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Multi-State Analysis of Marital Status Life Tables: Theory and Application

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1. INTRODUCTION

A major feature of recent methodological innovations in life-table construction has been the increase in dimensionality. Originally, the increase was confined to ways in which a member of a cohort could leave a particular life table. Typical illustrations are life tables by cause of death[1] and conventional nuptiality tables showing attrition from a cohort due to death and change of marital status. A common feature of these so-called multiple-decrement tables is that the various types of withdrawal from a life-table population are treated in the same way. Those who leave a particular life-table population are not accounted for, irrespective of the reason for their departure or whether they remain alive or not.

To keep track of individuals in various states needs a further generalization of the life table. People must not only be allowed to leave a particular status, but must also be able to enter or re-enter it as they age. Except for the *absorbing* state of death, most states are *transient* and may be left and entered again (in theory, at least). Such statuses may be labour force status (active, inactive), marital status, region of residence or any other possible classification of situations in the life cycle. The multi-state or increment-decrement life table is ideally suited for the study of mobility or transitions between life statuses, in addition to mortality. Furthermore, it allows for differentiation of the mortality patterns between the various states.

Multi-state or increment–decrement life tables have only come to be used relatively recently, but a good deal of work has been done on them. Rogers[2] has generalized the single-decrement life table described by Keyfitz[3] to study the mortality and migration of a population in a multi-regional system. Regions of residence are used to define life status. A major virtue of Rogers's approach is the use of matrix notation. He showed that by using matrix algebra, the study of multi-state populations is not at all complicated, and that some restrictive assumptions are no longer needed.

At about the same time, other writers attempted to generalize life-table concepts. Their work was independent of and much less comprehensive than the methodology developed by Rogers. It has, however, greatly enriched multi-state demography. Schoen and Nelson[4] tried to improve the construction of nuptiality tables by developing a procedure

[1] S. Preston, N. Keyfitz and R. Schoen, *Causes of Death: Life Tables for National Populations* (New York, Seminar Press, 1972).

[2] A. Rogers, 'The multi-regional life table', *Journal of Mathematical Sociology*, 3, (1973), pp. 127–137; 'The mathematics of multi-regional demographic growth', *Environment and Planning*, 5 (1973), pp. 3–29.

[3] N. Keyfitz, *Introduction to the Mathematics of Population* (Reading, Mass.: Addison-Wesley, 1968).

[4] R. Schoen and V. Nelson, 'Marriage, divorce and mortality: a life table analysis'. *Demography*, 11 (2), 1974, pp. 267–290.

which described the evolution of a cohort if passage to and from different categories of marital status is permitted. Schoen elaborated this approach[5] and derived formulae to estimate transition probabilities between the states of an increment–decrement life table. The main virtue of Schoen's work is the simultaneous estimation of all transition probabilities from observed or life-table rates. Rogers and Ledent[6] showed that the complex formulae presented by Schoen can be greatly simplified by using matrix notation. They also indicated some of the similarities and differences between Schoen's and Rogers's approaches.[7] Another independent attempt to generalize life-table concepts, which may, however, have been inspired by Schoen's article, is due to Hoem[8] and Hoem and Fong[9] in an application to labour-force participation. Hoem approached the problem of multi-state analysis from the point of view of the statistician; he devoted attention to assumptions underlying multi-state life-table models and to the relations between these models and the theory of stochastic processes.

The general aim of more recent work has been the evaluation and integration of the various perspectives in order to derive a multi-state life table that is theoretically correct, based on a few restrictive assumptions only, and easy to compute.[10] The focus of publications on multi-state or multi-dimensional demography is not limited to methodological issues. Applied research is becoming more common. Reports on applications using basically available methods include Smith and Schoen and Woodrow.[11] A major illustration of applied work may, however, be found in the country reports of the Comparative Migration and Settlement (C.M.S.) Study, carried out by the International Institute for Applied Systems Analysis (I.I.A.S.A.), in collaboration with scholars of I.I.A.S.A.'s 17 member countries. The aim of this project is a quantitative assessment

[5] R. Schoen, 'Constructing increment–decrement life tables', *Demography*, 12 (2), 1975, pp. 313–324.

[6] A. Rogers and J. Ledent, 'Increment–decrement life tables: a comment', *Demography*, 13 (2), 1976, pp. 287–290.

[7] A. Rogers, *Introduction to Multi-regional Mathematical Demography* (New York, Wiley, 1975).

[8] I. Hoem, 'A Markov chain model of working life tables', *Scandinavian Actuarial Journal* (1977), pp. 1–20.

[9] I. Hoem and M. Fong, *A Markov Chain Model of Working Life Tables: A New Method for the Construction of Tables of Working Life* (Copenhagen, University Laboratory of Actuarial Mathematics, Working Paper no. 2, 1976).

[10] For recent contributions see J. Ledent, *Some Methodological and Empirical Considerations in the Construction of Increment–Decrement Life Tables* (Laxenburg: International Institute for Applied Systems Analysis, Research Memorandum RM-78-25, 1978); 'Multi-state (increment–decrement) life tables: movement versus transition perspectives', *Environment and Planning* (A), 12 (1980), pp. 533–562; *Constructing Multi-regional Life Tables Using Place-of-Birth-Specific Migration Data* (Laxenburg: International Institute for Applied Systems Analysis, Working Paper WP-80-96, 1980). S. Krishnamoorthy, 'Classical approach to increment–decrement life tables: an application to the study of the marital status of United States females, 1970', *Mathematical Biosciences*, 44 (1979), pp. 139–154. P. Rees, 'Increment–decrement life tables: some further comments from a demographic-accounting point of view', *Environment and Planning* (A), 10 (1978), pp. 705–726. N. Keyfitz, 'Multi-dimensionaly in population analysis'. In: K. F. Schuessler (ed.), *Sociological Methodology 1980* (San Francisco, Jossey-Bass, 1979), pp. 191–218. F. Oechsli, 'A general method for constructing increment–decrement life tables that agree with the data', *Theoretical Population Biology*, 16 (1), 1979, pp. 13–24. R. Schoen and K. Land, 'A general algorithm for estimating a Markov-generated increment–decrement life table with applications to marital status patterns', *Journal of the American Statistical Association*, 74 (368), 1979, pp. 761–776. F. Willekens, 'Multi-state analysis: tables of working life', *Environment and Planning* (A), 12 (1980), pp. 563–588. Other contributions to multi-state or multi-dimensional demography are published in the collections of original papers: A. Rogers (ed.), *Essays in Multi-state Mathematical Demography*, special issue of *Environment and Planning* (A), 12, 5 (1980); A. Rogers (ed.), *Advances in Multi-regional Demography*, special issue of *I.I.A.S.A.-Reports* (*Journal of the International*

of migration and population distribution patterns in member nations by applying techniques of multi-regional demographic analysis.[12]

This paper reviews the mathematical theory of multi-state life-table construction and presents it in its simplest (matrix) form. Multi-regional demography provides a major input. The method is applied to the study of marital-status patterns in Belgium in 1971. Many demographers have applied life-table techniques to the analysis of marital status. An historical overview is provided by Schoen and Nelson.[13] Most authors studied the attrition from a status-specific population by death and transition to other marital statuses. A major shortcoming, however, was the impossibility of an individual re-entering the table and consequently to assess the impact of marital change on subsequent demographic experience. This would require a multi-state or increment–decrement life table.

In multi-state demography a number of questions may be answered that cannot be dealt with by using conventional theory. Some of the questions considered in this paper are beyond the scope of some very recent methodological work in the field of nuptiality table construction.[14] What is the probability that a married woman aged 26 will be divorced before her 27th birthday? How many members of a birth cohort of 100,000 are married and divorced in the same year? What is the average number of years that an individual aged 20 may expect to spend in the widowed state? How does this compare with someone aged 50? What difference does it make whether the individual is single, married, or already widowed at age 20? The latter question introduces an additional dimension into the analysis of marital status life tables.

Until now, duration measures have been obtained for an 'average individual' irrespective of his or her current marital status. The method presented in this paper makes it possible to calculate life-table statistics by marital status. This indicates the need to differentiate between *population-based* measures of time spent in the various marital statuses and *marital status-based* measures.[15] The former relate to an individual of a given age, irrespective of the marital status. The latter are conditional upon marital status. They are derived from a set of conditional probabilities. The status-based measures are of two types, depending on the age at which the marital status is considered. It may be a fixed age, say 20; or the current age. In the latter case the measures are specific to the individual's present status. Both the population-based and the status-based measures serve different purposes. If one were interested in the number of years that a never-married person or a person irrespective of marital status may expect to live in marriage, the population-based measure is appropriate. However, if the interest is in the years of married life remaining to a married individual, the marital status-based measure will be more appropriate.

The possibility of distinguishing between unconditional and conditional duration measures originated in multi-regional demography, where a distinction is made between

[12] The techniques applied in the C.M.S. study are described in F. Willekens and A. Rogers, *Spatial Population Analysis: Methods and Computer Programs* (Laxenburg: International Institute for Applied Systems Analysis, Research Report RR-78-18, 1978). The country reports are written by national scholars and published as I.I.A.S.A. Research Reports. The following reports are available: United Kingdom (P. Rees), Finland (K. Rikkinen), Sweden (Å. Andersson and I. Holmberg), German Democratic Republic (G. Mohs), The Netherlands (P. Drewe), Federal Republic of Germany (R. Koch and H. P. Gatzweiler), Soviet Union (S. Sobeleva), Hungary (K. Bies and K. Tekse), Canada (M. Termote), Austria (M. Sauberer), Poland (K. Dziewonski and P. Korcelli), Bulgaria (D. Philipov) and France (J. Ledent and D. Courgeau).

[13] *Loc. cit.*, in footnote 4.

[14] R. Schoen and K. Land, *loc. cit.*, in footnote 10.

[15] The terminology is adapted from that used in working life tables. The distinction was introduced by S. Wolfbein, 'The length of working life', *Population Studies*, 3 (1949), pp. 286–294, and has been applied to multi-state life tables by Willekens, *loc. cit.*, footnote 10.

life expectancies by region of birth (population-based measure) and region of current residence (status-based measure).[16] In fact, the computer program used to calculate the marital-status life table is a modified version of the multi-regional life table program devised by Willekens and Rogers.[17]

2. THE MATHEMATICAL THEORY OF MULTI-STATE LIFE TABLE CONSTRUCTION

A multi-state or increment–decrement life table depicts the movement of members of a given cohort through a multi-state system with time. In the system considered here the living and the dead are distinguished, and among the former there are four marital status categories: never married, currently married, widowed and divorced. There is one absorbing state (death), three transient states and one state which can only be left (never married). The system is represented graphically in Figure 1.

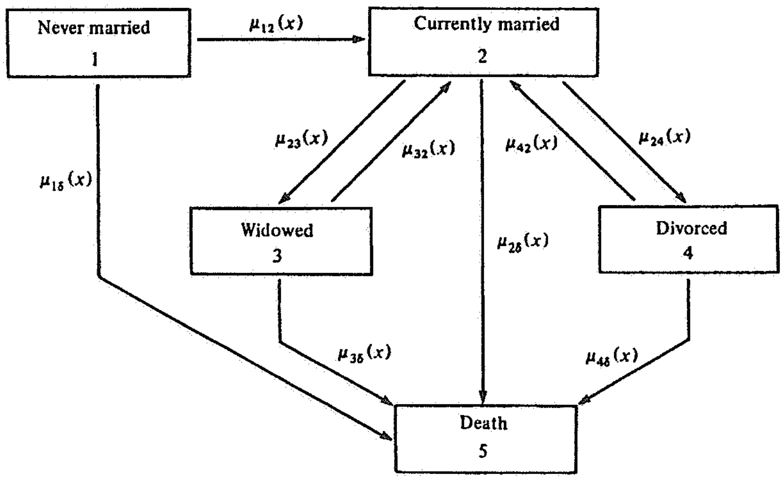

Fig. 1. The marital-status system.

Marital statuses and death constitute the elements of the state space of a Markov process. The probability of transition between two states, i and j, depends not only on the state occupied (i), but also on age, which will be denoted by x. The life-table model to be developed is a time-non-homogeneous, finite-space, continuous-time Markov process. In this regard, it does not differ from the perspective adopted by Hoem, Schoen and Land and Ledent.[18]

We follow the usual procedure of life-table construction and express the transition probabilities in terms of instantaneous rates or transition intensities. Let $\mu_{ij}(x)$ denote the instantaneous rate of transition from state i to state j at age x, and let $\mu_{i\delta}(x)$ be the force of mortality at age x in state i. Note that the age schedule of mortality is state-specific. Unlike Hoem and Hoem and Fong,[19] we do not assume equal mortality. The model can easily deal with differences in mortality by marital status.

[16] A. Rogers, *op. cit.*, in footnote 5.

[17] The program itself is labelled LIFEINDEC and is listed in F. Willekens, *Computer Program for Increment–Decrement (Multi-state) Life-Table Analysis: A User's Manual to LIFEINDEC* (Laxenburg, International Institute for Applied Systems Analysis, Working Paper WP-79-102, 1979).

[18] Hoem, *loc. cit.*, in footnote 8; Schoen and Land, *loc. cit.*, in footnote 10; Ledent, 'Multi-state...', *loc. cit.*, in footnote 10.

[19] *Loc. cit.*, in footnotes 8 and 9.

2.1. *Transition probabilities*

The transition from one state to another is governed by Kolmogorov's equation. Consider the cohort of people who are now at exact age y. Denote the probability that an individual aged y in state i will be in state j n years later by ${}_{iy}l_j(y+n)$. Denoting $y+n$ by x ($x \geqslant y$), this probability may be written as ${}_{iy}l_j(x)$. The probability that an individual aged y in state i will be in state j at age $(x+dx)$ is:

$$ {}_{iy}l_j(x+dx) = \sum_{k=1}^{N} {}_{iy}l_k(x)\,\mu_{kj}(x)\,dx, \tag{1} $$

where N is the number of non-absorbing states (in this case, four).

The product $\mu_{ij}(x)\,dx$ is the probability that an individual aged x in state i will be in state j at the end of the interval dx, and $\mu_{jj}(x)\,dx$ is the probability that an individual aged x in state j will still be in that state, dx years (or time-units) later.[20] The transition probabilities are independent of the status of the individual at age y, but do depend on his or her status at exact age y, i.e. at the beginning of the interval $(x, x+dx)$. Then:

$$ \begin{aligned} \mu_{jj}(x)\,dx &= 1-\Big[\sum_{k\neq j}\mu_{jk}(x)\,dx+\mu_{j\delta}(x)\,dx\Big] \\ &= 1-\hat{\mu}_{jj}(x)\,dx, \quad \text{say.} \end{aligned} \tag{2} $$

Hence (1) may be written as follows:

$$ \frac{{}_{iy}l_j(x+dx)-{}_{iy}l_j(x)}{dx} = -\hat{\mu}_{jj}(x)\,{}_{iy}l_j(x)+\sum_{k\neq j}\mu_{kj}(x)\,{}_{iy}l_k(x), $$

which yields Kolmogorov's differential equation for the Markov chain

$$ \frac{d}{dx}\,{}_{iy}l_j(x) = -\hat{\mu}_{jj}(x)\,{}_{iy}l_j(x)+\sum_{k\neq j}\mu_{kj}(x)\,{}_{iy}l_k(x). \tag{3} $$

Equation (3) describes the changes in the survival probability ${}_{iy}l_j(x)$ as a function of the instantaneous rates of mobility and mortality and of the initial condition, i.e. the state of a person at exact age x. The result may be written in matrix form,

$$ \frac{d}{dx}\,{}_y\mathbf{l}(x) = -\boldsymbol{\mu}(x)\,{}_y\mathbf{l}(x), \tag{4} $$

where $\boldsymbol{\mu}(x)$ is the matrix of instantaneous rates, arranged in the following way.[21]

$$ \boldsymbol{\mu}(x) = \begin{bmatrix} \hat{\mu}_{11}(x) & -\mu_{21}(x)\ldots & -\mu_{N1}(x) \\ -\mu_{12}(x) & \hat{\mu}_{22}(x)\ldots & -\mu_{N2}(x) \\ \vdots & \vdots & \vdots \\ -\mu_{1N}(x) & -\mu_{2N}(x)\ldots & \hat{\mu}_{NN}(x) \end{bmatrix}, \tag{5} $$

$$ {}_y\mathbf{l}(x) = \begin{bmatrix} {}_{1y}l_1(x) & {}_{2y}l_1(x)\ldots & {}_{Ny}l_1(x) \\ {}_{1y}l_2(x) & {}_{2y}l_2(x)\ldots & {}_{Ny}l_2(x) \\ \vdots & \vdots & \vdots \\ {}_{1y}l_N(x) & {}_{2y}l_N(x)\ldots & {}_{Ny}l_N(x) \end{bmatrix}. \tag{6} $$

The age y defines the cohort. If $y = 0$, the cohort is the birth cohort or radix. Another interesting cohort is $y = \bar{\alpha}$, where $\bar{\alpha}$ is the lowest age at which all marital statuses can be non-empty.[22] This will be called the *full cohort age*, the lowest age at which there can

[20] It is assumed that not more than one transition from one state to another is possible in the small interval dx.

[21] *Loc. cit.*, in footnote 6.

[22] In practice, $\bar{\alpha}$ is the minimum legal age at marriage.

be some members in each marital status category. At ages below $\bar{\alpha}$, some categories are empty. The full-cohort age is of particular relevance for the calculation of marital status-based life-table statistics. To solve the system of linear time-homogeneous differential equations (4) we may replace it be a system of integral equations.[23]

$$_y\mathbf{l}(x) = {_y\mathbf{l}(y)} - \int_0^n \mu(y+t)_y\mathbf{l}(y+t)\,dt, \tag{7}$$

where $n = x-y$.

The problem of solving the system of Kolmogorov differential equations (4) has been replaced by the problem of evaluating the integral

$$\int_0^n \mu(y+t)\,_y\mathbf{l}(y+t)\,dt.$$

This may be done in a number of steps by dividing the interval (y, x) into sub-intervals of length h:

$$\begin{aligned} {_y\mathbf{l}(y+h)} &= {_y\mathbf{l}(y)} - \int_0^h \mu(y+t)\,_y\mathbf{l}(y+t)\,dt, \\ {_y\mathbf{l}(y+2h)} &= {_y\mathbf{l}(y+h)} - \int_0^h \mu(y+h+t)\,_y\mathbf{l}(y+h+t)\,dt, \\ &\vdots \\ {_y\mathbf{l}(x+h)} &= {_y\mathbf{l}(x)} - \int_0^h \mu(x+t)\,_y\mathbf{l}(x+t)\,dt. \end{aligned} \tag{8}$$

Define the matrix of conditional probabilities:

$$\mathbf{P}(x) = \begin{bmatrix} p_{11}(x) & p_{21}(x)\ldots p_{N1}(x) \\ p_{12}(x) & p_{22}(x)\ldots p_{N2}(x) \\ \vdots & \vdots \\ p_{1N}(x) & p_{2N}(x)\ldots p_{NN}(x) \end{bmatrix},$$

where $p_{ij}(x)$ denotes the probability that an individual alive in state i at age x will be in state j, h years later, i.e. aged $x+h$; this probability is assumed to be independent of the state at age y, and to depend only on the state at the beginning of the interval h. The probability of dying is obtained by subtraction:

$$q_i(x) = 1 - \sum_{j-1}^{N} p_{ij}.$$

If $_y\mathbf{l}(x)$ is non-singular, $\mathbf{P}(x)$ is given by the following expression:

$$\mathbf{P}(x) = {_y\mathbf{l}(x+h)}[_y\mathbf{l}(x)]^{-1}. \tag{9}$$

The condition of non-singularity is generally satisfied for ages $x \geqslant \bar{\alpha}$. At ages below $\bar{\alpha}$, some values of $p_{ij}(x)$ may be zero; at ages below the youngest age of marriage, all $p_{ij}(x)$ are zero except for $p_{11}(x)$, which is simply the probability of surviving from age x to $x+h$. This probability is then equal to

$$p_{11}(x) = \frac{_{y1}l_1(x+h)}{_{y1}l_1(x)}.$$

In other words, the matrix equation (9) reduces to a scalar equation.

Equation (9) implies that $_y\mathbf{l}(x+h) = \mathbf{P}(x)\,_y\mathbf{l}(x)$. A comparison of this expression with (8) yields the following for $\mathbf{P}(x)$:

[23] See, for example, F. Brauer, J. Nohel and H. Schneider, *Linear Mathematics: An Introduction to Linear Algebra and Linear Differential Equations* (New York: Benjamin, 1970).

$$\mathrm{P}(x) = \left[\mathrm{I} - \int_0^h \mu(x+t)\,{}_x\mathrm{l}(x+t)\,[{}_y\mathrm{l}(x)]^{-1}dt\right]. \tag{10}$$

Note that we have obtained the expression for $\mathrm{P}(x)$ without making any assumption about the constancy of the instantaneous rates in the intervals of length h. In this regard, the derivation differs from that proposed by some authors,[24] and which implies the approximation, at the outset, of the $\mu(t)$-function by a set of step functions.

From (8) we may also derive an expression for the annual age-specific rates in the increment–decrement life table

$${}_y\mathrm{l}(x+h) - {}_y\mathrm{l}(x) = -\int_0^h \mu(x+t)\,{}_y\mathrm{l}(x+t)\,dt\left[\int_0^h {}_y\mathrm{l}(x+t)\,dt\right]^{-1}\left[\int_0^h {}_y\mathrm{l}(x+t)\,dt\right]. \tag{11}$$

The expression $\int_0^h {}_y\mathrm{l}(x+t)\,dt$ represents the number of years lived in each state between ages x and $x+h$, per person in each state at age y. Denote this by ${}_y\mathrm{L}(x)$:

$${}_y\mathrm{L}(x) = \int_0^h {}_y\mathrm{l}(x+t)\,dt. \tag{12}$$

The matrix ${}_y\mathrm{L}(x)$ may also be looked upon as representing the number of people by state in age group x to $x+h$, per person in each state at age y. Hence it gives the age distribution of the life-table population. The expression.

$$\left[\int_0^h \mu(x+t)\,{}_y\mathrm{l}(x+t)\,dt\right]\left[\int_0^h {}_y\mathrm{l}(x+t)\,dt\right]^{-1} = \mathrm{m}(x) \tag{13}$$

is then the matrix of age-specific life table rates.[25]

Equation (11) becomes, therefore,

$${}_y\mathrm{l}(x+h) - {}_y\mathrm{l}(x) = -\,\mathrm{m}(x)\,{}_y\mathrm{L}(x).$$

To derive an expression of $\mathrm{P}(x)$ in terms of life-table rates, recall that ${}_y\mathrm{l}(x+h) = \mathrm{P}(x)\,{}_y\mathrm{l}(x)$. Hence

$$[\mathrm{P}(x) - \mathrm{I}]\,{}_y\mathrm{l}(x) = -\mathrm{m}(x)\,{}_y\mathrm{L}(x),$$

$$\mathrm{P}(x) = \mathrm{I} - \mathrm{m}(x)\,{}_y\mathrm{L}(x)[{}_y\mathrm{l}(x)]^{-1}. \tag{14}$$

This expression may also be derived directly from (10) by applying (12) and (13).

Numerical approximation to $\mathrm{P}(x)$. All life-table functions may be derived from a knowledge of the transition probability matrices $\mathrm{P}(x)$. The expression $\mathrm{P}(x)$ in terms of instantaneous rates is given in (10) and (14). On the other hand, Rogers and Ledent have shown that $\mathrm{P}(x)$ may be written as follows:[26]

$$\mathrm{P}(x) = [\mathrm{I} + (h/2)\,\mathrm{M}(x)]^{-1}[\mathrm{I} - (h/2)\,\mathrm{M}(x)], \tag{15}$$

where $\mathrm{M}(x)$ is the matrix of observed (occurrence/exposure) rates, associated with the age group x to $x+h$, and with the same format as the matrix $\mu(x)$.

The transition from (14) to (15) involves a number of assumptions. First, the assumption that transitions and deaths are distributed uniformly over the interval x to $x+h$, yielding segmentally (piecewise) linear survival functions. The mean duration before transfer is therefore $h/2$, also in the case of multiple transitions.[27] The uniform distribution implies that the integral $\int_0^h {}_y\mathrm{l}(x+t)\,dt$ or ${}_y\mathrm{L}(x)$ may be approximated by the

[24] See Hoem and Fong, Krishnamoorthy and Ledent, *loc. cit.*, in footnotes 9 and 10.

[25] Note the difference in the expression obtained by Ledent, *loc. cit.* in footnote 10, which is not derived from the Kolmogorov equation but from the particular definition of the elements of $\mathrm{m}(x)$ in his equation (54).

[26] *Loc. cit.*, in footnote 6.

[27] Ledent, 'Some methodological...', *loc. cit.*, in footnote 10.

linear integration

$$_y\mathbf{L}(x) = (h/2)\,[_y\mathbf{l}(x) + {_y\mathbf{l}}(x+h)]. \tag{16}$$

Schoen and Land[28] show that the assumption of linearity is equivalent to assuming that the instantaneous rates of the life-table model are segmentally hyperbolic.

Introducing (16) in the expression for $\mathbf{P}(x)$ yields

$$\mathbf{P}(x) = \mathbf{I} - (h/2)\,\mathbf{m}(x)\,[_y\mathbf{l}(x) + {_y\mathbf{l}}(x+h)]\,[_y\mathbf{l}(x)]^{-1},$$
$$\mathbf{P}(x) = \mathbf{I} - (h/2)\,\mathbf{m}(x)\,[\mathbf{I} + \mathbf{P}(x)],$$
$$\mathbf{P}(x) = [\mathbf{I} + (h/2)\,\mathbf{m}(x)]^{-1}\,[\mathbf{I} - (h/2)\,\mathbf{m}(x)]. \tag{17}$$

To compute $\mathbf{P}(x)$ from observed statistics we introduce a third assumption: annual age-specific life-table rates are equal to annual age-specific rates in the observed population, i.e. $\mathbf{m}(x) = \mathbf{M}(x)$. This makes (17) equal to (15). This assumption, however, implies that period data (observed rates) provide adequate estimates of life table functions to be used in longitudinal analysis. Furthermore, equating life-table rates to observed occurrence/exposure rates implies the assumption that within each age interval and within each life status of the model, the observed population is stationary, i.e. is distributed as the life-table population. The total set of assumptions is as follows:

(i) independence of demographic events;
(ii) the transition is according to a Markov process (see equation (1));
(iii) using a linear approximation in determining $_y\mathbf{L}(x)$;
(iv) life-table rates are equal to observed occurrence/exposure rates.

We now have the necessary elements to derive some other interesting life-table functions, such as expectations of life.

2.2. *Other life-table statistics*

Several useful statistics of the life table may be derived from the matrices of probabilities $_y\mathbf{l}(x)$ and $\mathbf{P}(x)$. The procedures are analogous to those used in the construction of a multi-regional life table, in which states refer to regions.[29] The matrix $_y\mathbf{L}(x)$ has already been derived.

Note that for $y = 0$, $_y\mathbf{L}(x)$ denotes the average number of years lived between x and $x+h$ in each state per person in the birth cohort. If $x = y$, $_y\mathbf{L}(x)$ represents the number of years lived in each state per person aged x. Because linear interpolation was used, the latter measure is independent of the distribution of the x-year-olds among the different marital status groups and is simply equal to $(h/2)[\mathbf{I} + \mathbf{P}(x)]$. The matrix $_0\mathbf{L}(x)$ is an unconditional measure, whereas $_x\mathbf{L}(x)$ is conditional on reaching age x. They have their analogues in multi-regional demography, where $_0\mathbf{L}(x)$ and $_x\mathbf{L}(x)$ are respectively the matrix of duration of residence by region of birth, and by region of residence. These expressions of duration of residence provide a logical basis for the population-based and marital status-based measures of number of years lived and of life expectancies.

Before proceeding to the expectation of life, the formulae for $_y\mathbf{L}(x)$ and $_z\mathbf{L}(x)$ must be given for $x = z$, the last open-ended age group. Willekens and Rogers show[30] that, if the linear approximation is used for integration, the number of years lived in the last age group is given by the following equations:

$$_y\mathbf{L}(z) = [\mathbf{M}(z)]^{-1}\,{_y\mathbf{l}}(z),$$
$$_z\mathbf{L}(z) = [\mathbf{M}(z)]^{-1}, \tag{18}$$

[28] *Loc. cit.*, in footnote 10.
[29] *Op. cit.*, in footnote 7, chapter 2; see also Willekens and Rogers, *op. cit.*, in footnote 12.
[30] *Op. cit.*, in footnote 12.

where M(z) is the matrix of observed occurrence/exposure rates of the last age group.

The sum of ${}_y\mathrm{L}$-matrices over all ages greater than x yields the total number of person-years lived beyond age x by members of the cohort aged y.

$$ {}_y\mathrm{T}(x) = \sum_{t=x}^{z} {}_y\mathrm{L}(t). $$

For ages $y < \bar{\alpha}$, all members of the cohort are never married, and the matrices ${}_y\mathrm{L}(x)$, and ${}_y\mathrm{T}(x)$ consist of zero elements everywhere, except in the first column.

A particularly interesting life-table function is the expectation of life. As mentioned in the introduction to this paper, two measures of life expectancy may be distinguished in multi-state tables: those based on populations irrespective of marital status and those based on marital status.

(*a*) *Population-based measure of life expectancy*. This measure gives the number of years spent in each state beyond age x and the expectation of life at age x without reference to the person's state at age x or at some previous age. A convenient way to compute the population-based measure of life expectancy is to consider a cohort aged exactly $y < \bar{\alpha}$; for instance, the birth cohort. At age zero, all members are in the never-married state, and the life expectancy by state at birth automatically yields the population-based measure. The person-years lived in the various states beyond age x by a member of the birth cohort are contained in the non-zero elements (first column) of ${}_0\mathrm{T}(x)$. The population-based measure of life expectancy at age x is therefore

$$ {}_0\mathrm{e}(x) = \frac{1}{{}_{10}l_{.}(x)} {}_0\mathrm{T}(x) = \frac{1}{\sum_k {}_{10}l_k(x)} {}_0\mathrm{T}(x), \qquad (19) $$

where ${}_{10}l_{.}(x)$ is the probability that a member of the birth cohort reaches age x, irrespective of the marital status at that age. Equation (19) is the formula for the life expectancy by region of birth, but is applied here in a different context.

The first column of ${}_0\mathrm{e}(x)$ contains the relevant life expectancies. They show how many years a person aged x, irrespective of his or her marital status, may expect to spend in each status. The column sum is the total life expectancy.

(*b*) *Marital status-based measure of life expectancy*. This measure is status-specific and expresses the time spent in the various states beyond age x by the state occupied at age $y(y \leqslant x)$. If $y = x$, the status-based measure refers to a person's current status and the formula becomes particularly simple and illuminating. For instance, the total number of years a married person of age y may expect to spend in the married state is

$$ {}_{2y}e_2(y) = \int_0^{\omega-y} {}_{2y}l_2(y+t)\,dt, $$

with ${}_{2y}l_2(y+t)$ being the probability that a married person aged y will also be married t years later, and where ω is the highest age. In general, we may write

$$ {}_y\mathrm{e}(y) = \int_0^{\omega-y} {}_y\mathrm{l}(y+t)\,dt, $$

or, in discrete form,

$$ {}_y\mathrm{e}(y) = \sum_{t=0}^{z-y} {}_y\mathrm{L}(y+t) = {}_y\mathrm{T}(y). \qquad (20) $$

Equation (20) refers to the life expectancy beyond age y of persons aged y years (current age). What is the life expectancy beyond age x of persons in a given state at any previous age y? Their state at age x is of no importance here. The life expectancy beyond age x by future state and state at age y is

$$_y\mathbf{e}(x) = \left[\int_0^{\omega - x} {}_y\mathbf{l}(x+t)\,dt\right]\left[{}_y\hat{\mathbf{l}}(x)\right]^{-1}$$
$$= {}_y\mathbf{T}(x)[{}_y\hat{\mathbf{l}}(x)]^{-1}, \qquad (21)$$

where ${}_y\hat{\mathbf{l}}(x)$ is a diagonal matrix with elements ${}_{iy}l_{.}(x) = \Sigma_k\, {}_{iy}l_k(x)$. An element ${}_{iy}l_{.}(x)$ denotes the probability that a person aged y in state i will survive to age x. The life-expectancy matrix takes a form similar to ${}_y\mathbf{l}(x)$. An element ${}_{iy}e_j(x)$ denotes the number of years a person in state i at age y may expect to spend in state j after birthday x. The total expectation of life beyond age x of a person in state i at age y is given by the column sum. The number of years lived in each marital status is shown in the column. Some column elements will of course be zero, since, for instance, no married person can return to the never married state. These life expectancy measures are *marital status-based*, since they are state-specific.

Three remarks must be made at this point. First, Equation (20) is a special case of (21) since for $x = y$, ${}_y\mathbf{l}(x)$ is the identity matrix. Secondly, because ${}_y\mathbf{l}(x)$ must not be singular, the lowest age at which (21) may be applied is α. Thirdly, from the knowledge of ${}_y\mathbf{T}(x)$ and ${}_y\mathbf{l}(x)$, we can derive the matrix of life expectancies for any age $x \geqslant y$:

$$_x\mathbf{e}(x) = {}_y\mathbf{T}(x)\,[{}_y\mathbf{l}(x)]^{-1}. \qquad (22)$$

This equation is analogous to the formula of life expectancy by region of residence used in multi-regional demography.

3. A LIFE TABLE FOR BELGIUM BY MARITAL STATUS

In this section the mathematical theory of multi-state life-table construction is applied to Belgian statistics for 1970–71. The numerical results shown are only illustrative because of limitations in the data, and weaknesses in the method. The statistics are averages of two years and therefore subject to all the conceptual and other problems associated with the application of life-table techniques to period data. In developing the life table a few assumptions had to be made which render the model less realistic than one would like. A major concern is the Markovian assumption, which states that transition probabilities depend only on age and are independent of previous status or of time spent in the current status.[31] The assumption may be relaxed by increasing the state-space, as Ledent has shown.[32] Our data, however, do not permit this.

3.1. *Data*

In order to construct a multi-state life table we need to know the numbers of marriages and deaths as well as the populations separately for each age, sex and marital status category and the numbers of divorces and widowhoods by age and sex. Generally, the population figures are taken from censuses, the remaining figures from vital registration records. Statistics in the present paper are taken from the Belgian census taken on 31 December 1970 and from vital registration figures for 1970 and 1971.[33]

[31] This assumption is also implicit in classical approaches to the construction of nuptiality tables.

[32] Ledent, 'Constructing...', *loc. cit.*, in footnote 10.

[33] Population figures are given in Census Volume No. 5 (1974), pp. 140–141. Vital statistics are regularly published in 'Demographic statistics'. Mortality statistics for 1970 and 1971 are published in the issues 1974/4–2 (pp. 72–75) and 1975/1 (pp. 68–71), respectively. Marriage and divorce statistics are published in the issues 1974/4–2 (pp. 34–37; p. 63) and 1975/4 (pp. 47–50; p. 102).

To study widowhood we would need to know the deaths of married men and women, classified by the age of the surviving spouse. Such information is not, however, available for Belgium. We therefore estimated the number of widowhoods from statistics of deaths for the opposite sex. On average, a wife is about two years younger than her husband, but it was assumed that the deaths of married men in a given age group were equivalent to the number of new widows in the same age group.

The average number of events in 1970 and 1971 has been taken as the numerator for the central rates that were calculated. No adjustments or indirect estimates were made, nor were the rates graduated in any way. The results must therefore be taken as being illustrative only.

3.2. *Results*

In 1970–1 about 118,000 women or 2.4 per cent of the female population changed their marital status each year (Table 1). Marriages account for 62.4 per cent of the changes, widowhoods for 31.9 per cent and divorces for 5.7 per cent. First marriages amounted to 92.3 per cent of the total number of marriages. If the rates for 1970–1 were to remain constant, about 9.2 per cent of marriages would end in divorce and the mean duration of marriage would be 11 years. The divorce rate is 2.7 per thousand. About 57.8 per cent of divorced women would re-marry and the annual re-marriage rate would be 6.7 per cent. The mean age at first marriage is 22 years; at divorce 35 years and at re-marriage 38 years. This gives a general picture of the marital pattern of Belgian women.

In analysing nuptiality patterns, we distinguish between the population-based and the status-based life table. Population-based measures of duration of married life have also been derived and discussed by Schoen and Nelson and Krishnamoorthy.[34] Status-based measures can only be obtained by a multi-state approach. The multi-state life table provides detailed information on transitions at various ages and on average life histories of the synthetic cohorts. A discussion of the complete life-table output is beyond the scope of this paper. We restrict ourselves to a few demographic indicators of general interest.[35]

Table 1. *Pattern of marital change, women, Belgium 1970–1971 (population distribution and average annual number of changes)*

To	From				
	Never-married	Married	Widowed	Divorced	Total
Death	7,694	17,439	29,998	910	56,041
Never married	—	0	0	0	–
Married	67,857	—	1,778	3,874	73,509
Widowed	0	37,527	0	0	37,527
Divorced	0	6,727	0	0	6,727
Total	75,551	61,693	31,776	4,784	
Population 31/12/70	1,850,789	2,462,510	557,844	57,935	

(*a*) *Population-based analysis.* About 93 per cent of all girls born in Belgium will eventually marry if the mortality and marriage patterns observed in 1970–1 were to persist. More than half of them (54 per cent) will have married by the age of 22. In a

[34] *Loc. cit.*, in footnotes 4 and 10.

[35] The procedures used to arrive at these indicators are documented in N.I.D.I. Working Paper no. 17, which also contains the complete computer output of LIFEINDEC.

Table 2. *Patterns of first marriage; women, Belgium 1970–1971; United States, 1970*

	Belgium	United States
Proportion who never marry	0.935	0.940
Proportion of life expectancy in never married state	0.313	0.308
Proportion of life expectancy at age 20 in never married state	0.078	0.075

Table 3. *Demographic indicators of the married state; women, Belgium 1970–1971; United States, 1970*

	Belgium	United States
Expectation of life at age 20 in married state	41.33	35.93
Proportion of life spent in married state	0.550	0.489
Proportion of life spent in married state at age 20	0.736	0.650
Expected duration of a marriage	40.42	25.55
Number of marriages per person	1.01	1.43
Number of marriages per person marrying	1.08	1.52
Proportion of women who die married	0.350	0.281

Table 4. *Patterns of divorce; women, Belgium 1970–1971; United States, 1970*

	Belgium	United Stated
Proportion of cohort life spent in divorced state	0.018	0.069
Proportion of life expectancy at age 20 spent in divorced state	0.025	0.093
Probability that a marriage will end in a divorce	0.088	0.363
Proportion of women who die as divorcees	0.029	0.114
Number of divorces per 100 first marriages	9.6	55.3

Table 5. *Patterns of widowhood; women, Belgium 1970–1971; United States, 1970*

	Belgium	United States
Proportion of cohort life in widowed state	0.119	0.134
Proportion of life expectancy at age 50 spent in widowed state	0.326	0.351
Probability that a marriage will end in widowhood	0.565	0.441
Proportion of women who die as widows	0.558	0.545

cohort of 100,000 women, 95,748 would still be alive at age 40. Most of them will be married (87,404 or 91.3 per cent), 4,060 (4.2 per cent) would be single, 1,359 (1.4 per cent) widowed and 2,924 (3.1 per cent) divorced. A girl may expect to be married for 41 years of her life or 55 per cent of her total life expectancy. This figure remains remarkably stable up to the age of 23. At this age, the expected length of a marriage is 40 years, but amounts to 75 per cent of her total expectation of life at that age. A similar constancy is found for the expected length of time spent as a widow or divorced woman. The former figure comes to about 9 years whether measured at birth or at any age below 60 years; the latter measure remains at a level of 1.3 years up to the age of 30.

In Tables 2–6 we provide some aggregate information on the transitions between different statuses. For comparison, similar measures are given for United States women;

Table 6. *Patterns of re-marriage; women, Belgium 1970–1971; United States, 1970*

	Belgium	United States
Ratio of re-marriages of widows to widowhoods	0.024	0.136
Ratio of re-marriages of divorced women to divorces	0.688	0.781

they were calculated by Krishnamoorthy.[36] Note that the *proportion of life expectancy* at a given age in a given state is equal to the *proportion of time lived by the cohort* after the same age in that state. This follows from Equation (19). The number of events, e.g. marriages, an individual may expect to experience during her lifetime is the ratio of the number of events to the size of the birth cohort.

The expected duration of a marriage is the total number of years lived in the married state by the cohort divided by the total number of first marriages and re-marriages (40.42).

The probability that a marriage will end in divorce is the ratio of the number of marriages that end in divorce to the sum of first marriages and re-marriages.[37] The probability that a marriage will end in widowhood is calculated in a similar way.

There are some remarkable similarities between the pattern in Belgium and in the United States, but there are also substantial differences. The pattern of first marriages is similar; but that of divorces and re-marriages is different. The proportion of marriages ending in divorce is 36 per cent in the United States and 9 per cent in Belgium. Once a women is divorced, her chance of re-marriage does not differ much between the two countries. In the United States, 78 per cent of divorced women re-marry compared with 69 per cent in Belgium. The situation is completely different for widows. Not only is their rate of re-marriage much lower, but the difference between the countries is much larger. In Belgium only 2 per cent of the widows re-marry; in the United States 14 per cent. Much of the difference can be explained by sociological and religious factors.

(*b*) *Status-based analysis*. Life-table analysis shows that a woman aged 20 may expect to live another 56 years, irrespective of her marital status. Of this total, about 41 years or 74 per cent will be spent in marriage and 15 years outside marriage mainly as a widow (9 years). This is an average picture which changes considerably if the woman's marital status at age 20 is taken into account. If she is already married, she may expect to spend 45 years in marriage, but not necessarily on a continuous basis, and 9 years as a widow. However, if she is a young widow, she will spend on average only 31 years in marriage and no less than 23 years as a widow. Compare this with a divorced woman aged 20. She will re-marry much sooner and expects to spend only seven years on average as a divorcee.

These are some results that illustrate the potential contribution of multi-state life tables to the description and understanding of patterns of marriage and of marital dissolution. Status-based life tables may be constructed for any cohort at an age when all states are non-empty, i.e. for any age $x \geqslant \bar{\alpha}$, the full cohort age. In the computer program constructed for this study, the user specifies the initial age of the cohort.[38] For the present paper, a cohort of age 20 is considered. A distinction is made between the initial status of a person, in this case at age 20, and the status at age $x > 20$. The multi-state life table not only groups people by their current status (at age x) but also keeps track of their initial status. It does so by *simultaneously* tracing the life histories of various status-specific cohorts.

[36] *Loc. cit.*, in footnote 10.
[37] Schoen and Nelson, *loc. cit.*, in footnote 4.
[38] Willekens, *op. cit.*, in footnote 19.

The complete life histories (number of transitions) of the 20-year-olds in each marital status are not given but may be obtained from the authors. Table 7 provides a sample. It shows the changes in a cohort of 100,000 never-married women aged 20, throughout their lives. Similar tables may be constructed for each marital status category and for other ages. Of the 100,000 women still unmarried at age 20, 94,809 will eventually marry, 8,791 will experience a divorce, but 5,970 of these will re-marry. 57,917 will be widowed but only 1,373 will re-marry, a re-marriage rate of 2 per cent; but if the woman is already widowed at the age of 20, the probability of re-marriage is 79 per cent. However, most of those who re-marry (48,000 or 60 per cent) will be widowed for a second time. About 6 per cent of the marriages of widows will end in a divorce. The picture is quite different for 20-year-old divorcees. Not only will all of them re-marry but they will re-marry on average 1.04 times. At the age of 23, almost half the divorcees will have re-married, against 27 per cent of widows. About 8 per cent of these marriages end in a second divorce but again most will re-marry. Only 5 per cent of those divorced at the age of 20 will die as divorcees. The average time spent in the divorced state is very short, about 6.11 years for those divorced at the age of 20 and 15.58 years on average. This is consistent with the high re-marriage rate shown in Table 6. It is also interesting to note that women whose marriage has been dissolved through widowhood or divorce are less likely to be divorced after re-marriage than women married for the first time (Table 11). The same table shows that the probability of divorce is lower for women who marry at an age above 20 than for women married at an age below 20; the difference is about 12 per cent.

On the basis of the life table, we may calculate demographic indices which are

Table 7. *Deaths and marital changes after age 20 by 100,000 never-married women, Belgium 1970–1971*[39]

To	From: Never-married	Married	Widowed	Divorced
Death	4,964	35,445	56,667	2,924
Never-married	—	0	0	0
Married	94,809	—	1,373	5,970
Widowed	54	57,917	—	74
Divorced	173	8,791	5	—

Table 8. *Pattern of marriage: cohort of 20-year-old women, Belgium 1970–1971, by status at age 20*

	Status at age 20: Never-married	Married	Widowed	Divorced
Expectation of life in married state	40.07	45.36	30.57	40.06
Proportion of life expectancy at age 20 in married state	0.714	0.806	0.563	0.717
Expected duration of marriage	39.23	41.72	36.64	38.34
Number of marriages per woman	1.02	—	0.83	1.04
Number of marriages per woman marrying	1.08	—	1.05	1.01
Proportion of women dying married	0.354	0.374	0.294	0.365
Proportion dying in same state as at age 20	0.050	0.374	0.684	0.050

[39] Several transitions cannot be made directly and imply multiple passages. For instance, 54 women will marry for the first time and divorce in the same time (age) interval. Note that the numbers of deaths add up to 100,000, the total size of the cohort.

Table 9. *Pattern of widowhood of women by marital status at age 20, Belgium 1970–1971*

	Marital status at age 20			
	Never-married	Married	Widowed	Divorced
Expected number of years spent as a widow	8.93	9.41	22.72	9.17
Proportion of life expectancy in widowhood	0.159	0.167	0.419	0.119
Average duration of widowhood	15.42	15.43	15.35	15.40
Probability that a marriage will end in widowhood	0.57	0.56	0.58	0.57
Proportion of women who die as widows	0.567	0.595	0.684	0.584
Re-marriage probability of widows	0.024	0.026	0.537	0.023

Table 10. *Pattern of divorce of women by marital status at age 20, Belgium 1970–1971*

	Marital status at age 20			
	Never-married	Married	Widowed	Divorced
Expected number of years spent as a divorced woman	1.35	1.50	1.00	6.63
Proportion of life expectancy spent as a divorced woman	0.024	0.027	0.018	0.119
Average duration of divorce	15.04	14.44	16.50	6.11
Probability that a marriage will end in a divorce	0.086	0.096	0.073	0.081
Proportion of women dying as divorcees	0.029	0.031	0.023	0.052
Probability of re-marrying after divorce	0.68	0.69	0.66	0.95

Table 11. *Life expectancies in each marital status by status at age 20*

	Status at age 20			
Future marital status	Never-married	Married	Widowed	Divorced
	(*a*) Number of years			
Never-married	5.76	0.00	0.00	0.00
Married	40.07	45.36	30.57	40.06
Widowed	8.93	9.41	22.72	9.17
Divorced	1.35	1.50	1.00	6.63
Total	56.12	56.27	54.29	55.86
	(*b*) Percentages			
Never-married	10.3	0.0	0.0	0.0
Married	71.4	80.6	56.3	71.7
Widowed	15.9	16.7	41.8	16.4
Divorced	2.4	2.7	1.8	11.9
Total	100.0	100.0	100.0	100.0

analogous to those in Tables 2–6, but which are status-specific and investigate the differences caused by being in a specific state at a given age. For instance, Table 8 describes the currently married state from the point of view of a 20-year-old woman who is respectively never married, married, widowed or divorced. Note that the expected duration of marriage is the ratio of the total number of years lived in marriage by the state-specific cohort to the number of women in this cohort who marry. In other words, it is the number of years spent in marriage, given that the woman marries. For instance, for never-married women aged 20, the expected length of a marriage is 42.27 years. We observe considerable differences between the columns. The conclusion is straightforward:

a woman's future demographic experiences depend to a considerable extent on her marital status. Analogous results are calculated for widows and divorced women. The results are shown in Tables 9 and 10 respectively.

Life-table analysis provides estimates of duration for each marital status. Table 11 combines the first rows of Tables 8 and 10. The total life expectancy of 20-year-old widows is 2 years lower than for married women of the same age. Of the 56.3 years a 20-year-old married woman may expect to live, 9.4 years will be spent as a widow and 1.5 years as a divorced woman. The proportion of life spent as a widow increases with age. Note also the short period of time spent in the divorced state. A woman divorced at the age of 20 will spend only 12 per cent of her life in that state. This proportion rises with age and reaches 90 per cent for divorcees aged 60 years. Consequently, the average length of time spent in the divorced state increases with age. The differences in the indices demonstrate the importance of status-specific life-table analysis.

4. CONCLUSION

In this paper we have summarized the mathematical theory of multi-state life-table construction and applied it to investigate the patterns of first marriage, widowhood, divorce and re-marriage of the Belgian female population for 1970–1. We have shown that the mathematics of multistate life-table construction become simple if the matrix approach, initiated by Rogers for the design of multi-regional life tables is adopted. This approach not only makes the work easier; it also makes it possible to follow the life histories of cohorts while keeping track of their original marital status, and thus to study how an individual's demographic future is affected by his or her current marital status. It is only in the multi-state perspective that a *status-based life-table analysis* can be carried out, because such an analysis requires simultaneous consideration of all status-specific cohorts.

The multi-state marital status life table for Belgium is used as the basis for a population- and a status-based analysis of the patterns of marital change. The results are compared with those for the United States. Although patterns of first marriage are very similar in both countries, divorce patterns are very different. Although Belgium's divorce rate is one-quarter of that of the United States, the proportions of divorced women who re-marry are similar. On the other hand, the proportion of United States widows who re-marry exceeds that of Belgium by a factor of seven (14 per cent against 2 per cent).

In population-based life-table analysis the life histories of individuals of a given age are studied irrespective of their initial marital status. However, an individual's marital history is an important factor in understanding of his or her marital future. The status-based analysis carried out in this paper demonstrates the large differences in demographic behaviour between women in different marital statuses at age 20. For instance, while the average re-marriage rate of a widow is 2 per cent in Belgium, it is 79 per cent if the widow is aged 20. The difference for divorced women is not as large but is considerable. Whereas the average probability of re-marriage after divorce is around 69 per cent, it is 95 per cent if the divorcee is aged 20 years. A 20-year-old woman, irrespective of her marital status, who eventually will divorce may expect to live for about 16 years in the divorced state; however, if she is already divorced at age 20, then her total expectation of life as a divorced woman is only six years. In the text, several other illustrations of these types of differences are given. We, therefore, conclude that a woman's demographic future depends to a considerable extent on her current marital status. In this paper we have attempted to show how multi-state life-table analysis may successfully be used to study these differentials.