Chapter 8
The Life Table as a Theoretical Model

8.1 Introduction

The life table is most commonly thought of as a summary measure of period age-specific death rates, and typically is described as such to students and to the public – thus the term *ordinary* life table. This life table also is characterized as describing the hypothetical survival experience of a *synthetic* or *fictitious cohort*, subject to current death rates over an imagined lifetime.

A second interpretation views the life table's numbers as a description of the stationary population model, built up by a succession of birth cohorts of the same size, all of which experience the same age-specific death rates. Sometimes the last two interpretations – synthetic cohort experience and stationary population – have been confounded in the same table, with some column headings referring to cohort experience and others to the population model.

Less common than the ordinary or period life table is the cohort or generational life table, based on the actual historical experience of a real birth cohort. In either case, the life table is viewed primarily as a measurement device summarising observed death rates.

Shryock and Siegel's (1973) discussion of the life table is representative. At the outset, they note that 'A life table is designed essentially to measure mortality...,' and 'Life tables are, in essence, one form of combining mortality rates of a population at different ages into a single statistical model. They are principally used to measure the level of mortality of the population involved' (II: 429). They distinguish period and cohort tables by the reference year[s] involved, with a discussion and abbreviated example of a real-cohort table (446–447). All discussion is of life tables based on actual, observed data. There is no mention of life tables based on hypothetical data. They note that 'In general, unless otherwise specified, the term 'life table' is used...to refer to the current life table' (429).

More recent treatments in demographic texts do not differ appreciably from Shryock and Siegel, although there is more discussion of applying the 'life table

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concept' to other demographic processes, notably in event-history analysis. But the emphasis continues to be on the period mortality table as a measurement model. Most detailed examples are of such a table. I have found no treatment which begins with or emphasizes the completely general concept of the diminution of a cohort by some kind of attrition event.

There is historical justification for this emphasis, since the majority of published life tables have been and continue to be period tables – official life tables prepared by government statistical agencies, 'standard' tables used by insurance firms, and collections published in the U.N. *Demographic Yearbook*. Such tables have also formed the basis for several sets of 'model life tables.'

8.2 Another Perspective on Life Tables

A more fruitful approach, I submit, is to view the life table as a completely general theoretical construct, with many applications and empirical interpretations, of which current mortality measurement is only one.[1] The identification of the life table with the ordinary life table is a case of cultural lag. In the view of Wilson and Oeppen (2003), it is an example of reification, the fallacy of identifying an abstract, general idea with one of its concrete realisations.[2]

At the most general level, the life table expresses an abstract concept of the survival experience of some kind of cohort in the face of some kind of decrement or attrition-event. It is an *abstract model* of cohort survival. In the case of mortality, the model is that of a birth cohort being diminished by death according to some schedule of mortality until the last member is dead. For divorce, the model is that of a cohort of marriages or of married persons, being diminished by divorce over duration or age. This general idea can be expressed in words as a *verbal model*, or visually by means of a state diagram, a compartment model, or a flow diagram – a *visual model*.

In these forms, the model can only suggest a few limited ideas about the processes involved: over time/age some number or fraction of members of the original cohort will move from one state to another [life to death, married to divorced]; the survival curve, at least for these kinds of events, must be monotonic decreasing. And some or all of the cohort will eventually experience the event – all for death, some for divorce.[3]

[1]For an earlier statement of the value of differing interpretations and uses of the same demographic algorithm, see Romaniuc (1990). See also Burch (2005) and Chap. 4 above.

[2]Among philosophers, the concept of *reification* seems to have taken on slightly different meanings since A.N. Whitehead spoke of the 'fallacy of misplaced concreteness.' But all contain the central notion of a confusion of abstract entities with concrete reality.

[3]There is the additional issue of other events to which a cohort might be at risk, for example, the attrition of single persons by first marriage or death. This chapter discusses mainly single-decrement models, but the ideas extend easily to more complex survival tables.

The abstract concept can be further specified as an *algorithm*, a computational procedure expressed in a series of steps described verbally, in a set of equations, or in computer code. The algorithm assumes some set of death rates or probabilities of dying by age, or probabilities of some other attrition event, but need not specify these. The result is a template, an empty box that can be filled in many ways.

The most common realization of the life table, as noted above, is as measurement model**,** using as input observed period or real cohort age-specific death rates. Based as it is on actual data, this table in some sense answers the question 'What has actually happened?' In the case of a real cohort mortality table, the measurement is straightforward, and the table becomes a depiction of the actual lifetime experience of the cohort as it occurred in historical time. In the case of period mortality, interpretation is far from straightforward. The data underlying the table are real, but the process depicted is not, since it is a process that has not been and will never be experienced by any concrete group of human beings. In any case survival occurs in real time, and phases like 'this year's life expectancy' and 'current survival' are at best shorthand, at worst misleading. In the real world, average person-years lived in a given calendar year cannot exceed 1.0; realisation of average life expectancy requires a lifetime, real or imagined. The ordinary life table is thus measurement, but it also is a form of modeling or simulation [see below].

For purely descriptive purposes of current mortality levels, demography might have done just as well to adopt Schoen's (1970) suggestion to use the geometric mean as an age-standardised measure of age-specific death rates. Of course, there are other useful applications of the ordinary life table – survival ratios, for example – and these work well enough as long as its fictitious character is properly taken into account. Often it is not, as in frequent statements in the press and by students, equating the current e_0 with 'how long a baby born this year can expect to live.' This is confusion of an abstraction, the period life-table, with concrete future reality.

8.3 From Measurement to Simulation

Given the fact that demographers have been so completely comfortable with the fictions involve in the ordinary life table, it is surprising that we have not also been more comfortable with another application of the basic algorithm, as simulation or modeling**,** using whatever set of death rates that suit one's purpose. These rates can be observed rates, imaginary but plausible rates, or fanciful rates that serve some analytic purpose. Such a life table deals with the question 'What would happen if…?'

In a surprisingly sophisticated treatment for a text over 50 years old, Barclay (1958) graphs a comparison of an ordinary survival curve with the straight line that would result from equal numbers of deaths at each age. He mentions, but does not illustrate, the result of a constant proportion of deaths at each age, a negative exponential survival curve.

But there is no limit to the range of scenarios that might be explored in this way, for an increased understanding of survival processes and their implications. What would the survival curve look like if human beings were immortal? If the resulting horizontal straight line seems trivial, consider the position-time graph of a stationary object presented in an introductory physics text, in the discussion of straight-line motion. Rather than being trivial, this is a matter of starting at the beginning, with the simplest case, especially important for students. The simplest case also serves as a natural reference point for all others.

What-if scenarios can be played off the ordinary life table. How much would e_0 change if all deaths before 30 were eliminated? What would the survival curve look like if a typical set of q_x's were experienced by a cohort in reverse order [with the proviso that no $q_x = 1.0$]? The result is a reminder that the species could not survive with such a mortality pattern, combined with our relatively low fertility [compared to plants or many insects], and the long period of infant/child dependency. It's a reminder of how much of our social structure and culture is a result of overlapping generations.

Of current interest is the revised period life table proposed by Bongaarts and Feeney (2002), based on the age-specific mortality rates that would have been observed in the absence of any secular trend in mortality. Without trying to judge the deeper issues involved, I would note that their life table involves all the fictions involved in the ordinary period life table, plus the added fiction that mortality is not changing over time when in fact it is. Their argument does not seem to me to justify dismissal of the standard life table as biased. Both are abstract models, not concrete descriptions of anything. It's more a question of which fiction to use for which purpose.

In any event, with a willingness to imagine data, the life table model becomes a much more versatile scientific tool than when it is tied so closely to empirical data. It allows demographers and students of demography to undertake more active and imaginative analyses of decrement process, to engage in computer experiments about cohort experience.

The life table often is seen as a prediction model, forecasting future mortality experience of a population or cohort. The question at issue here is 'What will happen in the future?' Whether the life table is correctly interpreted in this way depends. In the case of the ordinary period life table, forecasting over a few following years is safe, assuming mortality is changing slowly. To interpret the life expectancy at birth as a prediction of the average length of life of persons currently being born – not uncommon in journalistic accounts – is misleading. Their length of life will depend on the next century or so of changing death rates.

A truly predictive life table, which is not yet in common use, would be based on age-specific death rates or probabilities of death by age, which have themselves been forecast far enough into the future to cover the mortality experience of living cohorts, but also those yet to be born. It would be in effect a generational life table projected into the future.[4] Such a life table could be constructed for any birth cohort.

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[4]To my knowledge, there are not many examples of such tables. One is Vallin and Meslé (2001).

For those already alive, it would be a hybrid of past and future experience. In such a future-oriented life table, the phrase *expectation of life* takes on more meaning specifically as a real expectation for the future, not measures on the imaginary lifetimes of a synthetic cohort. In accord with the best contemporary practise of mortality forecasting, life table measures could be given with error bounds. Such a life table, giving a realistic account of future mortality, would seem to be more useful for many kinds of demographic analysis that now rely on period tables.

Such life tables or their equivalent must surely underlie many official government population forecasts, but they seem seldom to be published as being of interest in their own right. The published and publicized life tables from government statistical agencies invariably are period tables, which are then duly misinterpreted by the press.

Interestingly, the suggestion to make more use of tables based on forecasts of future rates dates back to at least 1917 in Knibbs' appendix to the 1911 census of Australia. Knibbs termed it a 'fluent life table.' The suggestion was strongly reiterated by Dublin and Speigelman in a paper at the 1941 meetings of the Population Association of America (Dublin and Spiegelman 1941; contains reference to Knibbs). The failure of the discipline to implement these suggestions must have something to do with our fundamental preference for empirical data, which, rightly or wrongly, we equate with hard-rock reality. Simulated or modelled results are often viewed as fanciful – made-up data.

Finally, the basic life table can be extended to relate to the mortality, not of one cohort, but of a succession of fictitious cohorts of the same size, across a century or more, all subject to the same mortality schedule. The life table becomes a population model, specifically the stationary model. Combine with this an unchanging set of age-specific fertility rates and one has a stable population model, expressing in numerical terms some basic elements of stable population theory.[5]

8.4 Modeling as Theory

Granted that the basic life or survival table model can take many forms, is it a theoretical model, or theory? There are several justifications for such language. It accords with practice in some of the most successful disciplines, notably physics. If Newton's law of falling bodies is theory, then so is the life table. Newton's equation is an abstract model of a point mass falling in a vacuum with only two bodies in interaction. It can be used to approximate a concrete case with the insertion of a parameter for the force of gravity. But this parameter is not constant – even on earth it differs by location, altitude and other factors. Similarly, the algorithm for the life

[5]Some would say that the *theory* resides in the underlying equations, whereas a specific numerical example is to be called a *model*. Clearly there are differences between the two forms, but they are differences of specificity rather than of basic epistemological status.

table must be specified by insertion of a set of death rates. There may be no 'law of mortality,' but there is a limited range of life expectancies; and life table functions have similar shapes.[6]

Mortality data and life-table functions also can be represented by approximating functions (see Chap. 7), but these will be more complicated that Newton's law; instead of one parameter, they typically will require three or more. But the difference between these demographic functions and Newton's equation is quantitative not qualitative. Both are abstract models that approximate real-world phenomena.

This accords with the views of an increasing numbers of philosophers of science, in what has come to be known as the 'model-based' view of science (see especially Giere 1999, 2006; Teller 2001). In this approach, the basic element of science is not the law but the model, seen as a formally true abstract representation of some portion of reality. The most common type of model is the theoretical model, expressed in words, mathematical equations, or, increasingly, in computer code. The word *theory* can refer to a very general model or to a collection of smaller, more specific models, as in the phrase 'theory of harmonic oscillators' in physics, a collection of models dealing with objects such as springs and pendulums. In this latter sense, the life table is a theoretical model, an abstract representation of some aspects of the survival of a cohort.[7]

For the model-based school, the empirical question regarding a theoretical model is not whether it is true, but whether it applies to some part of the real [or at least observed] world closely enough, in certain respects, for a certain purpose. Thus, the ordinary life table is 'true' in this sense, and works well as a summary of current age-specific death rates. Whether it works well enough as an indicator of some current underlying mortality conditions not reflected accurately in current rates is a matter of current controversy. Clearly, it does not work well as a prediction of future mortality over the next century.

Closer to home, justification for viewing the life table as theory can be found in two prescient papers by Keyfitz (1971, 1975) in which he argues that most of what we reliably know about population dynamics comes from our use of models rather than empirical data, that models are the basis of our understanding. At many points, he uses the terms *model* and *theory* interchangeably. Also of interest is the fact that he does not distinguish between formal demographic and behavioral models; all have the same epistemological status.

But these are arguments from authority. The best argument for adopting this view of the life table is that it would be good for the discipline. Demography needs all the theory it can get if it is to be a science and not just a branch of applied statistics. In fact, we have much good theory, but we have tended not to recognise it

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[6]These facts are the basis for model life tables, and for attempts to define a mortality function, the Gompertz curve, for example.

[7]An interesting question regarding demographic usage is why we regularly speak of 'stable population theory' but refer to the cohort-component projection model as a 'forecasting technique.' Both are abstract representations of population dynamics.

as such. If the life table is theory, then so is the exponential growth formula, the stable model, the projection model, indeed much of so-called formal demography. This is not a word game. Such models give rigorous substantive insight into how populations and cohorts behave. And that is theory.

A systematic approach to the life table as a general model and many different specific realizations would in time help lessen the confusion that surrounds many of our models. The ordinary life table is better understood and less liable to misinterpretation if it is put in the context sketched above, which underlines its abstract and hypothetical character. This would be especially important to our students. And if we didn't reify the ordinary life table, then perhaps we could do a better job of explaining current results to journalists and the public. But even battle-hardened demographers are not immune to confusion, as is seen in the current discussions of the Bongaarts-Feeney modified life table.

Finally, there is much to learn from the life table through computer experiment as well as through its use for straightforward calculation with the usual data. Such work is scientific analysis as opposed to measurement, which is a prelude to scientific analysis, an essential prelude but a prelude nonetheless.

The model-based view of science has another important general implication for demography. If much of formal demography is theory, it also is the case that we can reinterpret many of our older, often rejected, behavioral models as perfectly good abstract theoretical models that may or may not fit a concrete case well enough for a specific analytic purpose. Much that we have rejected is perfectly good theory.

The two re-interpretations combined point to demography as a discipline with a rich body of theories about how populations work, not just a body of techniques or a branch of applied statistics.

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