.162433	0.241421	0.143522	67%	113%
95	0.182942	0.272746	0.158850	67%	115%
96	0.205707	0.308136	0.175434	67%	117%
97	0.230884	0.348118	0.193319	66%	119%
98	0.258610	0.393288	0.212545	66%	122%
99	0.288997	0.444318	0.233142	65%	124%
100	1.000000	0.501971	1.000000	199%	100%

8.4 Graduation methodology

The crude death rates were graduated using natural cubic splines with variable knots for the ages 2 to 85 years for both genders.

Natural cubic spline is a form of interpolation by using piecewise third-order polynomials subject to certain alignment at their joints. It is presented as an alternative to fit a single function over the entire range of data. In our study, we use natural cubic spline graduation by the least-squares method on crude rates, q_x^c, to derive the graduated rate q_x. It's also the graduation method used in HKA01 report.

The natural cubic spline graduation specifies that the second derivatives at each end are zero.

$$q(x) = \begin{cases} q_0(x) = a_0x^3 + b_0x^2 + c_0x + d_0, & x_0 \le x \le x_1 \\ q_1(x) = a_1x^3 + b_1x^2 + c_1x + d_1, & x_1 \le x \le x_2 \\ \vdots & \\ q_{n-1}(x) = a_{n-1}x^3 + b_{n-1}x^2 + c_{n-1}x + d_{n-1}, & x_{k-1} \le x \le x_k \end{cases}$$

where $x \in q_x^c$, and satisfies

$$\left.\begin{matrix} q_{i-1}(x) = q_i(x) \\ q'_{i-1}(x) = q'_i(x) \\ q''_{i-1}(x) = q''_i(x) \end{matrix}\right\} \forall \, \mathrm{i} = 1, 2, \dots, \mathrm{k}-1$$

where k is the number of knots – more knots used will increases the model fitness but reduce its smoothness.

Let the weight to be $w_x = \frac{n_x}{q_x * (1 - q_x)}$ where n_x is the exposure at age x.

And then the goal is to minimize:

$$SS = \sum_{x=1}^{n} w_x * (q_x^c - q_x)^2$$

The natural cubic spline graduation has the following advantages:

- Easy to calculate with fewer parameters;
- Fit to data better with multiple splines used while keeping higher smoothness;
- Less tendency to oscillate between data points;
- Interpolation error can be small even when using low degree polynomials;
- Obtain a simpler function than single adjustment on the whole data

By using natural cubic spline graduation, the graduated rates show similar goodness-of-fit and smoothness level among different numbers of knots used. Also, their fitness level increases as the number of knots increases, which aligns with the model design. Therefore, we used the testing method suggested by McCutcheon (i.e. the same method adopted by HKA01 report) to determine the number of knots for our final selection. The lowest t-test values are generated by 8 knots for both male and female, which means that those knots number have already resulted in the suitable models effectively. As a result, 8 knots is used for both male and female. Fitness and smoothness level are balanced out while the weighted least square criterion is effectively minimized.

As described in Section 4.3, the graduated rates above age 85 are obtained using Gompertz model. Makeham model, which is applied in HKA01 study, is not adopted this time, as the fitted curve of this model is higher than most of others, especially for female. By evaluating on each criteria and comparing with our crude data, we concluded that the Gompertz model and Kannisto model are more reliable models to choose. In our study, we finally decided to use Gompertz model for both male and female extrapolation for consistency.

8.5 Reference list

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8.6 Participating companies

Data for this study has been provided by the following companies:

1. AIA International Limited
2. AXA China Region Insurance Company Limited
3. BEA Life Limited
4. Blue Insurance Limited
5. BOC Group Life Assurance Company Limited
6. Chubb Life Insurance Company Ltd.
7. Fubon Life Insurance (Hong Kong) Company Limited
8. Hang Seng Insurance Company Limited
9. HSBC Life (International) Limited
10. Manulife (International) Limited
11. Prudential Hong Kong Limited
12. Standard Life (Asia) Limited
13. Sun Life Hong Kong Limited
14. Tahoe Life Insurance Company Limited
15. Transamerica Life (Bermuda) Ltd
16. YF Life Insurance International Ltd
17. Zurich Life Insurance (Hong Kong)