Mortality has long held a professional fascination for actuaries, and mathematicians before them, with Gompertz first drawing attention in 1825 to the exponential increase in rates of mortality that occurs over much of adult life. In the 21st century we have seen an explosion of interest in new and updated modelling techniques for projecting future mortality rates, taking advantage of rapid improvements in computer processing power.

Intelligent modelling of mortality

Daniel Ryan explains how predictive mortality models involve more than just historical extrapolation.

However, it is only recently that there has been a sustained effort to shift the focus from models of all-cause mortality to those that either consider trends in different causes of death across generations or the diagnosis and progression of diseases that conspire towards death in the individual. This takes mortality modelling substantially forward from the simplistic 'extrapolation of past trends' approach that had hitherto dominated.

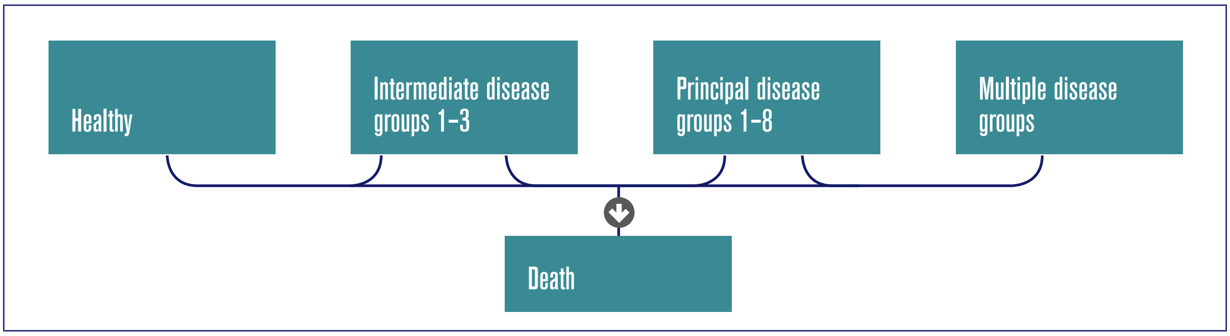
Cause and effect

The UK Actuarial Profession's 'Mortality Projections by Cause' Research Group has highlighted how longstanding series of cause-specific mortality studies in the general population can provide a basis for the forward projection of mortality through consideration of relatively simple boundary scenarios on a cause-by-cause basis. A Continuous Mortality Investigation (CMI) Working Party set up at the end of last year has developed a generic and modifiable model of mortality improvements that allows for the effect of year of birth, and that model will include comparisons against plausible scenarios for selected causes of death.

Watson Wyatt has long had a leading interest in research into mortality and longevity and the Watson Wyatt Mortality Morbidity Service was established in 2003. Member life offices and reinsurers have collectively directed, funded and benefited from multi-disciplinary investigations on a wide range of topics, based on models specifically developed for the service or jointly funded with Watson Wyatt.

Over the last two years a particular strand of research resulting from this joint funding has been the application of disease-based mortality models (DBMMs). These are multi-state transition models that track diagnoses of initial and subsequent selected diseases from the healthy population, as well as deaths from all states (see Figure 1). The significant data requirements of such models can only be met by large longitudinal databases that contain event-based clinical data on millions of patients, and we have developed

Figure 1 | Disease-based mortality model structure



Disease groups	Underlying diseases include:
Intermediate group (IG) 1	Diabetes, hypertension, TIA, high cholesterol, atherosclerosis
IG 2	Benign cancers and malignant skin cancers other than melanoma
IG 3	Multiple sclerosis, osteoporosis, osteoarthritis, rheumatoid arthritis
Principal Group (PG) 1 and 3	Stroke, ischaemic heart disease, aneurysms, heart failure
PG 2, 5 and 7	Cancers for 16 sites plus melanoma, myeloma, leukaemia and lymphomas
PG 4	Chronic obstructive disease, pneumonia, tuberculosis
PG 6	Ulcers, kidney failure, liver disease, Crohn's disease, ulcerative colitis
PG 8	Alzheimer's disease, Parkinson's disease, dementia

a bespoke tool with the leading commercial database in the UK, the General Practice Research Database, to extract the necessary information on disease diagnoses and deaths.

Advantages and applications

A key driver behind the increased attention given to cause-specific mortality models has been the need to develop suitable Individual Capital Assessment stress tests. A common initial approach was to consider the eradication of a particular cause of death, such as the elusive but often mooted concept of a 'cure for cancer'. Certain cancers have been strongly associated with prior infection, such as cervical cancer and human papilloma virus, and liver cancer and hepatitis. Vaccination against such viruses, if acceptable to the public, could prevent many cases of cancer that would otherwise occur. For other cancers, 'cure' is really a shorthand expression for diagnosis at an early stage through better screening and awareness and access to individually tailored treatment.

The difficulty that cause-specific mortality models need to address is that the original data sources do not provide information as to what other diseases the individual may have had prior to death, and hence the likely new cause of death after the 'cure'. In contrast, DBMMs have already identified the mosaic of different combinations of diseases in the population, and continuing transitions to other diseases will temper the immortality implied by a 'cure' scenario.

The modular structure of a DBMM readily lends itself to forward predictive modelling. An all-cause mortality model might use a floor to the long-term rate of mortality improvements as a heavy-handed reflection of expert views over the impact of future medical advances. However, a DBMM could combine forward predictions for those diseases where there was greater understanding of the natural history of the disease and greater transparency over likely benefits from new treatments with a projection approach for other diseases.

The segmentation of the population by different prior histories of disease is akin to the classical approach taken by actuaries in considering differences in mortality experience by sex, age and smoking status. We would suggest that DBMMs provide a fertile environment for the

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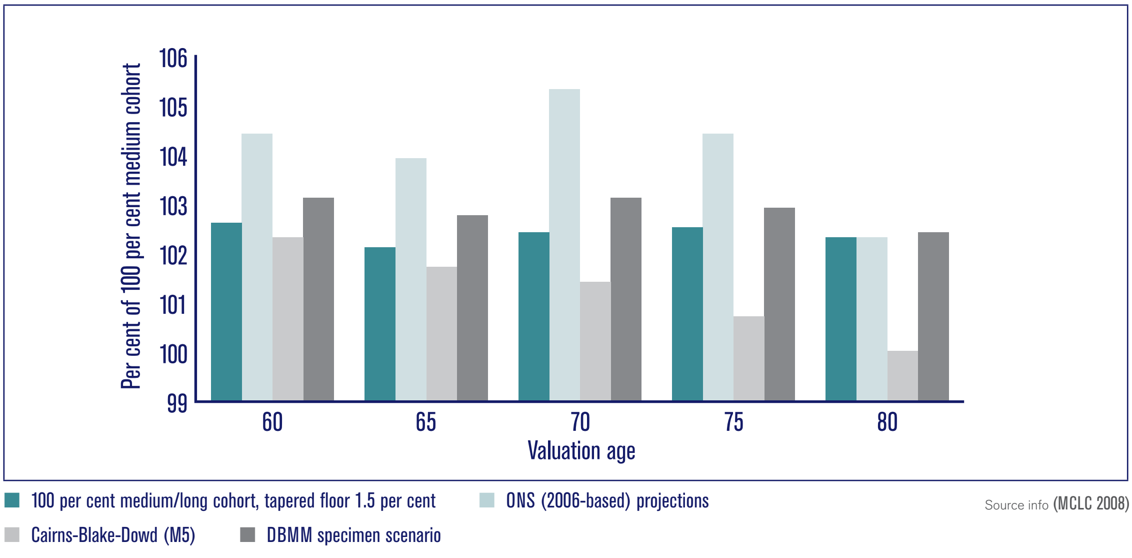
Figure 2 | Annuity comparisons with retirement at age 65 at 5 per cent with base mortality table of PNMA00



Source info (MCLC 2008)

collation and incorporation of expert opinion from doctors and epidemiologists by aligning the model structure with their areas of expertise. Generalists and epidemiologists can comment on likely future diagnosis rates from the general population, whilst specialists can inform as to how changes in risk factors and developments in those treatments that are either in clinical practice or in clinical trials may improve survival rates for those with disease.

Ongoing model development

We have an ongoing process of updating our forward predictive scenarios in collaboration with external experts to reflect changes in clinical guidance, based on collective understanding of the importance of risk factors and the status of likely medical advances. Such approaches provide a basis for comparative analyses with other widely used mortality improvement assumptions, such as the Interim Cohort Projections with a long-term floor. Figure 2 illustrates some high-level comparisons of life expectancies at different ages for men and women.

Furthermore, in contrast to existing mortality databases, we believe that large longitudinal databases such as GPRD and QRESEARCH offer significant potential for further data mining and justifiable refinement of our mortality models. Expected developments over the next six months include enhanced modelling of different severities of the same disease, whether that relates to stage at diagnosis in the case of cancer or wider involvement in the case of diabetes and circulatory disease, or the application of generalised linear models to individual patient medical records to quantify better the impact of different risk factors acting in combination.

The morbid but professional fascination that actuaries have for death is unlikely to disappear any time soon.

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