### Appendix C: Assumptions

*Appendix C1: Mortality Tables for Smokers and Non-Smokers*

Smoker and Non-Smoker Mortality Tables were constructed for our policyholders. First we considered the proportion of smokers at each age group for a comparable country (given the relatively similar life expectancies and mortality trends), the United States. From there we use the fact that 11.5% of the US’s population are smokers versus 18% of Lumaria’s population (Center for Disease Control and Prevention, 2023), giving us a scaler that we use to adjust to find the approximate proportion of smokers at each of these age groups in Lumaria (see below). For each age group, we assumed smoking proportion to be uniform across every age within the group.

|  |  |
| --- | --- |
| Proportion of Smokers in the United States | 11.5% |
| Porportion of Smokers in Lumaria | 18% |
| Scaler | 1.57 |

|  |  |  |
| --- | --- | --- |
| Age Group | Proportion of Smoker (US) | Proportion of Smoker (Lumaria) |
| 18-24 | 5.3% | 8.3% |
| 25-44 | 12.6% | 19.7% |
| 45-64 | 14.9% | 23.3% |
| 65-120 | 8.3% | 13.0% |

From there, we found mortality tables for male smokers, female smoker, male non-smokers and female non-smokers for the United Kingdom (Benjamin, B., and R. Michaelson, 1988), another comparable country. By approximating an equal proportion of males and females for each group, we condensed this into a smoker mortality table and a non-smoker mortality table. By considering the ratio of the mortality at each age between non-smokers and smokers, this gave us a mortality adjustment for non-smokers.

Using the approximated percentage of smokers at each age, the relative mortality of smokers and non-smokers at each age, and the Lumarian mortality table for the total population, we were able to derive mortality tables for both smokers and non-smokers, as per the equation: where is the overall mortality rate at a given age, is the mortality rate for smokers at that age, is the mortality rate for non-smokers at that age, is the proportion of smokers at that age, is the proportion of non-smokers at that age, and is the mortality improvement of non-smokers versus smokers.

However, comparing these population-level mortality tables against our in-force data, we noticed some discrepancies that we had to address through loading factors, namely that smokers had a much worse mortality at all ages, especially, ages 45 and older. For this reason, we applied mortality loadings to develop an estimate for the smoker mortality table for SuperLife’s policyholders.

The final mortality table for SuperLife’s smokers and non-smokers is shown below:

|  |  |  |
| --- | --- | --- |
| **Age** | **qx (Non-smokers)** | **qx (Smokers)** |
| 0 | 0.003547 | 0.003547 |
| 1 | 0.000337 | 0.000337 |
| 2 | 0.000240 | 0.000240 |
| 3 | 0.000180 | 0.000180 |
| 4 | 0.000158 | 0.000158 |
| 5 | 0.000147 | 0.000147 |
| 6 | 0.000138 | 0.000138 |
| 7 | 0.000129 | 0.000129 |
| 8 | 0.000126 | 0.000126 |
| 9 | 0.000125 | 0.000125 |
| 10 | 0.000137 | 0.000137 |
| 11 | 0.000145 | 0.000145 |
| 12 | 0.000161 | 0.000161 |
| 13 | 0.000181 | 0.000181 |
| 14 | 0.000217 | 0.000217 |
| 15 | 0.000263 | 0.000373 |
| 16 | 0.000315 | 0.000456 |
| 17 | 0.000376 | 0.000548 |
| 18 | 0.000407 | 0.000605 |
| 19 | 0.000441 | 0.000663 |
| 20 | 0.000476 | 0.000719 |
| 21 | 0.000499 | 0.000764 |
| 22 | 0.000516 | 0.000805 |
| 23 | 0.000517 | 0.000828 |
| 24 | 0.000519 | 0.000838 |
| 25 | 0.000488 | 0.000834 |
| 26 | 0.000498 | 0.000852 |
| 27 | 0.000511 | 0.000874 |
| 28 | 0.000525 | 0.000898 |
| 29 | 0.000543 | 0.000929 |
| 30 | 0.000570 | 0.000975 |
| 31 | 0.000602 | 0.001030 |
| 32 | 0.000635 | 0.001085 |
| 33 | 0.000675 | 0.001154 |
| 34 | 0.000717 | 0.001226 |
| 35 | 0.000766 | 0.001310 |
| 36 | 0.000833 | 0.001425 |
| 37 | 0.000911 | 0.001558 |
| 38 | 0.000992 | 0.001696 |
| 39 | 0.001075 | 0.001839 |
| 40 | 0.001173 | 0.002005 |
| 41 | 0.001270 | 0.002171 |
| 42 | 0.001380 | 0.002360 |
| 43 | 0.001499 | 0.002563 |
| 44 | 0.001629 | 0.002785 |
| 45 | 0.001728 | 0.002955 |
| 46 | 0.001875 | 0.003262 |
| 47 | 0.002056 | 0.003577 |
| 48 | 0.002247 | 0.003910 |
| 49 | 0.002457 | 0.004275 |
| 50 | 0.002682 | 0.004667 |
| 51 | 0.002941 | 0.005118 |
| 52 | 0.002090 | 0.009404 |
| 53 | 0.002300 | 0.010351 |
| 54 | 0.002540 | 0.011429 |
| 55 | 0.002811 | 0.012650 |
| 56 | 0.002462 | 0.016003 |
| 57 | 0.002703 | 0.017570 |
| 58 | 0.002968 | 0.019294 |
| 59 | 0.003286 | 0.021359 |
| 60 | 0.003625 | 0.023561 |
| 61 | 0.003962 | 0.025752 |
| 62 | 0.004333 | 0.028164 |
| 63 | 0.004728 | 0.030730 |
| 64 | 0.005167 | 0.033586 |
| 65 | 0.007555 | 0.049105 |
| 66 | 0.008276 | 0.053791 |
| 67 | 0.009042 | 0.058776 |
| 68 | 0.009906 | 0.064387 |
| 69 | 0.010879 | 0.070712 |
| 70 | 0.011993 | 0.077955 |
| 71 | 0.009786 | 0.109699 |
| 72 | 0.010878 | 0.121945 |
| 73 | 0.012179 | 0.136531 |
| 74 | 0.013680 | 0.153350 |
| 75 | 0.015403 | 0.172668 |
| 76 | 0.017394 | 0.194984 |
| 77 | 0.019620 | 0.219936 |
| 78 | 0.022097 | 0.247703 |
| 79 | 0.024800 | 0.278011 |
| 80 | 0.027772 | 0.311327 |
| 81 | 0.031116 | 0.348809 |
| 82 | 0.034873 | 0.390926 |
| 83 | 0.039110 | 0.438426 |
| 84 | 0.043688 | 0.489739 |
| 85 | 0.048471 | 0.543359 |
| 86 | 0.061251 | 0.551260 |
| 87 | 0.067685 | 0.609169 |
| 88 | 0.074775 | 0.672977 |
| 89 | 0.082615 | 0.743538 |
| 90 | 0.090402 | 0.813621 |
| 91 | 0.117530 | 0.763945 |
| 92 | 0.128011 | 0.832074 |
| 93 | 0.138841 | 0.902464 |
| 94 | 0.150460 | 0.977988 |
| 95 | 0.162410 | 1.055665 |
| 96 | 0.175066 | 1.137931 |
| 97 | 0.188465 | 1.225020 |
| 98 | 0.202111 | 1.313719 |
| 99 | 0.216371 | 1.406414 |
| 100 | 0.230728 | 1.499731 |
| 101 | 0.244850 | 1.591524 |
| 102 | 0.259309 | 1.685510 |
| 103 | 0.274022 | 1.781140 |
| 104 | 0.288892 | 1.877800 |
| 105 | 0.303827 | 1.974876 |
| 106 | 0.318841 | 2.072466 |
| 107 | 0.333962 | 2.170754 |
| 108 | 0.687915 | 0.000000 |
| 109 | 0.717620 | 0.000000 |
| 110 | 0.752108 | 0.000000 |
| 111 | 0.786407 | 0.000000 |
| 112 | 0.820477 | 0.000000 |
| 113 | 0.854275 | 0.000000 |
| 114 | 0.887760 | 0.000000 |
| 115 | 0.921073 | 0.000000 |
| 116 | 0.954387 | 0.000000 |
| 117 | 0.987700 | 0.000000 |
| 118 | 1.021014 | 0.000000 |
| 119 | 1.149310 | 0.000000 |

*Appendix C2: Lapse Rates*

The lapse rate assumption we used was the empirical lapse rate from our in-force T20 policies (note that there is the assumption of no lapse for WL policies). The following figure shows the number of lapses every year for policies issued in every year.

A screenshot of a computer screen

Description automatically generatedUsing this data, we obtain the following lapse rates assumption for T20 policies:

|  |  |
| --- | --- |
| Year | Lapse Rate |
| 1 | 0.61% |
| 2 | 0.62% |
| 3 | 0.62% |
| 4 | 0.62% |
| 5 | 0.61% |
| 6 | 0.61% |
| 7 | 0.64% |
| 8 | 0.62% |
| 9 | 0.62% |
| 10 | 0.64% |
| 11 | 0.62% |
| 12 | 0.62% |
| 13 | 0.61% |
| 14 | 0.61% |
| 15 | 0.62% |
| 16 | 0.61% |
| 17 | 0.60% |
| 18 | 0.59% |
| 19 | 0.59% |
| 20 | 58.66% |

*Appendix C3: Interest Rate Projection*

We have determined an estimate for the future interest rate using an ARIMA time series model. This was done by first considering the given 1-year risk free annual spot rates for 1962-2023, adjusting for outliers using the tso function in R (outliers were 1983, 1987 and 2023). The auto.arima function in R was then used to fit an ARIMA time series model and project the 1-year risk free annual spot rates for the next 60 years. The ARIMA(0,1,1) model was selected, and the projected 1-year risk free annual spot rate for the each of next 60 years was projected to be 2.97%. See below for a snippet of the code used.

A computer screen with white and green text

Description automatically generated

*Appendix C4: Population Projection*

To have confidence in our hypothesis that Lumaria would experience the phenomenon of an aging population over the duration of it’s programs, we developed a crude procedure to project the population in 20 years time, as well as, the population distribution across all ages.

This was done by considering the Lumarian mortality table and the distribution of ages given in the Encyclopedia. The distribution at each specific age within an age group was then determined by considering a hypothetical cohort at the start age, and using the mortality rates to obtain relative population proportions at each age within the group. This gave us an estimate for the current population distribution at every age, and ultimately the population at every age, using the total Lumarian population. Considering a 20 year time horizon, we were able to use the Lumarian mortality table to project the future population at every age 20 and older, adopting the assumption that Lumaria has no net migration. To obtain an approximation for the population below 20, we used the same relative proportions of population at ages below 20 to population of age 20. From this, we obtained a projection for the population and population distribution, as seen below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Age Group | Current Population | Proportion | Population in 20 Years | Proportion in 20 Years |
| 0-14 | 18,415,532 | 20% | 13,596,513 | 7% |
| 15-24 | 16,573,979 | 18% | 12,236,861 | 6% |
| 25-54 | 42,355,723 | 46% | 42,399,278 | 21% |
| 55-64 | 11,049,319 | 12% | 13,215,720 | 7% |
| 65-120 | 3,683,106 | 4% | 18,972,887 | 9% |
| Total | 92,077,659 | 100% | 100,421,368 | 100% |

While this projection method has made several major assumptions, it clearly confirms the future trend of an aging population in Lumaria, a consideration that impacted our life insurance offerings and program design.