Report on

Hong Kong Assured

Lives Mortality

2001

Actuarial Society of Hong Kong

Introduction

The Council of the Actuarial Society of Hong Kong has great pleasure in presenting its third full report on the mortality of assured lives in Hong Kong.

The Society is indebted to a number of people and companies:

David Alexander of Swiss Re Life & Health for taking responsibility within the Council for this project and seeing it through to a successful conclusion.

Joachim Zagrosek and Matthew Ha of Swiss Re Life & Health for the considerable time and effort which they put into the analysis and the production of this report.

Other members of the ASHK Experience Studies Committee, Thomas M N Lee of AIA, Linda Yip and Frederick Kong of AXA, Liu Siu Yin and Steven To of GeneralCologne Re, Clement Cheung and Lee Shing Ma of Manulife, Adrian Liu and May Chun of Tillinghast-Towers Perrin, Diane Chung of Watson Wyatt and Raymond Leung of Winterthur Life, who have given their guidance and advice on the analyses and their interpretation.

AIA, AXA, Bank of China, CIGNA, CMG, Eagle Star, Hang Seng Life, HSBC Life, ING Life, Manulife, Mass Mutual, MLC, Prudential, Scottish Provident International and Winterthur for contributing the underlying data and for providing valued assistance in interpreting this data.

The Council intends to continue analysing the emerging experience of mortality and morbidity of Hong Kong's assured lives, and as the volume of data grows, it will become possible to make even more credible analyses of different aspects of mortality and morbidity. The success of this work will depend on the continued valued participation of the life offices in Hong Kong, and of actuaries and actuarial students contributing their time and energy to the study.

Michael Ross
ASHK President

David Alexander
Chairman,
ASHK Experience Studies Committee

Hong Kong Assured Lives Mortality Study 2001

1. Executive summary

With the help of actuaries and students and their companies we have collected 30% more data than the last survey of assured lives mortality in Hong Kong. We believe that the survey is representative of the market average mortality for permanent assurances as it represents 57% of the in-force lives.

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

For this report, we have completed some extra analyses and included some additional information in terms of the description of the in-force and analysis of the results.

Our main output is a new mortality table for assured lives in Hong Kong which we hope that the profession and the industry will find useful in pricing, valuation and general research.

In terms of results, a brief summary of the conclusions would be:

- Generally mortality is improving for assured lives in Hong Kong at young and middle ages
- Mortality at older ages (over age 70) would seem to be increasing - although it is more difficult to interpret the figures at these ages due to the limited data
- Expectation of life is very similar to HKA97
- Cause of death seems to be consistent with previous surveys

In using the new table, please bear in mind the limitations of the survey as outlined in section 5 of the report and make appropriate adjustments according to the purpose for which you are using the table.

An electronic copy of this report is to be found on the website of the Actuarial Society of Hong Kong, www.actuaries.org.hk together with an electronic copy of the new assured lives mortality table.

Finally, we have decided to call the new table HKA01.

2. Data

The study period of the mortality is from 1/1/1991 to 1/1/2001. It was decided that the new mortality study should include an analysis based on lives and amounts assured. The questionnaire which was sent to the participating companies asked for the following parameters both on a per policies/per lives and a per amounts basis:

- age
- sex
- non-medical/medical cases
- duration 0, 1 and 2+
- cause of death in three age groups

Product type was also requested as an optional split of the data, however, insufficient data was received to complete the analysis. A very large proportion of the products in the survey are permanent assurances. The companies were asked to provide information for standard rated lives only.

Throughout the report, age is defined as age last and duration is curtate duration since inception.

2.1 Overview of data gathered

2.1.1 Penetration of survey

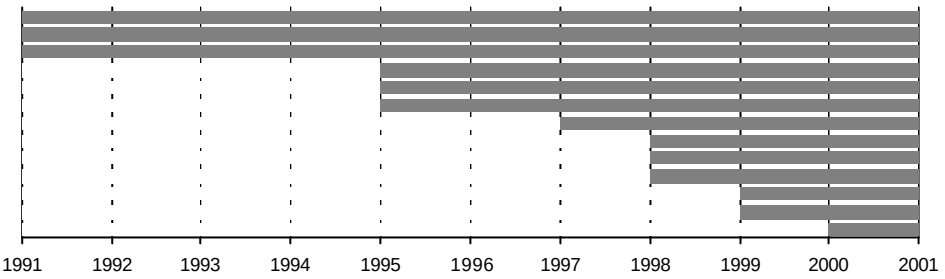
Fifteen companies delivered data for this survey. According to the Office of the Commissioner of Insurance 63 insurers were authorized to sell long term insurance at the end of 2000. Despite the small number of companies, this study was performed on 70% of the assured individual policies which were reported to the Commissioner of Insurance for the year 2000, ie, most of the larger companies are included.

HKA01 In-force policies reported at 1/1/2001	Total in-force policies in Hong Kong according to the Commissioner of Insurance report 2001	HKA01 study penetration
3 204 107	4 605 380	70%

The data collected includes experience from 8 of the top 10 long term insurance companies in terms of lives in-force. The remaining 43% of lives in-force included a large proportion of data which might not be relevant to this survey e.g. critical illness policies. The number of lives which the fifteen companies made available for this report make up 88% of their total portfolios as reported to the Commissioner of Insurance report 2001.

2.1.2 Data by company

The amount of data which the 15 participating companies made available varies in a wide range. Only three companies were able to deliver in-force data and death claims from 1991 to 2001. With the different sizes of the contributing companies the number of in-force lives differ from close to 10 million to a few hundred. The following graph shows the years of in-force with duration 2+ according to each contributing company. Since two companies delivered only duration 0 and 1 figures the total number of companies reduces to 13.



Six companies provided in-force data per policy. Seven companies delivered the data per life and 2 companies made available both per amounts and per life. From the data from these 2 companies a policy per life ratio of 1.1 for non-medical and 1.2 medical business was determined and applied to the per policy information. It is possible that multiple claim entries could cause some overstatement of mortality on a per lives basis.

2.1.3 Comparison of data with HKA97

The following tables highlight that the HKA01 mortality study is based on significantly higher experience data than its predecessor. The reason for this is both 30% more data collected and using the full dataset of 10 years which leads to a total increase of 70%. In contrast, HKA97 used 5 years of data although information for 10 years was collected.

HKA97 had a market penetration of 72% in the year 1997 compared to 70% for HKA01 in 2000.

		In-force lives		Deaths	
Gender	Duration	HKA01	HKA97	HKA01	HKA97
Male	0	1 692 291	1 203 271	850	603
	1	1 385 409	999 159	898	608
	2+	6 718 224	3 742 084	7 319	3 928
Female	0	1 487 363	938 413	361	246
	1	1 200 410	774 645	383	275
	2+	4 851 170	2 419211	3 006	1 471
Total		17 334 867	10 076 783	12 817	7 130

The reported in-force amounts and death claims total to HK$ 6,823 bn and HK$ 3,135 m, respectively.

Gender	Duration	In-force amount in HK$ m	Death claims in HK$ m
Male	0	762 969	254
	1	600 716	234
	2+	2 618 716	1 799
Female	0	584 323	84
	1	461 557	104
	2+	1 794 529	659
Total		6 822 809	3 135

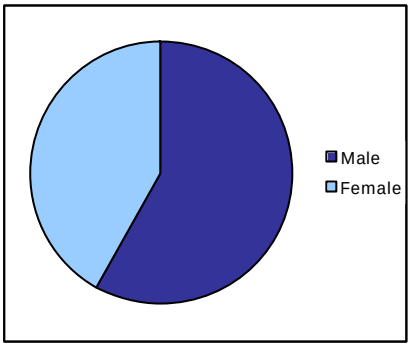
The average in-force per life amounts to HK$ 393,589 whereas the average claim is HK$ 244,597.

2.2 Analysis of in-force

2.2.1 In-force by gender

Male lives make up 58% of the total lives with duration 2+. When analysing new policies an interesting development can be seen. The female proportion is continuously rising and for the years 1999 and 2000 more female lives with duration 0 were reported than male lives. However, if the amounts assured are considered the male proportion still dominates with HK$ 129 bn to HK$ 105 bn for female lives for new policies as at 1/1/2001.

Breakdown of duration 2 + in-force lives by gender



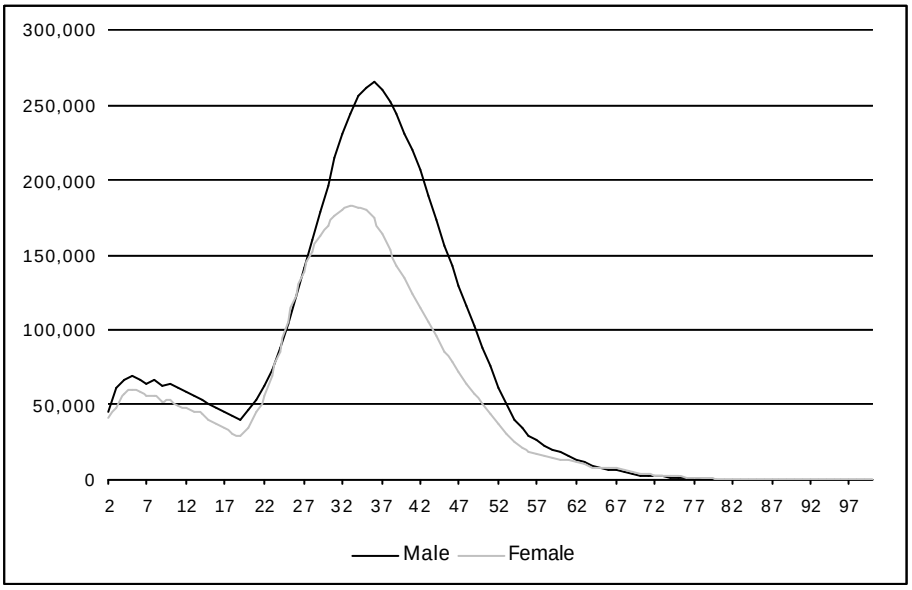
2.2.2 Non-medical versus medical business in-force

The proportion of the medical to the non-medical cases is fairly stable for the reporting period. Fifteen per cent of the total lives are medical cases. Not surprisingly the proportion is higher when considering the per amounts figures. The numbers are 22% for male and 16% for female lives which is a result of the higher average sums assured of male lives.

2.2.3 In-force age distribution

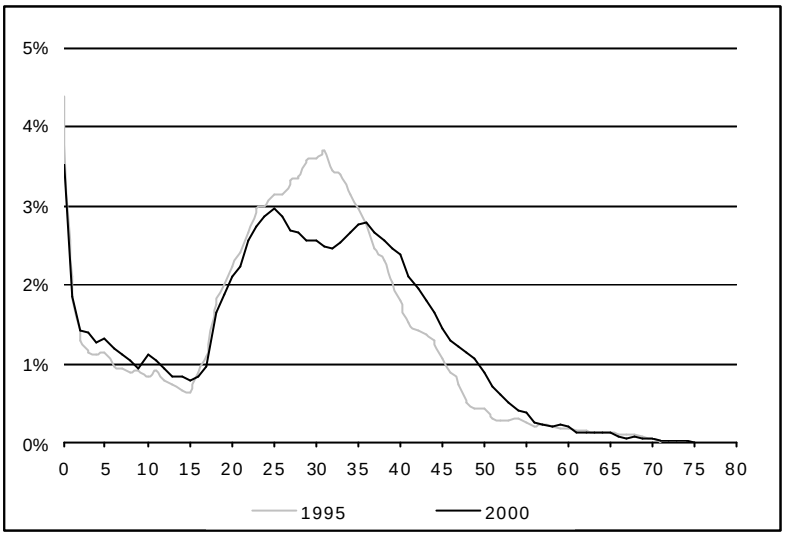
The age distributions of the male and female in-force have a similar shape. The aggregated male in-force data with duration 2+ peaks at age 36 where for female the peak age is 34 years.

Total in-force male and female lives for duration 2+ by age last

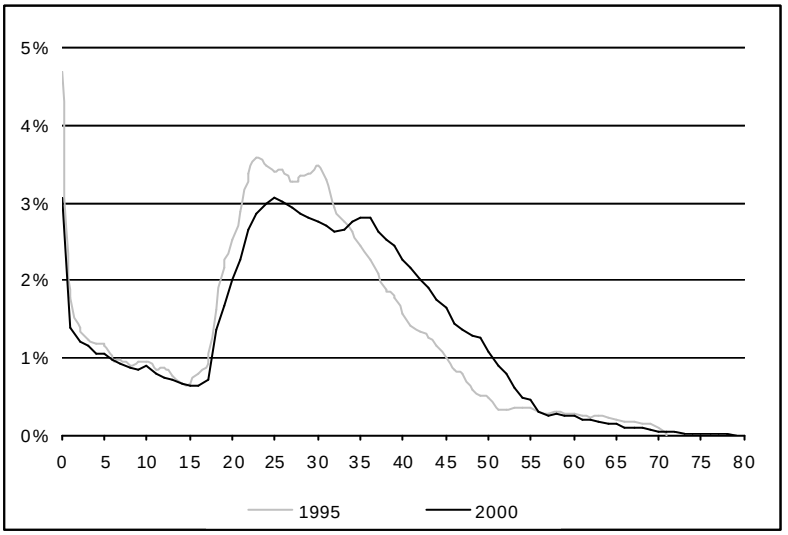


The change of the shape of the distribution of new policies from the early nineties to the present is due to the invention of new products such as juvenile policies, education and personal retirement plans. For both males and females there is a significant increase in the proportion of new business from people of age 40 to 50 years.

Distribution of duration 0 policies for male lives as at 1/1/1995 and 1/1/2000 by age last



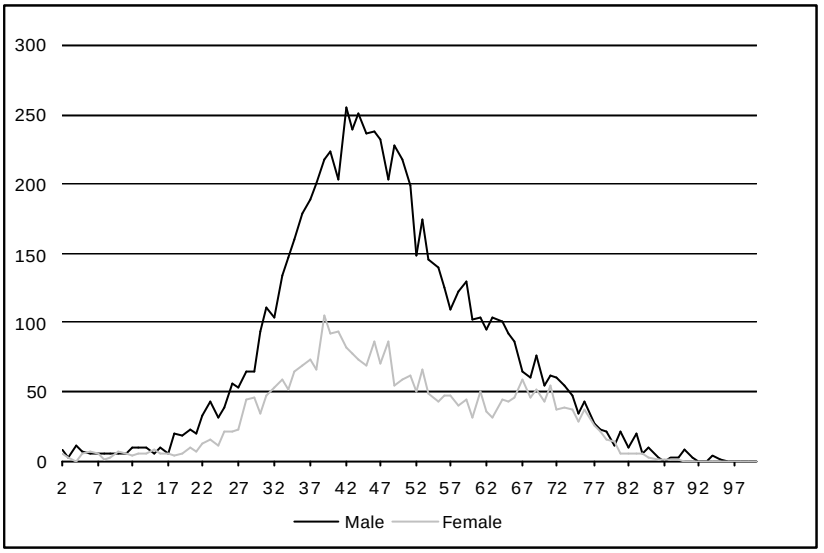
Distribution of duration 0 policies for female lives as at 1/1/1995 and 1/1/2000 by age last



2.3 Age distribution of deaths

The following graph shows the number of deaths per gender and contains some interesting information. The median age of the death claims is 42 for male and 39 for female lives. This is a reflection of the higher exposed to risk at these ages not higher mortality rates.

Total death claims by age last for male and female lives and duration 2+



This graph shows the scarcity of data below age 25 and above age 75.

2.4 Data validation

A number of tests were carried out to validate the crude data received from the participating companies. The following checks are a sample of the tests which were performed on the data of each company:

- maximum, minimum, average entry ages were determined and compared between per amounts and per lives file;
- average sum assured and average claim amount were compared;
- crude death rates were determined and compared to the outcome of the amounts and policy/life file;
- examination of the lapse rates between duration 0 versus duration 1, and duration 1 versus duration 2+;
- per amounts and per lives lapse rates were checked;
- trend of actual/expected for per lives and per amounts evaluated.

The results were sent back to the contributors to review.

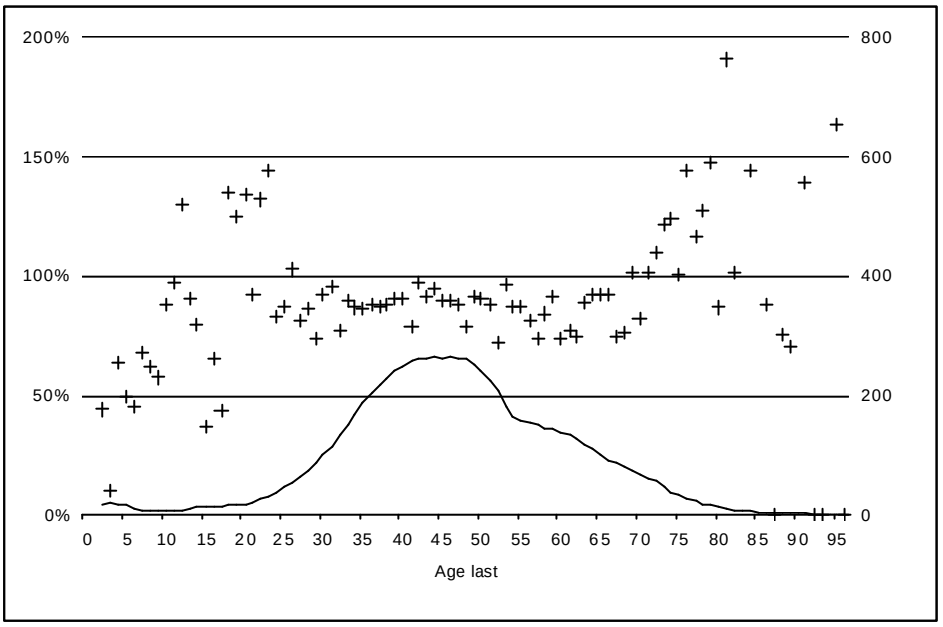
3. Results

The results presented in this section are based on the full dataset from 1991 to 2000. The previous studies HKA97 and HKA93 refer to a reduced amount of data of 5 years. Using 10 years might blur some trends but for maximum credibility of this study it was decided to make use of the whole collected data. The central year of the underlying exposure is 1997 for both male and female lives.

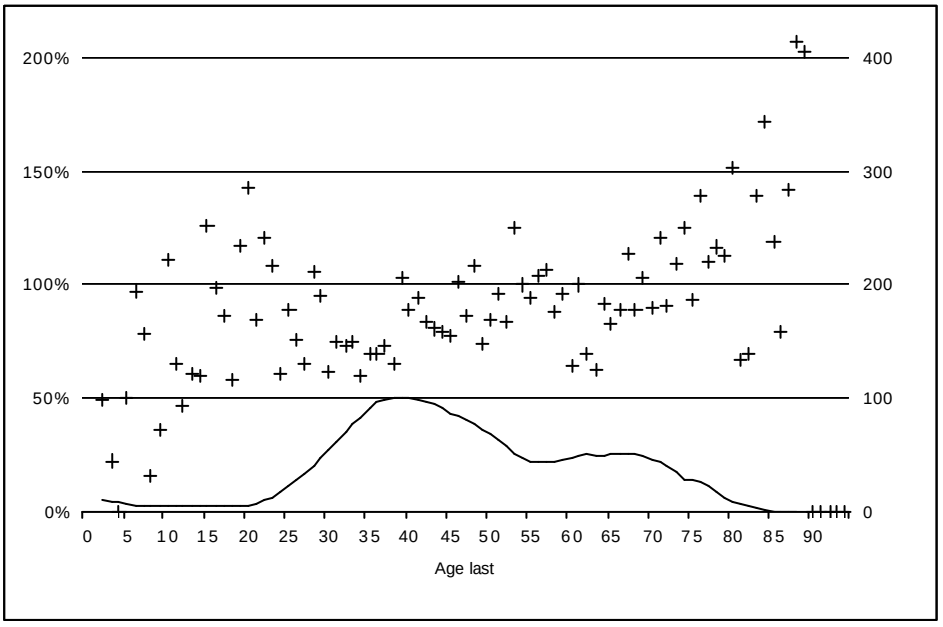
3.1 Actual versus expected (based on HKA97 mortality rates)

The figures below are based on duration 2+ numbers and contain two sets of information. The axis to the left refers to the crosses which show crude data from the HKA01 survey compared to the expected from HKA97. The axis on the right and the solid line display the expected number of deaths of the HKA01 in-force with the HKA97 mortality in order to give an appreciation of the credibility of these crude results. It is apparent that the mortality of the ages 25 to 70 improved for both genders. However, the results at older ages appear to be higher than HKA97.

Male crude / HKA97 death rates and expected number of deaths



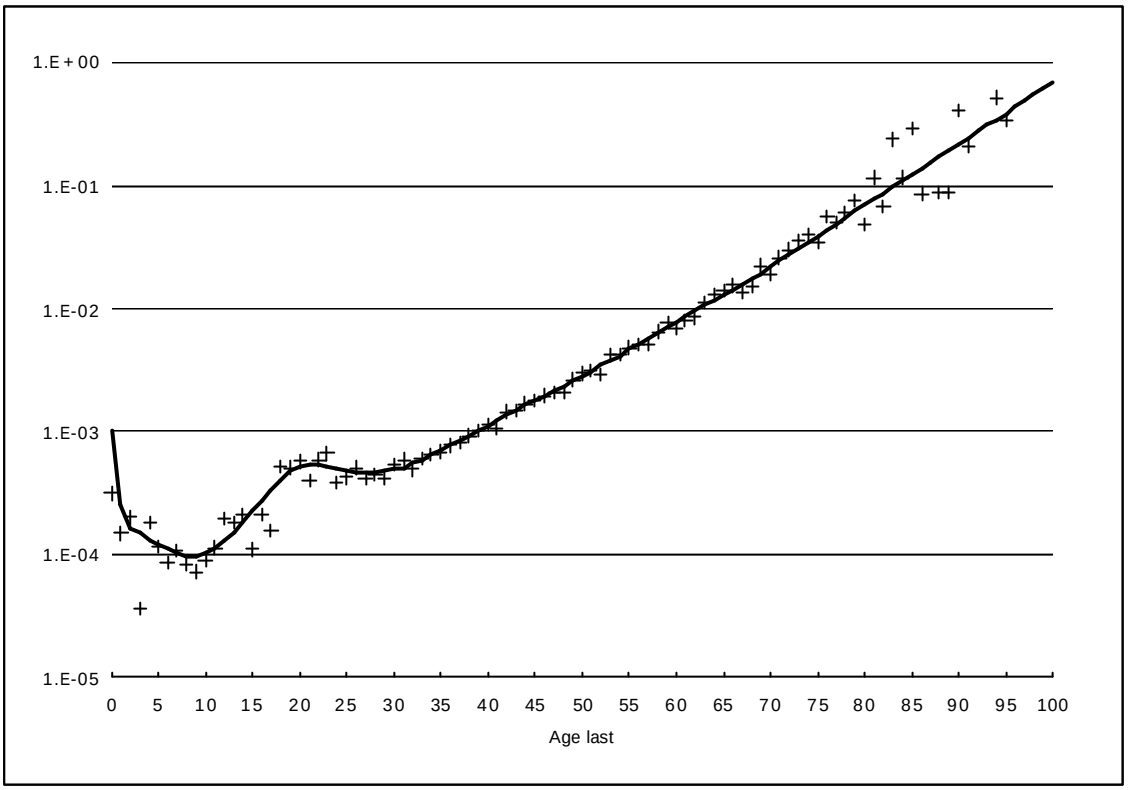
Female crude / HKA97 death rates and expected number of deaths



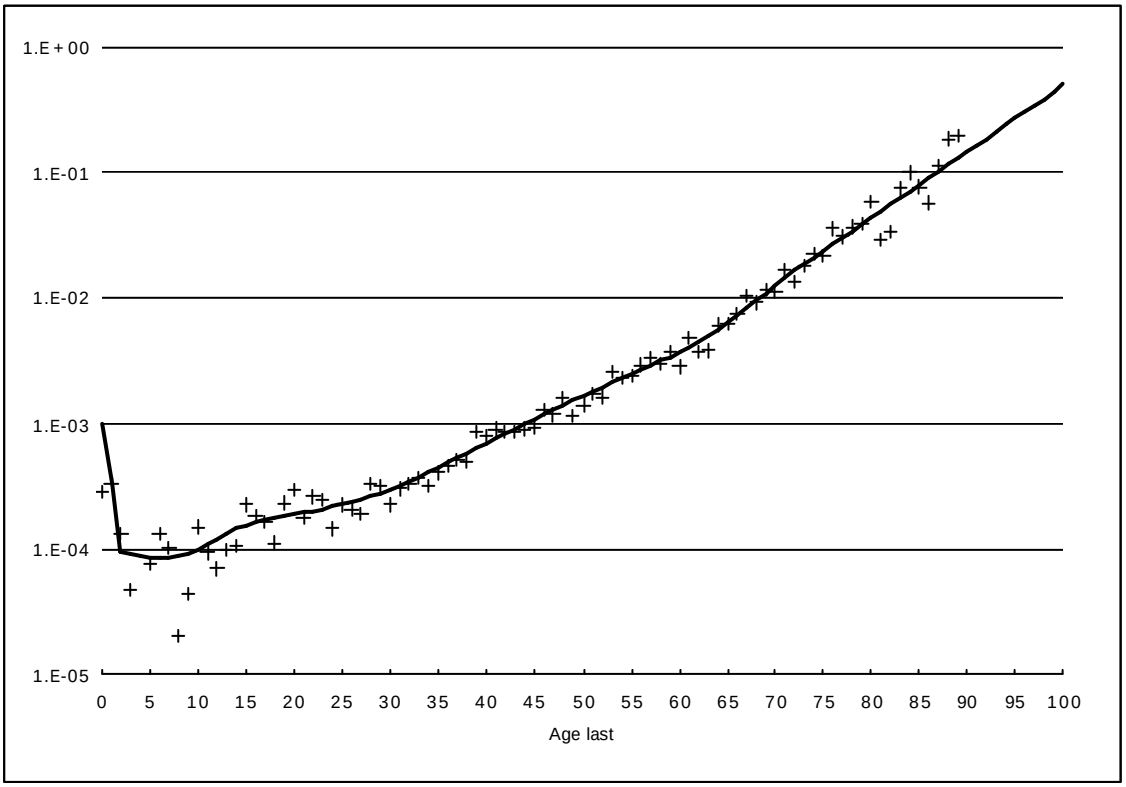
3.2 Graduated and crude mortality rates

The graduation was performed using cubic splines with variable knots. For ages above 70 years the mortality rates were graduated using Makeham type functions. The graduation method is described in appendix 6.4

Graduated and crude mortality rates for male lives

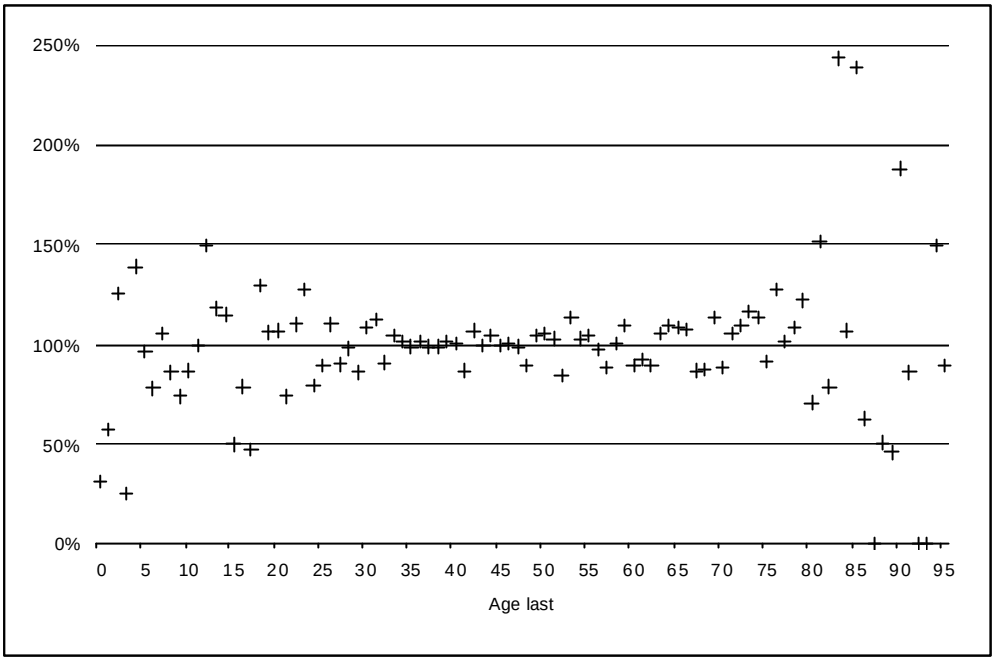


Graduated and crude mortality rates for female lives

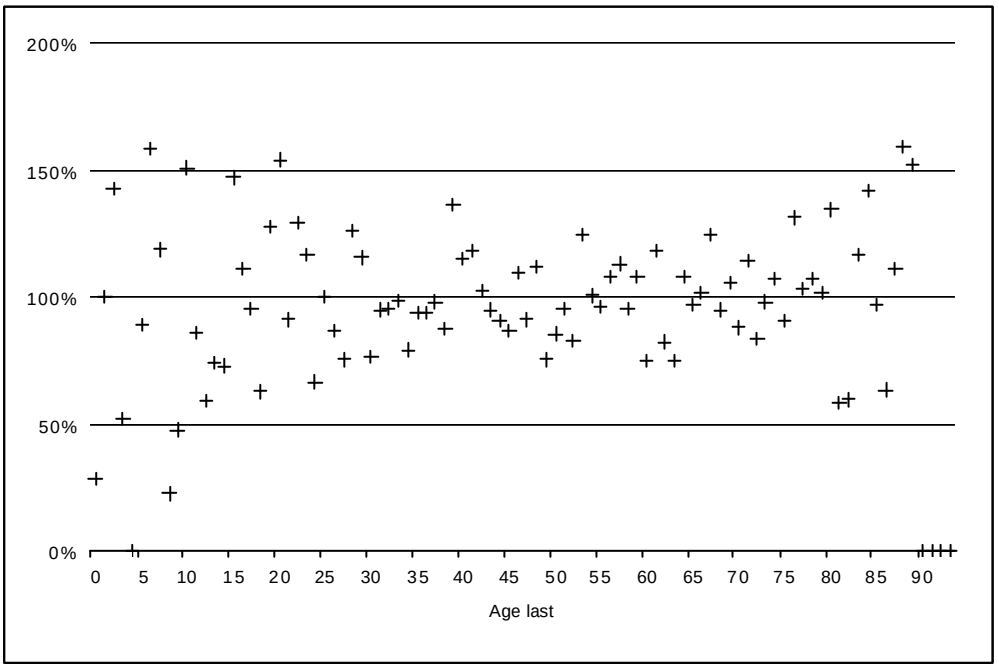


The following graphs illustrate the effect of the graduation in particular the additional credibility between ages 30 and 65 for males. Conversely the graphs show the dispersion of results for very young and old ages for males and all ages for females. The 100% figures represent the graduated rates in these graphs.

Crude / graduated mortality rates for male lives



Crude / graduated mortality rates for female lives



3.3 Comparison of HKA01 and HKA97

The mortality improvements from HKA97 to HKA01 for the ages between 20 and 70 are around 10% to 15% for both genders.

Male deaths:

Age group	Actual	Expected HKA01	Expected HKA97	A/E HKA01	A/E HKA97	Credibility of HKA01
< 20	171	248	636	69.0%	26.9%	33.4%
20 – 29	423	441	453	95.9%	93.4%	52.5%
30 – 39	1,530	1,515	1,739	101.0%	88.0%	99.8%
40 – 49	2,309	2,326	2,594	99.3%	89.0%	100.0%
50 – 59	1,509	1,493	1,767	101.1%	85.4%	99.1%
60 – 69	881	895	1,058	98.4%	83.2%	75.7%
70 – 79	427	401	386	106.6%	110.7%	52.7%
>= 80	96	87	64	110.2%	149.6%	25.0%
Total	7,345	7,406	8,697	99.2%	84.5%	100.0%

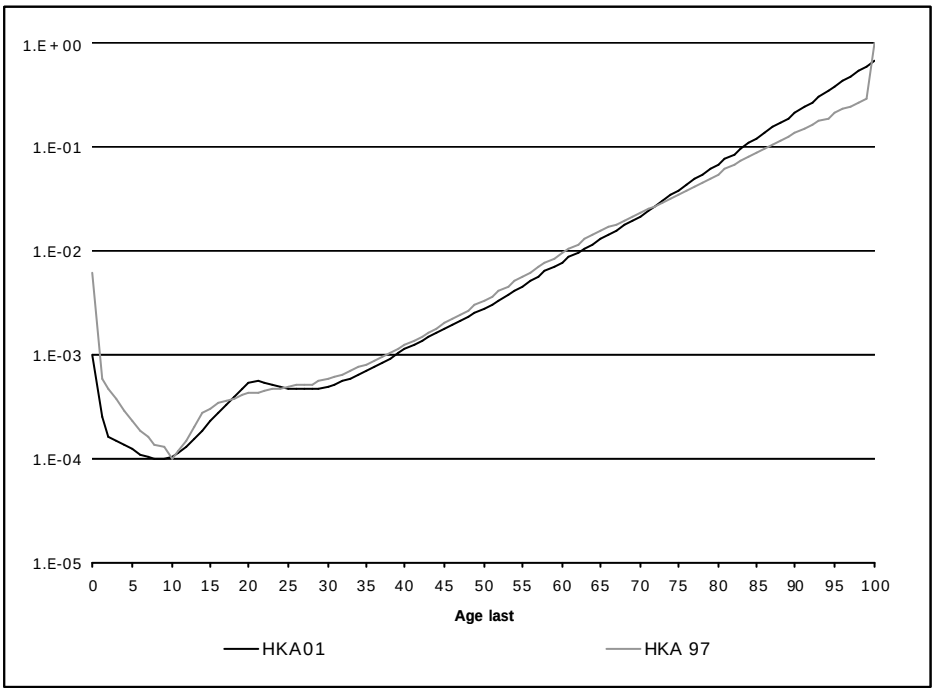
Female deaths:

Age group	Actual	Expected HKA01	Expected HKA97	A/E HKA01	A/E HKA97	Credibility of HKA01
< 20	106	158	410	67.0%	25.9%	26.3%
20 – 29	211	204	234	103.3%	90.1%	37.1%
30 – 39	619	639	840	96.7%	73.6%	63.4%
40 – 49	783	784	891	99.8%	87.8%	71.4%
50 – 59	507	508	520	99.8%	97.5%	57.4%
60 – 69	436	442	501	98.7%	87.1%	53.3%
70 – 79	337	333	309	101.1%	108.9%	46.8%
>= 80	38	39	34	96.3%	112.9%	15.7%
Total	3,036	3,108	3,739	97.7%	81.2%	100.0%

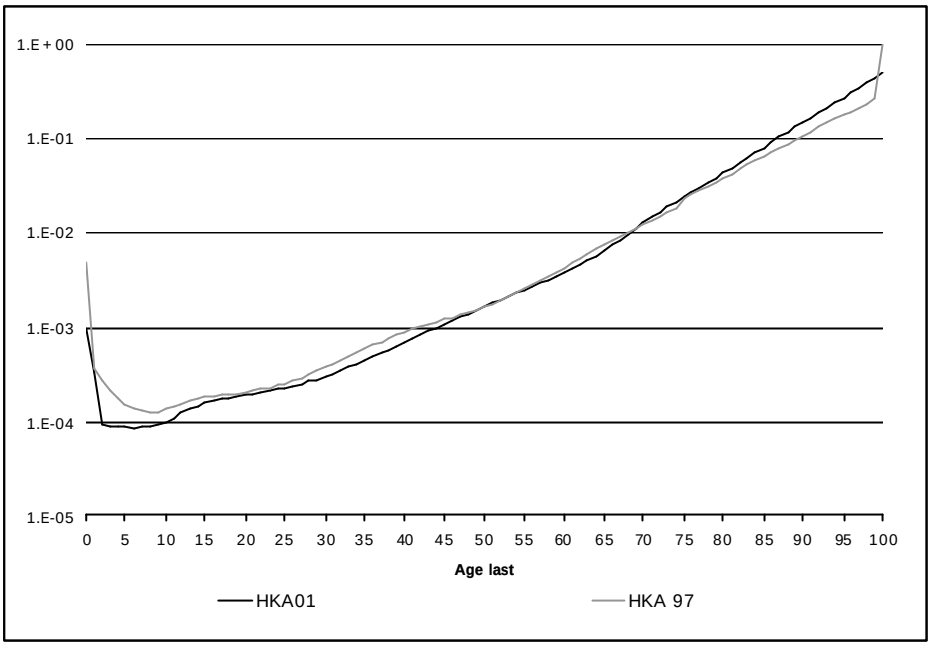
See section 6.4 for definition of credibility.

The two graphs below illustrate the changes of the mortality from HKA97 to HKA01.

Comparison of graduated q_x for male lives



Comparison of graduated q_x for female lives



3.4 High and low ages

Due to the sparse data sets at the ends of the tables, the spline graduation could not be extended to high and low ages. For HKA97 this was solved by using a constant proportion of the Hong Kong Life Table 1995 for the ages below 14 and above 74. The proportion used was equal to the ratios of the graduated rates to the Hong Kong Life Table 1995 for the ages 14 and 74.

When analysing the data of the 2001 Mortality study we realized that it was not possible to apply the same method since the mortality for ages above 70 was significantly higher than HKA97, in contrast to the better mortality for lives below 70 years.

For male lives over 70 the actual deaths are 523 compared to 450 expected claims with the HKA97 rates. For females 375 claims compare to 343 expected.

As suggested by Benjamin and Pollard[1] functions of the Makeham type were used to approximate the mortality of the ages over 70 years for HKA01. However due to the sparse data sets for this age range and hence the low credibility of results, the parameters were chosen such that the deterioration of the mortality rates is not fully reflected in the new rates. The expected claims of HKA01 amount to 488 for male and 372 for female lives.

For the ages 0 and 1 the actual deaths were far from the expected based on HKA97 (see table below). Since the number of claims is fairly small it was decided to take a cautious view compared to the new experience. This set of rates is also supported by infant mortality rates for children of age 30 to 365 days (post neo-natal age) from the study "Demographic Trends in Hong Kong 1981 – 1996"[2] by the Census and Statistics Department Hong Kong. The 30 day lower age is chosen as most insurance companies will not accept proposals on lives under 30 days.

Gender	Actual	Expected HKA01	Expected HKA97
Male	26	73	403
Female	30	68	282

3.5 Expectation of life

According to this analysis, the expectation of life for assured lives in Hong Kong did not improve or even decreased since the last investigation in 1997. The improved mortality for the ages 25 to 70 years are offset by the increased mortality for higher ages.

Based on the graduated mortality rates, the expectation of assured life at birth for females is 83.2 years compared to 83.6 years with the HKA97 rates. For male lives the life expectancy at birth for HKA01 is 78.6 years which is exactly the same as for HKA97. The changing expectation of life may reflect a different population insured rather than a genuine change in the underlying mortality.

The following tables compare the expectation of life at different ages of HKA01, HKA97, HKA93 and the Hong Kong Life Table 1996[3] (population statistics).

Male Expectation of Life:

Age last	HKA01 (1991-2000)	HKA97 (1991-1996)	HKA93 (1987-1991)	Hong Kong Life Table 1996
0	78.6	78.6	80.2	75.8
10	68.8	69.3	71.2	66.1
20	58.9	59.4	61.4	56.3
30	49.2	49.7	51.6	46.7
40	39.5	40.0	41.9	37.2
50	30.1	30.7	32.5	28.0
60	21.3	22.1	23.7	19.6
70	13.4	14.8	15.9	12.6

Female Expectation of Life:

Age last	HKA01 (1991-2000)	HKA97 (1991-1996)	HKA93 (1987-1991)	Hong Kong Life Table 1996
0	83.2	83.6	85.0	81.4
10	73.4	74.1	75.9	71.7
20	63.5	64.3	66.1	61.8
30	53.6	54.4	56.4	52.0
40	43.8	44.7	46.7	42.2
50	34.2	35.2	37.1	32.7
60	25.0	25.9	28.0	23.5
70	16.3	17.5	19.5	15.1

3.6 Selection effect

To investigate the selection effect, an actual/expected analysis was performed for various age groups. The expected claims are calculated using the HKA01 rates.

The result shows that the selection effect for older ages is higher than for younger lives. For lives under 20 years be aware that the expected number of claims reflects the high rates of HKA01 for age 0.

Male lives at duration 0:

Age group	Actual	Expected	Actual/expected
0 – 1	24	68	35.2%
2 – 19	41	60	67.2%
20 – 29	162	209	77.6%
30 – 39	212	280	75.6%
40 – 49	207	306	67.6%
50 – 59	104	187	55.7%
60 – 69	77	158	48.4%
70 – 79	24	47	51.5%
>= 80	0	2	0.0%
Total	850	1,317	64.5%

Male lives at duration 1:

Age group	Actual	Expected	Actual/expected
1 – 19	42	58	71.9%
20 – 29	146	160	91.0%
30 – 39	242	245	98.5%
40 – 49	233	268	86.9%
50 – 59	125	158	79.2%
60 – 69	86	135	63.9%
70 – 79	23	52	44.3%
>= 80	0	4	0.0%
Total	895	1,079	83.0%

Female lives at duration 0:

Age group	Actual	Expected	Actual/expected
0 – 1	20	60	33.2%
2 – 19	21	30	70.8%
20 – 29	69	91	75.3%
30 – 39	71	144	49.0%
40 – 49	67	169	39.3%
50 – 59	46	111	41.4%
60 – 69	52	104	49.7%
70 – 79	17	45	37.6%
>= 80	0	2	0.0%
Total	361	756	47.8%

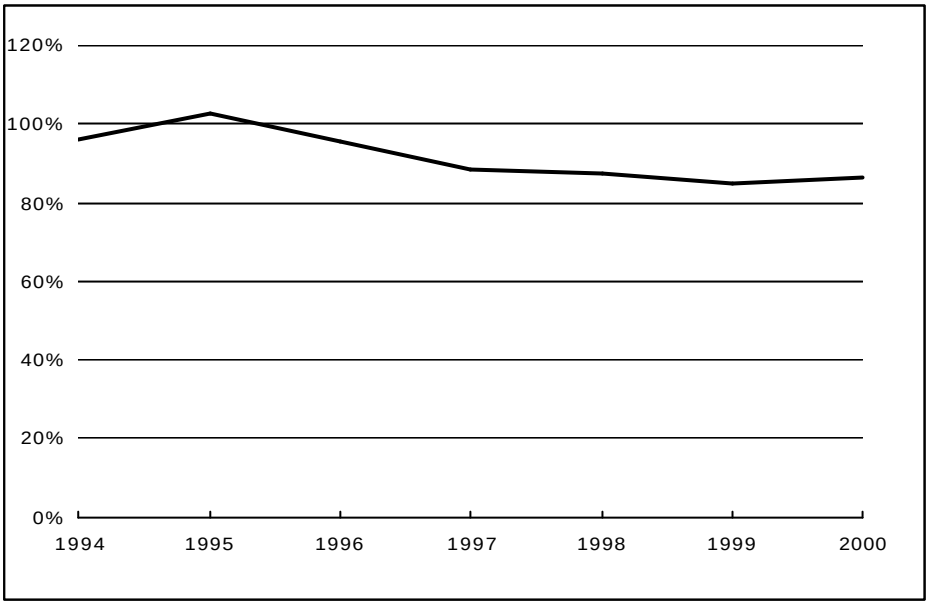
Female lives at duration 1:

Age group	Actual	Expected	Actual/expected
1 – 19	35	38	92.6%
20 – 29	46	71	63.9%
30 – 39	75	120	62.4%
40 – 49	94	137	68.4%
50 – 59	53	89	59.9%
60 – 69	51	89	57.0%
70 – 79	29	50	57.6%
>= 80	0	3	0.0%
Total	382	598	63.9%

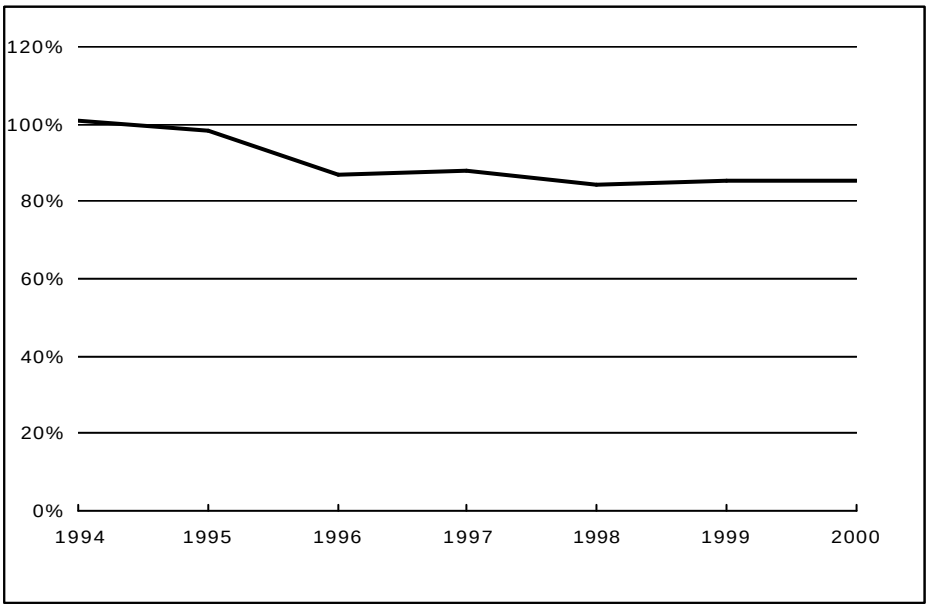
3.7 Trends in mortality

The following graphs show the development of the mortality (duration 2+ experience) from 1994 to 2000 compared to HKA97. The data for 1995 (the mid point of the previous survey) is close to 100%. The difference between this survey and HKA97 for the overlapping time period of 1994 to 1996 (i.e. the difference between the solid line and 100%) is a reflection of a different set of contributed data for this time period. The rates gradually dropped from this level and stabilized at about 85% of the expected number of deaths based on the rates of the last survey.

Male actual claims / expected (HKA97)



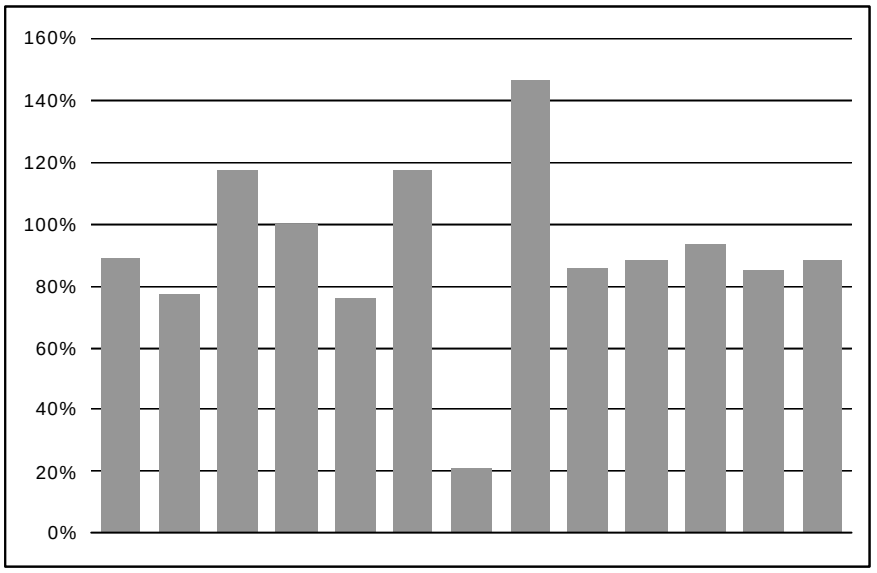
Female actual claims / expected (HKA97)



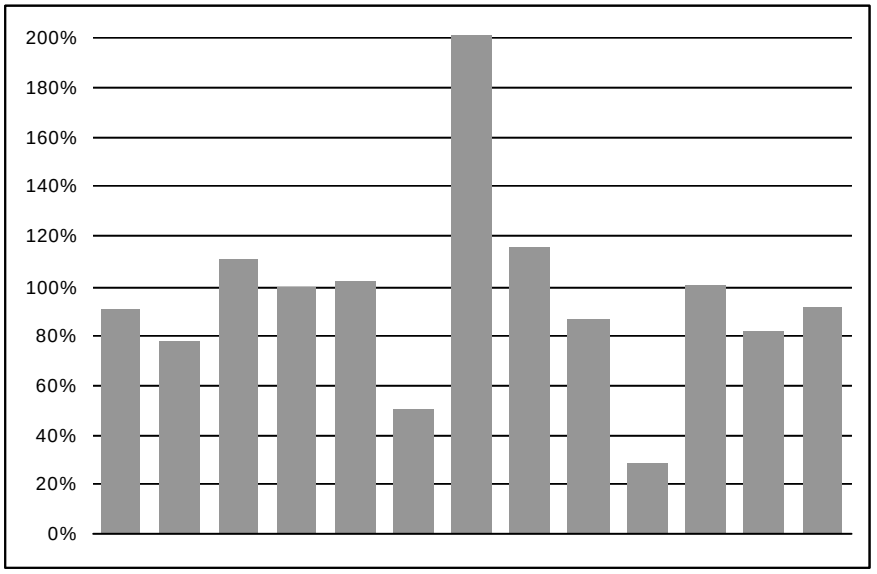
3.8 Variations by company

The results of the 13 individual companies which delivered exposure data for duration 2+ show a high variation. When reading the graphs below please keep in mind that the amount of exposure data varies among the contributing companies from several hundred to millions of lives and therefore the expected claims (based on HKA01) from around 2 lives to several thousand. The horizontal bar represents the total actual / expected for male and female lives. The companies are listed in random order. However, the order is the same for the two graphs.

Actual / expected for male lives per company



Actual / expected for female lives per company



3.9 Lives versus amounts

The analysis per amounts (duration 2+ only versus HKA01) reveals a substantially decreased mortality compared to the view per lives. This holds true for both genders and over the entire age range. The reason for this is better underwriting and better mortality for lives with high sums assured.

Gender	Actual in HK$ 1000	Expected in HK$ 1000	Actual/expected
Male	1,799,263	2,745,256	65.5%
Female	658,965	1,019,502	64.6%

3.10 Non-medical and medical cases

The analysis of the non-medically to the medically underwritten lives reveals that the mortality of the latter group is better for duration 0 and 1 than for the non-medical cases. However for duration 2+ the mortality of the medical cases slightly higher than for the comparison group. The following table shows actual over expected ratios for different durations and underwriting. The expected number of claims is based on HKA01 rates.

Gender	Underwriting	Duration 0	Duration 1	Duration 2+
Male	Non-medical	67.3%	85.5%	99.7%
	Medical	57.7%	79.0%	101.1%
Female	Non-medical	50.1%	64.7%	96.6%
	Medical	40.7%	63.5%	103.4%

4. Cause of death study

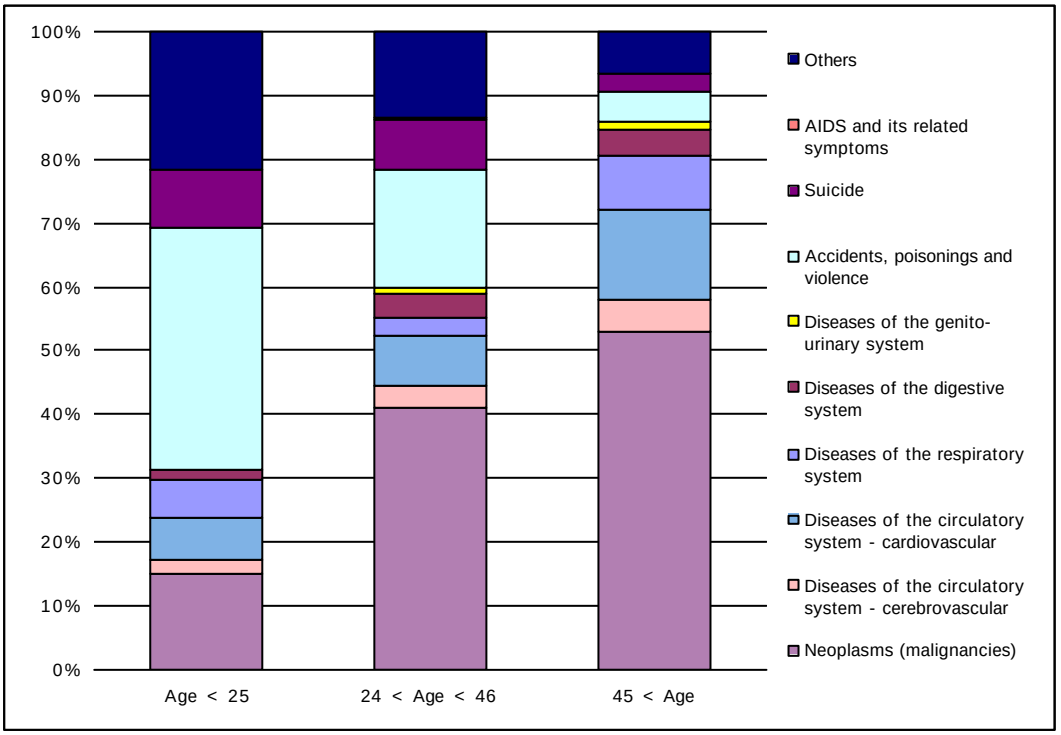
4.1 Cause of death summary (1991 - 2000)

A typical pattern emerges from the analysis of death by cause. Accidental death and suicide prevail at young ages whilst cancer prevails at older ages.

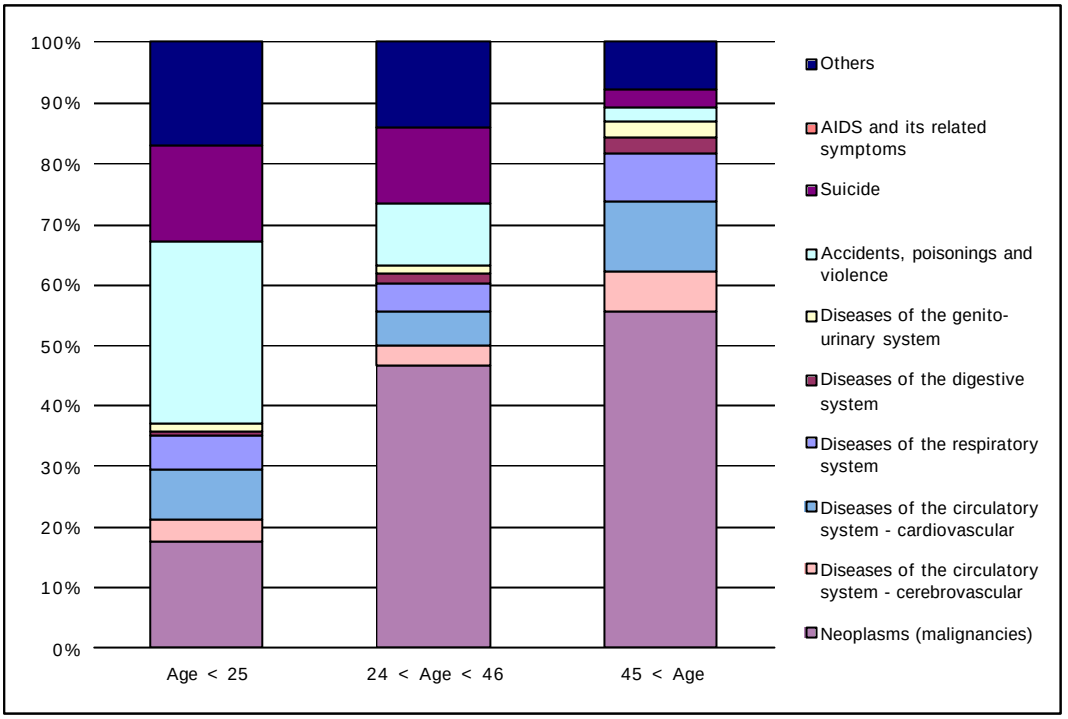
4.2 Cause of death breakdown

The graphs show the percentages of the numbers of deaths for 10 different diseases. The order of causes of death in the legend is the same as it is in the columns. Claims related to AIDS still play a very minor role for assured individuals in Hong Kong. The exact figures are shown in the section 4.3.

Cause of death for male lives



Cause of death for female lives



4.3 Comparison with HKA97

The reported proportion of cancer rose steeply. For example, for male lives above 45 from 39% to 53% of the reported deaths. But at the same time the number of claims in the category "Others" dropped by 8% and we believe that part of the increase is due to better reporting of cancer claims.

In contrast to the cause of deaths investigation in 1997, the diseases of the Circulatory System were split up into cerebrovascular and cardiovascular.

Age group under 25 years:

	Male		Female	
	HKA97	HKA01	HKA97	HKA01
Neoplasms (malignancies)	10%	15%	12%	18%
Diseases of the circulatory system – cerebrovascular	7%	2%	12%	3%
Diseases of the circulatory system – cardiovascular		7%		8%
Diseases of the respiratory system	5%	6%	5%	5%
Diseases of the digestive system	2%	2%	2%	1%
Diseases of the genito-urinary system	1%	0%	1%	2%
Accidents, poisonings and violence	42%	38%	29%	30%
Suicide	8%	9%	13%	16%
AIDS and its related symptoms	0%	0%	0%	0%
Others	27%	22%	28%	17%

Age group between 25 and 45 years:

	Male		Female	
	HKA97	HKA01	HKA97	HKA01
Neoplasms (malignancies)	29%	41%	37%	47%
Diseases of the circulatory system – cerebrovascular	9%	4%	10%	3%
Diseases of the circulatory system – cardiovascular		8%		6%
Diseases of the respiratory system	7%	3%	6%	4%
Diseases of the digestive system	6%	4%	3%	2%
Diseases of the genito-urinary system	1%	1%	3%	1%
Accidents, poisonings and violence	20%	18%	12%	10%
Suicide	7%	8%	12%	13%
AIDS and its related symptoms	0%	0%	0%	0%
Others	21%	14%	18%	14%

Age group over 45 years:

	Male		Female	
	HKA97	HKA01	HKA97	HKA01
Neoplasms (malignancies)	39%	53%	42%	55%
Diseases of the circulatory system – cerebrovascular	20%	5%	18%	7%
Diseases of the circulatory system – cardiovascular		14%		12%
Diseases of the respiratory system	11%	9%	13%	8%
Diseases of the digestive system	7%	4%	5%	3%
Diseases of the genito-urinary system	2%	1%	4%	3%
Accidents, poisonings and violence	4%	5%	3%	2%
Suicide	2%	3%	1%	3%
AIDS and its related symptoms	0%	0%	0%	0%
Others	15%	7%	13%	8%

4.4 Comparison with the general population of Hong Kong

The distribution of the causes of death in 2000 of the HKA01 study is compared with the information which is published in the Hong Kong Annual Digest of Statistics, Edition 2001[4]. The most prominent difference for both genders is the significantly higher cancer claims for the assured population than for the overall public. Since the categories of claims do not correspond for the two studies, a reduced set of 8 causes of deaths are used.

Male lives in the year 2000:

	0 - 44		>=45	
	General population	HKA01	General population	HKA01
Neoplasms (malignancies)	27.8%	38.1%	36.8%	51.9%
Diseases of the circulatory system – cardiovascular	6.9%	7.6%	15.4%	13.9%
Diseases of the circulatory system – cerebrovascular	3.6%	4.8%	9.5%	5.4%
Diseases of the respiratory system	4.0%	2.9%	9.9%	9.1%
Diseases of the digestive system	2.1%	2.8%	1.6%	2.9%
Diseases of the genito-urinary system	0.9%	0.9%	2.9%	1.4%
Accidents, poisonings, violence	38.1%	18.2%	3.7%	5.1%
Others	16.7%	24.6%	20.1%	10.3%

Female lives in the year 2000:

	0 - 44		>=45	
	General population	HKA01	General population	HKA01
Neoplasms (malignancies)	38.8%	46.0%	28.4%	55.6%
Diseases of the circulatory system – cardiovascular	4.3%	8.3%	19.2%	10.6%
Diseases of the circulatory system – cerebrovascular	3.0%	3.5%	12.9%	6.8%
Diseases of the respiratory system	3.1%	5.4%	11.0%	7.3%
Diseases of the digestive system	0.6%	1.3%	1.2%	2.9%
Diseases of the genito-urinary system	2.1%	1.6%	4.4%	2.6%
Accidents, poisonings, violence	29.2%	7.9%	2.8%	2.6%
Others	18.9%	26.0%	20.1%	11.7%

5. Use of HKA01

Clearly, actuaries in Hong Kong will be interested to make use of this new table. As with HKA97 actuaries intending to use these tables should bear in mind:

- the data is based on predominantly permanent assurance experience;
- the data excludes the first two years of policy duration;
- despite the 70% increase in exposure compared to HKA97, the tables are based on a relatively small amount of data especially for very young and old ages;
- accelerated critical illness policies may affect these mortality results although we believe the effect to be insignificant;
- the tables pool data across all offices and considerable variations in experience between offices have been observed;
- the tables pool data across 10 calendar years;
- there is no explicit margin for conservatism built into these tables.

Actuaries using these tables should therefore consider the need for any adjustment in order that the mortality used is appropriate for the purpose.

An electronic copy of this report is to be found on the website of the Actuarial Society of Hong Kong, www.actuaries.org.hk together with an electronic copy of the new assured lives mortality table.

Appendix 6.1 HKA01 mortality table

Hong Kong Assured Lives Mortality Table 2001 (Males) – HKA01(M)

Age last	q_x	l_x	d_x	L_x	T_x	e_x
0	0.001000	1000.00	1.00	999.15	78613.01	78.6
1	0.000257	999.00	0.26	998.87	77613.86	77.7
2	0.000161	998.74	0.16	998.66	76614.99	76.7
3	0.000147	998.58	0.15	998.51	75616.33	75.7
4	0.000133	998.44	0.13	998.37	74617.82	74.7
5	0.000120	998.30	0.12	998.24	73619.45	73.7
6	0.000110	998.18	0.11	998.13	72621.21	72.8
7	0.000102	998.07	0.10	998.02	71623.08	71.8
8	0.000098	997.97	0.10	997.92	70625.06	70.8
9	0.000098	997.87	0.10	997.82	69627.14	69.8
10	0.000103	997.78	0.10	997.72	68629.31	68.8
11	0.000113	997.67	0.11	997.62	67631.59	67.8
12	0.000130	997.56	0.13	997.49	66633.97	66.8
13	0.000153	997.43	0.15	997.35	65636.48	65.8
14	0.000184	997.28	0.18	997.18	64639.12	64.8
15	0.000224	997.09	0.22	996.98	63641.94	63.8
16	0.000272	996.87	0.27	996.73	62644.96	62.8
17	0.000330	996.60	0.33	996.43	61648.22	61.9
18	0.000399	996.27	0.40	996.07	60651.79	60.9
19	0.000476	995.87	0.47	995.63	59655.72	59.9
20	0.000528	995.40	0.53	995.13	58660.09	58.9
21	0.000546	994.87	0.54	994.60	57664.95	58.0
22	0.000539	994.33	0.54	994.06	56670.35	57.0
23	0.000518	993.79	0.52	993.53	55676.29	56.0
24	0.000495	993.28	0.49	993.03	54682.76	55.1
25	0.000476	992.79	0.47	992.55	53689.72	54.1
26	0.000465	992.31	0.46	992.08	52697.17	53.1
27	0.000460	991.85	0.46	991.62	51705.09	52.1
28	0.000463	991.40	0.46	991.17	50713.47	51.2
29	0.000473	990.94	0.47	990.70	49722.30	50.2
30	0.000490	990.47	0.49	990.23	48731.60	49.2
31	0.000515	989.98	0.51	989.73	47741.37	48.2
32	0.000548	989.47	0.54	989.20	46751.64	47.2
33	0.000590	988.93	0.58	988.64	45762.44	46.3
34	0.000639	988.35	0.63	988.03	44773.80	45.3
35	0.000697	987.72	0.69	987.37	43785.77	44.3
36	0.000763	987.03	0.75	986.65	42798.40	43.4
37	0.000838	986.27	0.83	985.86	41811.75	42.4
38	0.000923	985.45	0.91	984.99	40825.89	41.4
39	0.001016	984.54	1.00	984.04	39840.90	40.5
40	0.001118	983.54	1.10	982.99	38856.86	39.5
41	0.001230	982.44	1.21	981.83	37873.87	38.6
42	0.001352	981.23	1.33	980.57	36892.03	37.6
43	0.001484	979.90	1.45	979.18	35911.47	36.6
44	0.001625	978.45	1.59	977.65	34932.29	35.7
45	0.001777	976.86	1.74	975.99	33954.64	34.8
46	0.001941	975.12	1.89	974.18	32978.65	33.8
47	0.002121	973.23	2.06	972.20	32004.47	32.9
48	0.002322	971.17	2.26	970.04	31032.27	32.0
49	0.002548	968.91	2.47	967.68	30062.23	31.0
50	0.002803	966.44	2.71	965.09	29094.56	30.1

Hong Kong Assured Lives Mortality Table 2001 (Males) – HKA01(M)

Age last	q_x	l_x	d_x	L_x	T_x	e_x
51	0.003090	963.73	2.98	962.24	28129.47	29.2
52	0.003415	960.75	3.28	959.11	27167.23	28.3
53	0.003782	957.47	3.62	955.66	26208.11	27.4
54	0.004194	953.85	4.00	951.85	25252.45	26.5
55	0.004656	949.85	4.42	947.64	24300.60	25.6
56	0.005172	945.43	4.89	942.98	23352.96	24.7
57	0.005747	940.54	5.41	937.84	22409.97	23.8
58	0.006384	935.13	5.97	932.15	21472.13	23.0
59	0.007088	929.16	6.59	925.87	20539.99	22.1
60	0.007862	922.58	7.25	918.95	19614.11	21.3
61	0.008712	915.33	7.97	911.34	18695.16	20.4
62	0.009641	907.35	8.75	902.98	17783.82	19.6
63	0.010653	898.60	9.57	893.82	16880.85	18.8
64	0.011754	889.03	10.45	883.81	15987.03	18.0
65	0.012945	878.58	11.37	872.89	15103.23	17.2
66	0.014236	867.21	12.35	861.03	14230.33	16.4
67	0.015673	854.86	13.40	848.16	13369.30	15.6
68	0.017345	841.46	14.59	834.17	12521.13	14.9
69	0.019341	826.87	15.99	818.87	11686.97	14.1
70	0.021752	810.88	17.64	802.06	10868.10	13.4
71	0.024403	793.24	19.36	783.56	10066.04	12.7
72	0.027377	773.88	21.19	763.29	9282.48	12.0
73	0.030714	752.69	23.12	741.13	8519.19	11.3
74	0.034457	729.58	25.14	717.01	7778.06	10.7
75	0.038657	704.44	27.23	690.82	7061.05	10.0
76	0.043368	677.20	29.37	662.52	6370.23	9.4
77	0.048653	647.84	31.52	632.08	5707.71	8.8
78	0.054583	616.32	33.64	599.50	5075.64	8.2
79	0.061235	582.68	35.68	564.84	4476.14	7.7
80	0.068698	547.00	37.58	528.21	3911.30	7.2
81	0.077070	509.42	39.26	489.79	3383.10	6.6
82	0.086463	470.16	40.65	449.83	2893.31	6.2
83	0.097001	429.51	41.66	408.68	2443.48	5.7
84	0.108822	387.84	42.21	366.74	2034.80	5.2
85	0.122085	345.64	42.20	324.54	1668.06	4.8
86	0.136964	303.44	41.56	282.66	1343.52	4.4
87	0.153656	261.88	40.24	241.76	1060.86	4.1
88	0.172383	221.64	38.21	202.54	819.10	3.7
89	0.193392	183.43	35.47	165.70	616.56	3.4
90	0.216961	147.96	32.10	131.91	450.87	3.0
91	0.243403	115.86	28.20	101.76	318.96	2.8
92	0.273067	87.66	23.94	75.69	217.20	2.5
93	0.306347	63.72	19.52	53.96	141.51	2.2
94	0.343682	44.20	15.19	36.60	87.55	2.0
95	0.385568	29.01	11.19	23.42	50.94	1.8
96	0.432559	17.82	7.71	13.97	27.53	1.5
97	0.485276	10.11	4.91	7.66	13.56	1.3
98	0.544418	5.21	2.83	3.79	5.90	1.1
99	0.610768	2.37	1.45	1.65	2.11	0.9
100	0.685205	0.92	0.92	0.46	0.46	0.5

Note: $L_0 = I_0 - 0.85 * d_0$

Hong Kong Assured Lives Mortality Table 2001 (Females) – HKA01(F)

Age last	q_x	l_x	d_x	L_x	T_x	e_x
0	0.001000	1000.00	1.00	999.15	83,218.28	83.2
1	0.000333	999.00	0.33	998.83	82,219.13	82.3
2	0.000093	998.67	0.09	998.62	81,220.30	81.3
3	0.000090	998.57	0.09	998.53	80,221.68	80.3
4	0.000088	998.48	0.09	998.44	79,223.15	79.3
5	0.000086	998.40	0.09	998.35	78,224.71	78.4
6	0.000085	998.31	0.08	998.27	77,226.36	77.4
7	0.000086	998.23	0.09	998.18	76,228.09	76.4
8	0.000088	998.14	0.09	998.10	75,229.91	75.4
9	0.000092	998.05	0.09	998.01	74,231.81	74.4
10	0.000099	997.96	0.10	997.91	73,233.81	73.4
11	0.000108	997.86	0.11	997.81	72,235.90	72.4
12	0.000120	997.75	0.12	997.69	71,238.09	71.4
13	0.000134	997.63	0.13	997.57	70,240.40	70.4
14	0.000146	997.50	0.15	997.43	69,242.83	69.4
15	0.000156	997.35	0.16	997.28	68,245.40	68.4
16	0.000164	997.20	0.16	997.12	67,248.13	67.4
17	0.000172	997.03	0.17	996.95	66,251.01	66.4
18	0.000179	996.86	0.18	996.77	65,254.06	65.5
19	0.000185	996.69	0.18	996.59	64,257.29	64.5
20	0.000191	996.50	0.19	996.41	63,260.69	63.5
21	0.000197	996.31	0.20	996.21	62,264.29	62.5
22	0.000203	996.11	0.20	996.01	61,268.08	61.5
23	0.000210	995.91	0.21	995.81	60,272.06	60.5
24	0.000218	995.70	0.22	995.59	59,276.26	59.5
25	0.000227	995.48	0.23	995.37	58,280.66	58.5
26	0.000238	995.26	0.24	995.14	57,285.29	57.6
27	0.000250	995.02	0.25	994.90	56,290.15	56.6
28	0.000264	994.77	0.26	994.64	55,295.25	55.6
29	0.000280	994.51	0.28	994.37	54,300.61	54.6
30	0.000299	994.23	0.30	994.08	53,306.24	53.6
31	0.000321	993.93	0.32	993.78	52,312.16	52.6
32	0.000346	993.62	0.34	993.44	51,318.38	51.6
33	0.000374	993.27	0.37	993.09	50,324.94	50.7
34	0.000407	992.90	0.40	992.70	49,331.85	49.7
35	0.000443	992.50	0.44	992.28	48,339.15	48.7
36	0.000483	992.06	0.48	991.82	47,346.88	47.7
37	0.000528	991.58	0.52	991.32	46,355.06	46.7
38	0.000577	991.05	0.57	990.77	45,363.74	45.8
39	0.000632	990.48	0.63	990.17	44,372.98	44.8
40	0.000692	989.86	0.69	989.51	43,382.81	43.8
41	0.000758	989.17	0.75	988.80	42,393.29	42.9
42	0.000830	988.42	0.82	988.01	41,404.50	41.9
43	0.000908	987.60	0.90	987.15	40,416.49	40.9
44	0.000992	986.70	0.98	986.22	39,429.33	40.0
45	0.001083	985.73	1.07	985.19	38,443.12	39.0
46	0.001182	984.66	1.16	984.08	37,457.93	38.0
47	0.001287	983.49	1.27	982.86	36,473.85	37.1
48	0.001401	982.23	1.38	981.54	35,490.99	36.1
49	0.001524	980.85	1.49	980.10	34,509.45	35.2
50	0.001657	979.36	1.62	978.55	33,529.35	34.2

Hong Kong Assured Lives Mortality Table 2001 (Females) – HKA01(F)

Age last	q_x	l_x	d_x	L_x	T_x	e_x
51	0.001801	977.73	1.76	976.85	32,550.80	33.3
52	0.001956	975.97	1.91	975.02	31,573.95	32.4
53	0.002124	974.06	2.07	973.03	30,598.93	31.4
54	0.002306	972.00	2.24	970.87	29,625.90	30.5
55	0.002502	969.75	2.43	968.54	28,655.02	29.5
56	0.002714	967.33	2.63	966.02	27,686.48	28.6
57	0.002942	964.70	2.84	963.28	26,720.47	27.7
58	0.003187	961.86	3.07	960.33	25,757.18	26.8
59	0.003453	958.80	3.31	957.14	24,796.85	25.9
60	0.003754	955.49	3.59	953.69	23,839.71	25.0
61	0.004109	951.90	3.91	949.95	22,886.01	24.0
62	0.004538	947.99	4.30	945.84	21,936.07	23.1
63	0.005060	943.69	4.78	941.30	20,990.23	22.2
64	0.005694	938.91	5.35	936.24	20,048.93	21.4
65	0.006458	933.57	6.03	930.55	19,112.69	20.5
66	0.007373	927.54	6.84	924.12	18,182.14	19.6
67	0.008457	920.70	7.79	916.80	17,258.02	18.7
68	0.009730	912.91	8.88	908.47	16,341.22	17.9
69	0.011210	904.03	10.13	898.96	15,432.75	17.1
70	0.012917	893.89	11.55	888.12	14,533.78	16.3
71	0.014593	882.35	12.88	875.91	13,645.66	15.5
72	0.016486	869.47	14.33	862.30	12,769.75	14.7
73	0.018626	855.14	15.93	847.17	11,907.45	13.9
74	0.021042	839.21	17.66	830.38	11,060.27	13.2
75	0.023773	821.55	19.53	811.79	10,229.89	12.5
76	0.026857	802.02	21.54	791.25	9,418.11	11.7
77	0.030342	780.48	23.68	768.64	8,626.86	11.1
78	0.034279	756.80	25.94	743.83	7,858.22	10.4
79	0.038727	730.86	28.30	716.70	7,114.39	9.7
80	0.043752	702.55	30.74	687.18	6,397.69	9.1
81	0.049429	671.81	33.21	655.21	5,710.50	8.5
82	0.055843	638.61	35.66	620.78	5,055.29	7.9
83	0.063089	602.95	38.04	583.93	4,434.52	7.4
84	0.071275	564.91	40.26	544.77	3,850.59	6.8
85	0.080523	524.64	42.25	503.52	3,305.82	6.3
86	0.090971	482.40	43.88	460.45	2,802.30	5.8
87	0.102775	438.51	45.07	415.98	2,341.84	5.3
88	0.116110	393.44	45.68	370.60	1,925.86	4.9
89	0.131176	347.76	45.62	324.95	1,555.26	4.5
90	0.148197	302.14	44.78	279.76	1,230.31	4.1
91	0.167426	257.37	43.09	235.82	950.55	3.7
92	0.189150	214.28	40.53	194.01	714.73	3.3
93	0.213693	173.75	37.13	155.18	520.72	3.0
94	0.241421	136.62	32.98	120.13	365.54	2.7
95	0.272746	103.64	28.27	89.50	245.41	2.4
96	0.308136	75.37	23.22	63.76	155.91	2.1
97	0.348118	52.15	18.15	43.07	92.15	1.8
98	0.393288	33.99	13.37	27.31	49.08	1.4
99	0.444318	20.62	9.16	16.04	21.77	1.1
100	0.501971	11.46	11.46	5.73	5.73	0.5

Note: $L_0 = I_0 - 0.85 * d_0$

Appendix 6.2 - Actual and expected deaths

Actual and expected (HKA01) deaths – male lives duration 2+

Age last	Exposure	Crude q_x	Graduated q_x	Actual deaths	Expected deaths	Actual / Expected
0	60,683	0.000313	0.001000	19	61	0.31
1	47,797	0.000146	0.000257	7	12	0.57
2	39,532	0.000202	0.000161	8	6	1.26
3	54,404	0.000037	0.000147	2	8	0.25
4	59,549	0.000185	0.000133	11	8	1.39
5	60,336	0.000116	0.000120	7	7	0.96
6	58,211	0.000086	0.000110	5	6	0.78
7	55,718	0.000108	0.000102	6	6	1.05
8	59,161	0.000085	0.000098	5	6	0.86
9	55,180	0.000072	0.000098	4	5	0.74
10	56,199	0.000089	0.000103	5	6	0.86
11	53,010	0.000113	0.000113	6	6	1.00
12	51,426	0.000194	0.000130	10	7	1.50
13	49,637	0.000181	0.000153	9	8	1.18
14	47,102	0.000212	0.000184	10	9	1.15
15	45,136	0.000111	0.000224	5	10	0.49
16	41,885	0.000215	0.000272	9	11	0.79
17	38,514	0.000156	0.000330	6	13	0.47
18	36,750	0.000517	0.000399	19	15	1.30
19	35,509	0.000507	0.000476	18	17	1.06
20	40,622	0.000566	0.000528	23	21	1.07
21	47,091	0.000403	0.000546	19	26	0.74
22	55,507	0.000595	0.000539	33	30	1.10
23	64,891	0.000663	0.000518	43	34	1.28
24	77,633	0.000393	0.000495	31	38	0.79
25	92,142	0.000423	0.000476	39	44	0.89
26	108,685	0.000511	0.000465	56	51	1.10
27	125,206	0.000415	0.000460	52	58	0.90
28	141,624	0.000452	0.000463	64	66	0.98
29	157,458	0.000406	0.000473	64	74	0.86
30	174,307	0.000534	0.000490	93	85	1.09
31	190,049	0.000581	0.000515	111	98	1.13
32	205,205	0.000500	0.000548	103	113	0.91
33	215,847	0.000616	0.000590	133	127	1.05
34	227,339	0.000647	0.000639	147	145	1.01
35	230,885	0.000691	0.000697	160	161	0.99
36	232,459	0.000770	0.000763	179	177	1.01
37	227,598	0.000826	0.000838	188	191	0.99
38	219,422	0.000911	0.000923	200	202	0.99
39	211,818	0.001027	0.001016	218	215	1.01
40	198,372	0.001126	0.001118	223	222	1.01
41	189,245	0.001073	0.001230	203	233	0.87
42	176,377	0.001444	0.001352	255	238	1.07
43	161,712	0.001482	0.001484	240	240	1.00
44	147,880	0.001701	0.001625	252	240	1.05
45	133,003	0.001774	0.001777	236	236	1.00
46	121,642	0.001948	0.001941	237	236	1.00
47	110,266	0.002104	0.002121	232	234	0.99
48	98,066	0.002070	0.002322	203	228	0.89
49	85,811	0.002663	0.002548	229	219	1.05
50	73,575	0.002949	0.002803	217	206	1.05

Note: For age 0 duration 0 data is shown and for age 1 duration1 data is shown.

Appendix 6.2 continued - Actual and expected deaths

Actual and expected (HKA01) deaths – male lives duration 2+

Age last	Exposure	Crude q_x	Graduated q_x	Actual deaths	Expected deaths	Actual / Expected
51	62,112	0.003188	0.003090	198	192	1.03
52	51,174	0.002892	0.003415	148	175	0.85
53	40,787	0.004291	0.003782	175	154	1.13
54	33,485	0.004330	0.004194	145	140	1.03
55	28,577	0.004864	0.004656	139	133	1.04
56	24,667	0.005047	0.005172	125	128	0.98
57	21,682	0.005073	0.005747	110	125	0.88
58	19,049	0.006431	0.006384	123	122	1.01
59	16,764	0.007755	0.007088	130	119	1.09
60	14,587	0.006992	0.007862	102	115	0.89
61	12,784	0.008057	0.008712	103	111	0.92
62	11,008	0.008630	0.009641	95	106	0.90
63	9,225	0.011219	0.010653	104	98	1.05
64	7,762	0.012883	0.011754	100	91	1.10
65	6,466	0.014073	0.012945	91	84	1.09
66	5,537	0.015352	0.014236	85	79	1.08
67	4,773	0.013619	0.015673	65	75	0.87
68	4,021	0.015171	0.017345	61	70	0.87
69	3,424	0.021901	0.019341	75	66	1.13
70	2,860	0.019229	0.021752	55	62	0.88
71	2,419	0.025627	0.024403	62	59	1.05
72	2,005	0.029924	0.027377	60	55	1.09
73	1,534	0.035848	0.030714	55	47	1.17
74	1,205	0.038988	0.034457	47	42	1.13
75	963	0.035299	0.038657	34	37	0.91
76	758	0.055431	0.043368	42	33	1.28
77	547	0.049389	0.048653	27	27	1.02
78	389	0.059061	0.054583	23	21	1.08
79	293	0.075032	0.061235	22	18	1.23
80	227	0.048478	0.068698	11	16	0.71
81	180	0.116918	0.077070	21	14	1.52
82	132	0.068155	0.086463	9	11	0.79
83	81	0.235981	0.097001	19	8	2.43
84	51	0.116591	0.108822	6	6	1.07
85	34	0.291521	0.122085	10	4	2.39
86	23	0.085437	0.136964	2	3	0.62
87	23	0.000000	0.153656	0	3	0.00
88	23	0.086985	0.172383	2	4	0.50
89	23	0.088591	0.193392	2	4	0.46
90	20	0.407722	0.216961	8	4	1.88
91	10	0.208696	0.243403	2	2	0.86
92	7	0.000000	0.273067	0	2	0.00
93	5	0.000000	0.306347	0	2	0.00
94	6	0.514286	0.343682	3	2	1.50
95	3	0.342857	0.385568	1	1	0.89
96	1	0.000000	0.432559	0	0	0.00
97	N/A	0.000000	0.485276	0	0	N/A
98	N/A	0.000000	0.544418	0	0	N/A
99	N/A	0.000000	0.610768	0	0	N/A
100	N/A	0.000000	0.685205	0	0	N/A

Note: For age 0 duration 0 data is shown and for age 1 duration1 data is shown.

Appendix 6.2 continued – Actual and expected deaths

Actual and expected (HKA01) deaths - female lives duration 2+

Age last	Exposure	Crude q_x	Graduated q_x	Actual deaths	Expected deaths	Actual / Expected
0	52,986	0.000283	0.001000	15	53	0.28
1	44,992	0.000333	0.000333	15	15	1.00
2	37,453	0.000133	0.000093	5	4	1.43
3	42,412	0.000047	0.000090	2	4	0.52
4	51,061	0.000000	0.000088	0	4	0.00
5	52,118	0.000077	0.000086	4	4	0.89
6	51,903	0.000135	0.000085	7	4	1.59
7	49,187	0.000102	0.000086	5	4	1.19
8	49,791	0.000020	0.000088	1	4	0.23
9	45,577	0.000044	0.000092	2	4	0.48
10	46,898	0.000149	0.000099	7	5	1.51
11	42,806	0.000093	0.000108	4	5	0.86
12	42,360	0.000071	0.000120	3	5	0.59
13	40,411	0.000099	0.000134	4	5	0.74
14	37,754	0.000106	0.000146	4	5	0.73
15	34,864	0.000229	0.000156	8	5	1.47
16	32,737	0.000183	0.000164	6	5	1.11
17	30,368	0.000165	0.000172	5	5	0.96
18	26,586	0.000113	0.000179	3	5	0.63
19	25,458	0.000236	0.000185	6	5	1.27
20	30,592	0.000294	0.000191	9	6	1.54
21	38,884	0.000180	0.000197	7	8	0.91
22	49,270	0.000264	0.000203	13	10	1.30
23	60,793	0.000247	0.000210	15	13	1.17
24	75,540	0.000146	0.000218	11	16	0.67
25	92,655	0.000227	0.000227	21	21	1.00
26	107,033	0.000206	0.000238	22	25	0.87
27	121,546	0.000189	0.000250	23	30	0.76
28	132,107	0.000333	0.000264	44	35	1.26
29	141,706	0.000325	0.000280	46	40	1.16
30	147,909	0.000230	0.000299	34	44	0.77
31	154,376	0.000304	0.000321	47	50	0.95
32	157,459	0.000330	0.000346	52	54	0.95
33	159,169	0.000371	0.000374	59	60	0.99
34	157,754	0.000323	0.000407	51	64	0.80
35	155,914	0.000414	0.000443	65	69	0.93
36	149,962	0.000453	0.000483	68	72	0.94
37	139,798	0.000519	0.000528	73	74	0.98
38	130,948	0.000504	0.000577	66	76	0.87
39	121,199	0.000862	0.000632	105	77	1.36
40	114,130	0.000797	0.000692	91	79	1.15
41	104,629	0.000898	0.000758	94	79	1.19
42	96,604	0.000849	0.000830	82	80	1.02
43	89,090	0.000864	0.000908	77	81	0.95
44	81,006	0.000901	0.000992	73	80	0.91
45	72,523	0.000938	0.001083	68	79	0.87
46	67,119	0.001296	0.001182	87	79	1.10
47	60,232	0.001170	0.001287	71	78	0.91
48	54,193	0.001568	0.001401	85	76	1.12
49	47,885	0.001149	0.001524	55	73	0.75
50	41,675	0.001416	0.001657	59	69	0.85

Note: For age 0 duration 0 data is shown and for age 1 duration1 data is shown.

Appendix 6.2 continued – Actual and expected

Actual and expected (HKA01) deaths - female lives duration 2+

Age last	Exposure	Crude q_x	Graduated q_x	Actual deaths	Expected deaths	Actual / Expected
51	36,120	0.001717	0.001801	62	65	0.95
52	30,813	0.001623	0.001956	50	60	0.83
53	24,960	0.002644	0.002124	66	53	1.24
54	20,703	0.002318	0.002306	48	48	1.01
55	17,815	0.002414	0.002502	43	45	0.96
56	15,975	0.002942	0.002714	47	43	1.08
57	14,098	0.003334	0.002942	47	41	1.13
58	13,123	0.003048	0.003187	40	42	0.96
59	12,072	0.003728	0.003453	45	42	1.08
60	11,025	0.002812	0.003754	31	41	0.75
61	10,277	0.004865	0.004109	50	42	1.18
62	9,342	0.003746	0.004538	35	42	0.83
63	8,190	0.003785	0.005060	31	41	0.75
64	7,310	0.006156	0.005694	45	42	1.08
65	6,708	0.006261	0.006458	42	43	0.97
66	6,129	0.007505	0.007373	46	45	1.02
67	5,597	0.010541	0.008457	59	47	1.25
68	4,969	0.009257	0.009730	46	48	0.95
69	4,316	0.011817	0.011210	51	48	1.05
70	3,747	0.011344	0.012917	43	48	0.88
71	3,263	0.016704	0.014593	55	48	1.14
72	2,759	0.013775	0.016486	38	45	0.84
73	2,141	0.018219	0.018626	39	40	0.98
74	1,638	0.022583	0.021042	37	34	1.07
75	1,300	0.021531	0.023773	28	31	0.91
76	1,046	0.035387	0.026857	37	28	1.32
77	800	0.031236	0.030342	25	24	1.03
78	569	0.036882	0.034279	21	20	1.08
79	379	0.039539	0.038727	15	15	1.02
80	237	0.058961	0.043752	14	10	1.35
81	173	0.028872	0.049429	5	9	0.58
82	120	0.033420	0.055843	4	7	0.60
83	68	0.073951	0.063089	5	4	1.17
84	39	0.101383	0.071275	4	3	1.42
85	26	0.077762	0.080523	2	2	0.97
86	17	0.057996	0.090971	1	2	0.64
87	9	0.114286	0.102775	1	1	1.11
88	5	0.184615	0.116110	1	1	1.59
89	5	0.200000	0.131176	1	1	1.52
90	3	0.000000	0.148197	0	0	0.00
91	1	0.000000	0.167426	0	0	0.00
92	1	0.000000	0.189150	0	0	0.00
93	1	0.000000	0.213693	0	0	0.00
94	0	0.000000	0.241421	0	0	0.00
95	0	N/A	0.272746	0	0	N/A
96	0	N/A	0.308136	0	0	N/A
97	0	N/A	0.348118	0	0	N/A
98	0	N/A	0.393288	0	0	N/A
99	0	N/A	0.444318	0	0	N/A
100	0	N/A	0.501971	0	0	N/A

Note: For age 0 duration 0 data is shown and for age 1 duration1 data is shown.

Appendix 6.3 - Comparison of HKA01 with HKA97 and Hong Kong Life Table 1996[3]

Male lives

Age last	HKA01 q_x	HKA97 q_x	HKLT96 q_x	HKA01/ HKA97	HKA01/ HKLT96
0	0.001000	0.006176	0.002427	16%	41%
1	0.000257	0.000583	0.000340	44%	76%
2	0.000161	0.000461	0.000255	35%	63%
3	0.000147	0.000365	0.000197	40%	75%
4	0.000133	0.000290	0.000157	46%	85%
5	0.000120	0.000233	0.000130	52%	92%
6	0.000110	0.000189	0.000112	58%	98%
7	0.000102	0.000158	0.000099	65%	103%
8	0.000098	0.000137	0.000091	72%	108%
9	0.000098	0.000127	0.000094	78%	105%
10	0.000103	0.000101	0.000111	102%	93%
11	0.000113	0.000116	0.000140	97%	81%
12	0.000130	0.000149	0.000181	87%	72%
13	0.000153	0.000200	0.000233	77%	66%
14	0.000184	0.000267	0.000294	69%	63%
15	0.000224	0.000301	0.000360	74%	62%
16	0.000272	0.000332	0.000428	82%	64%
17	0.000330	0.000359	0.000494	92%	67%
18	0.000399	0.000384	0.000557	104%	72%
19	0.000476	0.000406	0.000614	117%	78%
20	0.000528	0.000424	0.000664	125%	80%
21	0.000546	0.000438	0.000708	125%	77%
22	0.000539	0.000450	0.000746	120%	72%
23	0.000518	0.000461	0.000778	112%	67%
24	0.000495	0.000474	0.000803	104%	62%
25	0.000476	0.000487	0.000821	98%	58%
26	0.000465	0.000497	0.000830	93%	56%
27	0.000460	0.000509	0.000835	90%	55%
28	0.000463	0.000525	0.000836	88%	55%
29	0.000473	0.000548	0.000837	86%	56%
30	0.000490	0.000576	0.000839	85%	58%
31	0.000515	0.000608	0.000845	85%	61%
32	0.000548	0.000646	0.000859	85%	64%
33	0.000590	0.000691	0.000886	85%	67%
34	0.000639	0.000744	0.000931	86%	69%
35	0.000697	0.000805	0.000999	87%	70%
36	0.000763	0.000873	0.001091	87%	70%
37	0.000838	0.000949	0.001207	88%	69%
38	0.000923	0.001035	0.001345	89%	69%
39	0.001016	0.001133	0.001497	90%	68%
40	0.001118	0.001241	0.001652	90%	68%
41	0.001230	0.001355	0.001805	91%	68%
42	0.001352	0.001483	0.001955	91%	69%
43	0.001484	0.001628	0.002107	91%	70%
44	0.001625	0.001795	0.002267	91%	72%
45	0.001777	0.001977	0.002449	90%	73%
46	0.001941	0.002172	0.002664	89%	73%
47	0.002121	0.002390	0.002927	89%	72%
48	0.002322	0.002640	0.003247	88%	72%
49	0.002548	0.002933	0.003629	87%	70%
50	0.002803	0.003261	0.004074	86%	69%

Note: At ages 0 and 100 the method of construction of the tables and the adjustment to give consistent age definitions give unusual results

Appendix 6.3 continued - Comparison of HKA01 with HKA97 and Hong Kong Life Table 1996[3]

Male lives

Age last	HKA01 q_x	HKA97 q_x	HKLT96 q_x	HKA01/ HKA97	HKA01/ HKLT96
51	0.003090	0.003615	0.004577	85%	68%
52	0.003415	0.004011	0.005138	85%	66%
53	0.003782	0.004461	0.005759	85%	66%
54	0.004194	0.004979	0.006433	84%	65%
55	0.004656	0.005558	0.007151	84%	65%
56	0.005172	0.006188	0.007914	84%	65%
57	0.005747	0.006882	0.008736	84%	66%
58	0.006384	0.007649	0.009635	83%	66%
59	0.007088	0.008503	0.010643	83%	67%
60	0.007862	0.009439	0.011793	83%	67%
61	0.008712	0.010449	0.013109	83%	66%
62	0.009641	0.011539	0.014609	84%	66%
63	0.010653	0.012715	0.016301	84%	65%
64	0.011754	0.013983	0.018169	84%	65%
65	0.012945	0.015343	0.020182	84%	64%
66	0.014236	0.016787	0.022314	85%	64%
67	0.015673	0.018320	0.024558	86%	64%
68	0.017345	0.019944	0.026930	87%	64%
69	0.019341	0.021662	0.029427	89%	66%
70	0.021752	0.023472	0.032046	93%	68%
71	0.024403	0.025372	0.034834	96%	70%
72	0.027377	0.027363	0.037866	100%	72%
73	0.030714	0.029444	0.041227	104%	74%
74	0.034457	0.031616	0.043945	109%	78%
75	0.038657	0.035065	0.047157	110%	82%
76	0.043368	0.038522	0.051916	113%	84%
77	0.048653	0.042310	0.057136	115%	85%
78	0.054583	0.046459	0.062860	117%	87%
79	0.061235	0.051000	0.069131	120%	89%
80	0.068698	0.055968	0.075999	123%	90%
81	0.077070	0.061398	0.083513	126%	92%
82	0.086463	0.067330	0.091728	128%	94%
83	0.097001	0.073803	0.100702	131%	96%
84	0.108822	0.080861	0.110495	135%	98%
85	0.122085	0.088550	0.121171	138%	101%
86	0.136964	0.096915	0.132793	141%	103%
87	0.153656	0.106005	0.145431	145%	106%
88	0.172383	0.115870	0.159153	149%	108%
89	0.193392	0.126559	0.174027	153%	111%
90	0.216961	0.138122	0.190122	157%	114%
91	0.243403	0.150609	0.207503	162%	117%
92	0.273067	0.164064	0.226234	166%	121%
93	0.306347	0.178532	0.246372	172%	124%
94	0.343682	0.194051	0.267964	177%	128%
95	0.385568	0.210653	0.291049	183%	132%
96	0.432559	0.228361	0.315598	189%	137%
97	0.485276	0.247187	0.341727	196%	142%
98	0.544418	0.267130	0.369424	204%	147%
99	0.610768	0.288174	0.691810	212%	88%
100	0.685205	1.000000	1.000000	69%	69%

Note: At ages 0 and 100 the method of construction of the tables and the adjustment to give consistent age definitions give unusual results

Appendix 6.3 continued - Comparison of HKA01 with HKA97 and Hong Kong Life Table 1996[3]

Female lives

Age last	HKA01 q_x	HKA97 q_x	HKLT96 q_x	HKA01/ HKA97	HKA01/ HKLT96
0	0.001000	0.005014	0.001923	20%	52%
1	0.000333	0.000365	0.000189	91%	177%
2	0.000093	0.000269	0.000171	35%	55%
3	0.000090	0.000210	0.000155	43%	58%
4	0.000088	0.000174	0.000141	50%	62%
5	0.000086	0.000152	0.000128	57%	67%
6	0.000085	0.000138	0.000116	62%	73%
7	0.000086	0.000129	0.000106	66%	81%
8	0.000088	0.000124	0.000096	71%	92%
9	0.000092	0.000121	0.000115	76%	80%
10	0.000099	0.000135	0.000145	73%	68%
11	0.000108	0.000143	0.000157	76%	69%
12	0.000120	0.000152	0.000170	79%	71%
13	0.000134	0.000164	0.000185	82%	72%
14	0.000146	0.000176	0.000202	83%	72%
15	0.000156	0.000181	0.000220	86%	71%
16	0.000164	0.000185	0.000240	89%	69%
17	0.000172	0.000189	0.000260	91%	66%
18	0.000179	0.000194	0.000280	92%	64%
19	0.000185	0.000200	0.000292	93%	63%
20	0.000191	0.000206	0.000296	93%	65%
21	0.000197	0.000211	0.000301	93%	66%
22	0.000203	0.000218	0.000305	93%	67%
23	0.000210	0.000227	0.000310	93%	68%
24	0.000218	0.000239	0.000314	91%	69%
25	0.000227	0.000254	0.000319	90%	71%
26	0.000238	0.000270	0.000323	88%	73%
27	0.000250	0.000290	0.000328	86%	76%
28	0.000264	0.000312	0.000332	84%	79%
29	0.000280	0.000340	0.000337	83%	83%
30	0.000299	0.000372	0.000351	81%	85%
31	0.000321	0.000407	0.000378	79%	85%
32	0.000346	0.000447	0.000410	77%	84%
33	0.000374	0.000491	0.000449	76%	83%
34	0.000407	0.000538	0.000493	76%	82%
35	0.000443	0.000590	0.000545	75%	81%
36	0.000483	0.000647	0.000604	75%	80%
37	0.000528	0.000708	0.000668	75%	79%
38	0.000577	0.000769	0.000738	75%	78%
39	0.000632	0.000830	0.000811	76%	78%
40	0.000692	0.000889	0.000885	78%	78%
41	0.000758	0.000947	0.000959	80%	79%
42	0.000830	0.001006	0.001033	82%	80%
43	0.000908	0.001069	0.001108	85%	82%
44	0.000992	0.001137	0.001183	87%	84%
45	0.001083	0.001206	0.001261	90%	86%
46	0.001182	0.001275	0.001344	93%	88%
47	0.001287	0.001349	0.001437	95%	90%
48	0.001401	0.001437	0.001543	98%	91%
49	0.001524	0.001543	0.001666	99%	91%
50	0.001657	0.001661	0.001809	100%	92%

Note: At ages 0 and 100 the method of construction of the tables and the adjustment to give consistent age definitions give unusual results

Appendix 6.3 continued Comparison of HKA01 with HKA97 and Hong Kong Life Table 1996[3]

Female lives

Age last	HKA01 q_x	HKA97 q_x	HKLT96 q_x	HKA01/ HKA97	HKA01/ HKLT96
51	0.001801	0.001787	0.001974	101%	91%
52	0.001956	0.001931	0.002164	101%	90%
53	0.002124	0.002103	0.002385	101%	89%
54	0.002306	0.002313	0.002634	100%	88%
55	0.002502	0.002553	0.002910	98%	86%
56	0.002714	0.002815	0.003213	96%	84%
57	0.002942	0.003114	0.003550	94%	83%
58	0.003187	0.003460	0.003931	92%	81%
59	0.003453	0.003868	0.004366	89%	79%
60	0.003754	0.004329	0.004867	87%	77%
61	0.004109	0.004834	0.005444	85%	75%
62	0.004538	0.005396	0.006109	84%	74%
63	0.005060	0.006026	0.006877	84%	74%
64	0.005694	0.006735	0.007742	85%	74%
65	0.006458	0.007519	0.008694	86%	74%
66	0.007373	0.008371	0.009733	88%	76%
67	0.008457	0.009296	0.010874	91%	78%
68	0.009730	0.010300	0.012147	94%	80%
69	0.011210	0.011391	0.013580	98%	83%
70	0.012917	0.012566	0.015201	103%	85%
71	0.014593	0.013820	0.017045	106%	86%
72	0.016486	0.015156	0.019152	109%	86%
73	0.018626	0.016576	0.021762	112%	86%
74	0.021042	0.018082	0.028044	116%	75%
75	0.023773	0.022939	0.034810	104%	68%
76	0.026857	0.025496	0.038986	105%	69%
77	0.030342	0.028334	0.043661	107%	69%
78	0.034279	0.031485	0.048642	109%	70%
79	0.038727	0.034980	0.051404	111%	75%
80	0.043752	0.038856	0.054456	113%	80%
81	0.049429	0.043153	0.060668	115%	81%
82	0.055843	0.047913	0.067880	117%	82%
83	0.063089	0.053182	0.075924	119%	83%
84	0.071275	0.059013	0.084889	121%	84%
85	0.080523	0.065458	0.094870	123%	85%
86	0.090971	0.072577	0.105970	125%	86%
87	0.102775	0.080433	0.118299	128%	87%
88	0.116110	0.089093	0.130666	130%	89%
89	0.131176	0.098628	0.137856	133%	95%
90	0.148197	0.109112	0.146150	136%	101%
91	0.167426	0.120623	0.161728	139%	104%
92	0.189150	0.133241	0.179768	142%	105%
93	0.213693	0.147048	0.199580	145%	107%
94	0.241421	0.162124	0.221278	149%	109%
95	0.272746	0.178549	0.244965	153%	111%
96	0.308136	0.196399	0.270734	157%	114%
97	0.348118	0.215743	0.298658	161%	117%
98	0.393288	0.236640	0.328783	166%	120%
99	0.444318	0.259138	0.672200	171%	66%
100	0.501971	1.000000	1.000000	50%	50%

Note: At ages 0 and 100 the method of construction of the tables and the adjustment to give consistent age definitions give unusual results

Appendix 6.4 Graduation methodology

The crude death rates were graduated using natural cubic splines with variable knots for the age range 2 to 70 years for both genders. The advantage of this method is that through varying the number and position of the knots of the cubic spline it is possible to steer the trade-off between fit and smoothness of the graduated q_x. By definition of the cubic splines the resulting curve is smooth to the second order.

The algorithm to determine the natural cubic spline interpolating a set of knots was adopted from the "Numerical Recipes in C" textbook[5].

The choice of the positions of the knots followed McCutcheon's "Some Remarks on Splines"[6]. The quadratic form z to minimize for a given number of knots is:

$$z = \sum_{x=a}^{b} w_x (q_x^l - q_x)^2$$

Where

$$w_x = \frac{E_x}{q_x(1-q_x)}$$

E_x denotes the exposure to risk at age x, q^l_x the crude death rates, q_x the graduated death rates and (a, b) define the interval on which the graduation is carried out.

McCutcheon[7] proposes a criterion for the number of knots for a set of crude death rates together with the functional *z*. Applied to the male and female datasets, splines with 8 and 7 knots respectively are determined as the best-fitting splines.

For the sparse datasets at the high ages or the rapid change of mortality from age 0 to 2 the spline graduation delivered non-satisfactory results. As described in section 3.4 the graduated rates above age 70 are obtained using Makeham functions since the range of uncertainty is so big for the sparse dataset that it is hardly justified to apply a method which follows the data more closely. These functions are particularly easy to adjust for desired outcome (=actual).

Credibility in section 3.3 is defined as follows:

- Full credibility is being assigned if the number of actual claims is greater than 1 537.
- Partial credibility is defined as $Z=(Actual\ Deaths/1537)^{.5}$.

Appendix 6.5 - Reference list

1 B. Benjamin and J.H. Pollard, The Analysis of Mortality and other Actuarial Statistics, Institute of Actuaries and the Faculty of Actuaries in Scotland, 1993

2 Demographic Trends in Hong Kong 1981 –1996, Census and Statistics Department Hong Kong Special Administrative Region, 1997

3 Hong Kong Life Tables 1996 - 2029, Census and Statistics Department Hong Kong Special Administrative Region 2000

4 Hong Kong Annual Digest of Statistics, 2001 Edition, Census and Statistics Department Hong Kong Special Administrative Region

5 Numerical Recipes in C, Cambridge University Press, Cambridge, 1997

6 J.J. McCutcheon, Some Remarks on Splines, TFA vol. 37 (1979-81)

7 J.J. McCutcheon, Spline Graduation with Variable Knots, Proceedings of the 22nd International Congress of Actuaries, Vol. 4, p 47, Sydney, 1984

Appendix 6.6 - Participating companies

- American International Assurance Company (Bermuda) Limited
- AXA China Region Insurance Company (Hong Kong and Bermuda) Limited
- BOC Group Life Assurance Company Limited
- CIGNA Worldwide Insurance Company
- CMG Asia Limited
- Eagle Star Life Assurance Company Limited
- Hang Seng Life Limited
- HSBC Life (International) Limited
- ING Life Insurance Company (Bermuda) Limited
- Manulife International Limited
- MassMutual Asia Limited
- MLC (Hong Kong) Limited
- The Prudential Assurance Company Limited
- Scottish Provident International Limited
- Winterthur Life Hong Kong