A MULTI-STATE MODEL OF DISABILITY FOR THE UK: IMPLICATIONS FOR FUTURE NEED FOR LONG TERM CARE FOR THE ELDERLY

BY B. D. RICKAYZEN
DEPARTMENT OF ACTUARIAL SCIENCE
CITY UNIVERISTY
LONDON EC1V OHB
ENGLAND

E-MAIL: B.D.RICKAYZEN@CITY.AC.UK
TELEPHONE: +44 (0)20 7040 8499
FAX:+44 (0)20 7040 8838

ABSTRACT

This paper develops a multiple state model to project the number of people with disabilities in the UK over the next 35 years, thereby looking at the implications for demand for long term care for the elderly in the future.
The model requires 3 types of data: prevalence rate data, transition rate data and trends data. Trends are based on past healthy life expectancy and assumptions to project suitable future trends in disability rates of the UK population.
Although there will be a large increase in the number of elderly people in the UK over the next 35 years, the projections suggest that the implications for the number of elderly people requiring long term care could be ameliorated by a reduction in the proportion of older people who are severely disabled.

KEYWORDS

Long term care; Multiple state model; Healthy life expectancy

1. INTRODUCTION

This paper describes a model which has been developed to project the number of people in the United Kingdom who will be disabled over the next forty years. The projections give an indication of the long-term care needs of the UK population in the future. The paper is a summary of the three papers: Walsh and Rickayzen (2000a), Rickayzen and Walsh (2000) and Walsh and Rickayzen (2000b).

The number of elderly people in the UK is growing both in absolute terms and in relation to the number of people of working age. According to the projections produced by the Government Actuary's Department (GAD) in 1998 there will be around 4.3 million people aged 80 or more in forty years' time compared with about 2.3 million now. The number of people aged between 20 and 64 is expected to fall slightly from 34.8 million to 33.8 million (Government Actuary, 1998).

At present the prevalence of disability amongst elderly people is much higher than for the rest of the population. As this situation is likely to continue it is possible that there will be very many more people with some degree of disability in the future. Such people will need some form of long-term care.

The provision of long-term care is expensive (in terms of both time and money). Hence it is very important to be able to estimate the numbers of people who are likely to need long-term care, although it is also necessary to recognise that any such estimate will be subject to much uncertainty. The numbers, while they are fundamental, are only one of several aspects that will affect the provision of long-term care. The other aspects include the connection between the severity and nature of a disability and the cost of caring for someone with the disability; the split between formal and informal provision of care services; and methods of paying for the cost of care provision. This paper focuses on the issue of the number of people who will require care and does not address the other key aspects mentioned above.

The output from the model, for a given set of assumptions, is an estimate of the number of people who are healthy and the number who are disabled. (In this paper we use the terms "healthy", "able" and "not disabled" interchangeably.) The number of disabled people is further split into several categories of disability from relatively mild to very severe. The model covers people aged 20 and over and goes up to the year 2036. The numbers are produced for all combinations of age, year and sex.

The output is very sensitive to the assumptions put into the model, and the necessity of describing these assumptions and the sensitivities accounts for the length of the paper. We describe in some detail the data which we have used as a starting point and the various trends which we have included in the projections. We also present the results of projections produced using a range of assumptions.

This paper follows an earlier one in the UK actuarial literature by Nuttall et al (1994). That paper covered more ground than this one, in particular the financial implications of future demand for long-term care were considered. There are, naturally, some important similarities between the model which we use for the projection of the number of disabled people and the model which Nuttall et al used. There are, though, some key differences as well and we have added considerably to the complexity of the earlier model. Just as important as the new developments in modelling is the existence of new data. The most important new data to be published since Nuttall et al (1994) relates to trends in healthy life expectancy. We discuss this data in detail in section 2.3 and section 3.

The model that we describe in this paper relates to the number of people with disabilities. We do not go into any detail on the associated provision of care services and the cost of these services. Much work has been done in the area of the cost of care. See the review by Darton (1994) for a discussion of the levels of dependency of people in residential care and nursing homes. See Bone (1995) for figures showing how the utilisation of care services depends on levels of disability. The costs of providing care services have been compiled by Netten & Dennett (1997) and have been incorporated within the model described by Wittenberg et al (1998).

There are important financial implications of the split between formal and informal care. This topic is discussed by Nuttall et al (1994) who estimate that the bulk of care provision is informal, i.e. it is carried out by family, friends and neighbours of the disabled people rather than by care professionals. Green (1985) has analysed who it is that provides informal care and Glendinning (1992) discusses some of the implications for the carers. The model used by Wittenberg et al (1998) treats informal care as a function of both the level of disability of an elderly person and whether or not the elderly person lives with other people. The provision of informal care in the future will depend on such statistics as the proportion of the elderly population that is married and how far the children of elderly disabled people live from their parents' home.

Section 1 describes the data that feed into our model. We highlight the data which are particularly important to the projected number of disabled people and the main areas of uncertainty relating to the data.

We need data for three parts of the model:

- Prevalence rate data are needed as a starting point for the model. The data must show what proportion of people at each age have disabilities now.
- Transition rate data are needed so that we can follow the current population forward. Transitions include, for example, a healthy person becoming disabled and a moderately disabled person becoming severely disabled. There is not much published data that can help us to set the transition rates used in the model.
- Trends data are needed to indicate how transition rates change over time. For example, are people becoming more or less likely to become disabled at a particular age? There is some information which can be used indirectly to answer this sort of question.

Section 3 contains a description of the model and section 4 discusses the way in which trends in healthy life expectancy can be used to determine the trends in transition rates which should be incorporated in the model.

In section 5 we discuss the results from the projection model for three sets of assumptions. We refer to the many uncertainties that surround the projection model in section 6. For a fuller discussion, the reader is referred to Walsh & Rickayzen (2000b).

2. Data Sources

2.1 *Prevalence rate data*

The starting point for a model that projects the number of people requiring long-term care in the future is a set of data that shows how many people require long-term care now. There is no completely satisfactory set of data for the UK but there have been a number of disability surveys which are useful.

The data from the surveys are generally presented in terms of the proportion of males and females in a range of age bands who are unable to perform one or more specified activities. The surveys differ from each other in many aspects: the number of people surveyed; the date of survey; the activities which are used to categorise disability; the survey method, such as the use of interviews or questionnaires; and whether the target population includes people in households or institutions or both.

It is essential to recognise that the estimates of the number of people with disabilities in the future that are produced by any projection model will be directly related to the current level of disability rates. This means that the usefulness and accuracy of any projected numbers will inevitably be limited by any problems relating to the initial data. We describe in some detail the data which we use and discuss the limitations associated with them.

Although there have been several disability surveys, we have used one to provide the initial data for the number of people with disabilities. This survey is the OPCS survey of disability in Great Britain (Martin et al, 1988). The reasons for relying on this particular survey are:

- The coverage included both private households and communal establishments;
- The survey was based on interviews rather than responses to a questionnaire;
- The sample was large;
- A wide range of disabilities was covered;
- The survey covers all adults whereas some surveys cover only people over 65 and therefore miss a significant number of disabled people;
- The survey report presents the data in a useful form involving several disability categories and age groups.

This survey was conducted as follows. For private households, a sample of 100,000 addresses was chosen for screening. A short questionnaire was either posted to these addresses or taken along by an interviewer. Questionnaires which indicated that there was a disabled person at the address led to a full interview. 14,308 adults were interviewed. The screening and interviewing took place in 1985.

For the survey of disabled people in communal establishments, 1,408 institutions were contacted. This resulted in a sample of 570 institutions in which interviewing took place. 3,775 adults were interviewed. The screening and interviewing took place in 1986.

The report on the survey allocates disabled people into one of ten categories with category 1 being the least severe and category 10 being the most severe. The categorisation process was developed to handle the data collected from the survey interviews. There have been a few subsequent surveys which have used the same disability scale. However, most surveys do not use the same procedures and definitions and the results from these cannot be compared directly with this large disability survey.

The following pair of tables show the estimated number of disabled adults in Great Britain. These tables are taken from Appendix 5 of Dullaway & Elliott (1998). The numbers are based on the OPCS survey but the original report did not show males and females separately.

Table 1a. OPCS Estimates of the number of disabled females (thousands)

		OPCS Disability Category									
Age	Able	1	2	3	4	5	6	7	8	9	10
20–29	4,102	21	13	14	21	18	18	11	10	8	6
30–39	3,660	36	15	23	27	24	18	15	12	7	4
40–49	2,958	50	28	27	34	30	25	20	15	9	3
50–59	2,604	87	54	57	55	55	36	28	22	19	5
60–69	2,266	138	111	94	86	90	55	49	34	37	11
70–79	1,427	161	151	132	116	122	112	86	66	57	34
80+	364	86	72	80	79	106	96	111	84	100	79

Source: Dullaway & Elliott (1998)

Table 1b. OPCS Estimates of the number of disabled males (thousands)

		OPCS Disability Category									
Age	Able	1	2	3	4	5	6	7	8	9	10
20–29	4,235	24	15	14	16	13	13	9	8	5	7
30–39	3,717	42	16	22	20	18	13	11	10	4	5
40–49	3,015	57	30	25	25	21	18	15	11	6	4
50–59	2,577	100	58	53	41	40	25	21	18	12	6
60–69	1,956	173	116	81	69	58	32	32	30	27	11
70–79	1,020	152	117	86	71	60	46	38	38	29	13
80+	137	55	39	37	38	41	29	34	33	38	18

Source: Dullaway & Elliott (1998)

Another way of presenting the same information is as prevalence rates per 1,000 of population at each age (i.e. the proportion of males or females of a particular age who have each level of disability, scaled so that the proportions at each age add up to 1,000). The following pair of tables presents the information in this form.

Table 2a. OPCS Disability prevalence rates for females (per 1,000)

Age	Able	OPCS Disability Category									
		1	2	3	4	5	6	7	8	9	10
20–29	967.0	5.0	3.1	3.3	5.0	4.2	4.2	2.6	2.4	1.9	1.4
30–39	952.9	9.4	3.9	6.0	7.0	6.2	4.7	3.9	3.1	1.8	1.0
40–49	924.7	15.6	8.8	8.4	10.6	9.4	7.8	6.3	4.7	2.8	0.9
50–59	861.7	28.8	17.9	18.9	18.2	18.2	11.9	9.3	7.3	6.3	1.7
60–69	762.7	46.4	37.4	31.6	28.9	30.3	18.5	16.5	11.4	12.5	3.7
70–79	579.1	65.3	61.3	53.6	47.1	49.5	45.5	34.9	26.8	23.1	13.8
80+	289.6	68.4	57.3	63.6	62.8	84.3	76.4	88.3	66.8	79.6	62.8

Table 2b. OPCS Disability prevalence rates for males (per 1,000)

Age	Able	OPCS Disability Category									
		1	2	3	4	5	6	7	8	9	10
20–29	971.6	5.5	3.4	3.2	3.7	3.0	3.0	2.1	1.8	1.1	1.6
30–39	958.5	10.8	4.1	5.7	5.2	4.6	3.4	2.8	2.6	1.0	1.3
40–49	934.3	17.7	9.3	7.7	7.7	6.5	5.6	4.6	3.4	1.9	1.2
50–59	873.3	33.9	19.7	18.0	13.9	13.6	8.5	7.1	6.1	4.1	2.0
60–69	756.7	66.9	44.9	31.3	26.7	22.4	12.4	12.4	11.6	10.4	4.3
70–79	610.8	91.0	70.1	51.5	42.5	35.9	27.5	22.8	22.8	17.4	7.8
80+	274.5	110.2	78.2	74.1	76.2	82.2	58.1	68.1	66.1	76.2	36.1

Since any projections of the number of people needing long-term care in the future are heavily dependent on the initial data, it is worth considering the key aspects of the OPCS survey data which might cause problems.

All people aged over 80 are put into a single age category. This may be quite a serious problem. Table 1 shows how rapidly numbers and prevalence rates change with age and it is very likely that rates which apply to people in their early eighties do not apply to people over 90. The number of people who survive to ages well in excess of 80 is expected to grow rapidly over the next few decades, hence it is very important to have some knowledge of the prevalence of disability amongst the most elderly people. The costs of caring for disabled people at these ages may be very high.

The extent of this problem depends on what the prevalence rates are used for. If the only use of the rates were as a starting point for projections, there would be no problem. In projections to, say, 2020 the people who will be aged 90 or more would have been in their 50s and 60s when the OPCS survey was carried out and it is irrelevant that there is some uncertainty about disability amongst the elderly in the mid 1980s. However, in our projections, transition rates are used and we need, for example, some estimate of the probability that a non-disabled 85 year old female will become disabled in the next year. We will choose this probability, along with a great many others, to be compatible with the prevalence rate data. This means that the prevalence rates of disability in the OPCS survey do feed through into the projected prevalence rates in the future.

The information collected in the survey is sufficient to allow prevalence rates to be calculated for narrower age bands. As far as we know, this information has not been published. There is one graph in Martin et al (1988, Figure 3.3) which does show some information broken down into five year age bands.

Other limitations of the OPCS disability survey prevalence rates include:

- The OPCS disability definitions are not directly linked to cost.
- The process of assigning a disability category is complex and hence errors or peculiarities may have crept in.
- Despite the large sample size, if the data are split into the two sexes, seven age groups and eleven disability categories (including "able") there will be some degree of random errors.
- The survey was carried out in 1985 and 1986 and is therefore out of date. We deal with this point in our models by starting all projections in 1986 rather than starting from the present.

Although the disability definitions are not directly linked to care costs, there is some information which shows how much additional expenditure is incurred by disabled people in private households and where the same definitions of disability are used as in the OPCS survey (Matthews & Truscott, 1990). Also, the report on the survey (Martin et al, 1988) does show the proportion of people in each disability category and at each age who were in institutions at the time of the survey. For the people in the more severe categories, it is reasonable to assume most of the institutions were providing care. This, therefore, gives a useful indicator of how care utilisation relates (or, more accurately, related at the survey date) to disability.

There have been other large surveys which cover disability. We have not used the data from these surveys. We comment on these surveys and, where possible, compare their findings with those of the OPCS disability survey in Walsh and Rickayzen (2000a).

The General Household Survey (GHS) is carried out annually (see, for example, Thomas et al, 1998). The survey has a large sample size (22,001 in 1996, for example). It includes two questions about disability:

1. *Do you have any long-standing illness, disability or infirmity? By long-standing I mean anything that has troubled you over a period of time or that is likely to affect you over a period of time.*
2. *Does this illness or disability limit your activities in any way?*

The answers to the second of these questions should provide useful information about the level of disability in the population. It is also potentially useful that the survey is carried out every year. We return to this point in section 2.3, when discussing trends.

The survey is confined to households so that there are bound to be differences compared with the OPCS survey which included people in communal establishments. However, there are also very clear differences between the number of people disabled according to the second GHS question given above and the number of people in private households who have any disability according to the OPCS survey. Martin et al (1988) show these differences in their figure 3.4 and table 3.5. Both of these compare the prevalence rates per thousand of population at various ages for GHS survey of 1985 and the OPCS disability survey. The GHS shows substantially more disabled people below the age of 75 and substantially fewer over the age of 75.

The differences below age 75 are explained by Martin et al (1988) as being due to the GHS question allowing any disability to count while the interview based OPCS survey questions related to specific tasks or functions. The suggested reason for the difference amongst people over 75 is that these people may not see themselves as disabled. Any limitations which they have may be thought of as due to old age rather than disability.

As well as the questions contained each year in the General Household Survey, there are supplementary questions which are repeated every few years. One of the areas in which there are a large number of supplementary questions is the health of people over 65. As a result there is much more information available on the abilities of the elderly in the surveys of 1980, 1985, 1991, 1994 and 1996. The availability of this information is very important in showing changes over time. These GHS surveys provide the key data discussed in section 2.3 concerning trends.

People are asked about a variety of tasks such as climbing stairs, dressing, shopping and using a vacuum cleaner. The data are summarised in the form of the proportion of men and women in each of five age groups who have difficulty with each task. The proportions are given separately for each task.

An established way of categorising disabilities is to measure the ability of people to perform certain tasks known as activities of daily living (ADLs). There are a few different definitions in use, but six usual ADLs are bathing, dressing, going to the toilet, transferring (to and from a bed or chair), continence and feeding.

Some research work has been done which enables some comparison between the OPCS disability categories and the ADL based categories which are measured by the GHS. Bone (1995, chapter 3) has defined a disability scale based on ADLs and has reported on the disability prevalence rates shown by the people responding to the GHS surveys.

The GHS surveys have regularly covered only four of the six usual ADLs: feeding, transferring to or from bed, going to the toilet and bathing. The surveys also cover some instrumental activities of daily living (IADLs), specifically shopping, cooking, house cleaning, laundry and travel. The disability scale reflects failure in IADLs and ADLs as shown in Table 3.

Table 3. The dependency scale used by Bone (1995) for analysing GHS data

Dependency	Level	Definition
Independent	1	Manages all ADLs and IADLs without help
Least dependent	2	Cannot manage one or more IADL alone but can manage ADLs
	3	Cannot manage one ADL alone and cannot manage one or more IADL
	4	Cannot manage two ADLs alone and cannot manage one or more IADL
	5	Cannot manage three ADLs alone and cannot manage one or more IADL
Most dependent	6	Cannot manage four ADLs alone and cannot manage one or more IADL

Source: Bone (1995)

With these definitions the following levels of dependency were found in the 1985 GHS survey (i.e. the one closest to the date of the OPCS disability survey). These figures refer only to people in households and they are combined values for males and females.

Table 4. Disability prevalence rates (%) according to the 1985 GHS survey

Age	Category				
	2–6	3–6	4–6	5–6	6
65–69	13	3	1	1	0
70–74	18	4	1	0	0
75–79	30	9	3	1	0
80–84	49	15	2	0	0
85+	77	31	9	5	1

Source: 1985 GHS Survey

The prevalence of disability amongst people in private households according to the OPCS survey, using the OPCS disability categories, is given in Table 5.

Table 5. Disability prevalence rates (%) according to the OPCS disability survey (In private households only)

Age	Category									
	1–10	2–10	3–10	4–10	5–10	6–10	7–10	8–10	9–10	10
60–69	23.6	18.0	13.9	10.8	8.0	5.3	3.8	2.4	1.3	0.3
70–79	39.5	31.8	25.3	20.0	15.5	11.1	7.4	4.6	2.3	0.6
80+	67.4	58.4	51.6	44.5	37.7	29.1	22.2	14.2	8.5	2.5

Source: Martin et al (1988)

A comparison of Table 4 with Table 5 suggests, very roughly, that failing an IADL (Bone's category 2) corresponds with OPCS category 3 in terms of the cumulative prevalence rates. Also, the failure of an ADL (Bone's category 3) appears to correspond, roughly, to OPCS category 7. This is, however, quite misleading. As the examples given earlier indicate, a category 7 disability on the OPCS scale is very severe and would be equivalent to the failure of more than one ADL. The reason why there are so many people in the high OPCS disability categories compared with the high GHS disability categories might be that the OPCS definition of disability covers some elements not measured by ADLs.

Another difference between the two sets of data is that the OPCS survey covered Great Britain whereas the figures analysed by Bone (1995) are for England only.

The fact that the OPCS disability scale is difficult to mesh with an ADL based scale has meant that we have relied solely on the OPCS survey results for providing prevalence rate data. However, we have had to rely on GHS surveys to provide information on trends. This is clearly not an ideal situation.

There is a lack of useful data on transition rates in the UK and because there are some transition rate data in the US it would be advantageous to be able to use it. However, an analysis of US data shows that they are very different from English data. This might be due to: different policies as to who receives care in the community and who goes into an institution to receive care, different surveying methods, different definitions of ADL failure or populations with different levels of disability. Whichever is the case, it provides a warning regarding the use of overseas data.

2.2 *Transition rate data*

In order to project forward the number of people with disabilities we use a transition rate model. This model requires assumptions for the likelihood of various transitions occurring. The sort of transitions we are interested in include:
- A healthy person becoming moderately disabled
- A healthy person becoming severely disabled
- A healthy person dying
- A moderately disabled person becoming severely disabled
- A moderately disabled person recovering from their disability and becoming healthy
- A moderately disabled person dying

In practice, we do not limit ourselves to two categories of disability, moderate and severe, but use all ten of the OPCS categories.

We require estimates of the probabilities of these transitions occurring. The probabilities are likely to depend on age and sex. Many probabilities will also depend on which particular disability category or categories is involved. The probabilities may well change over time and we will need trend data to model this (see section 2.3).

There are a great number of transitions in which we are potentially interested but unfortunately there is very little UK information that we can use to estimate the transition rates. There has been no large scale longitudinal survey which tracks a population at frequent intervals over a number of years and records information on disabilities. We have the choice of using small scale UK longitudinal data sets, larger US longitudinal data sets or not using any longitudinal data at all.

Transition rates between various levels of disability have been analysed in the US. A report by the Society of Actuaries Long-Term Care Valuation Insurance Methods Task Force (1995) considers data from the National Long-Term Care Surveys of 1982 and 1984. The surveys cover Medicare enrolees in the community and institutions. In table 5 of that report, the number of people who have transferred between each of several disability states is given. Table 6 is based on that data. Transition rates have been found and divided by two to give approximate annual transition probabilities. The numbers in italics are the probabilities of not changing category. These are calculated as 100% minus the sum of the probabilities of moving out of the category.

Table 6. US transition rates (% per year)

	Age	Initial status	Status after 2 years				
			0 ADL	1 ADL	2 ADL	3+ ADL	DEAD
Males	65–74	0 ADL	*94.23*	0.45	0.27	0.48	4.57
		1 ADL	17.60	*59.60*	5.20	3.60	14.00
		2 ADL	9.80	9.80	*56.86*	5.88	17.65
		3+ ADL	5.97	1.49	4.48	*66.42*	21.64
	75–84	0 ADL	*89.50*	1.21	0.47	0.92	7.89
		1 ADL	10.98	*54.55*	4.92	5.30	24.24
		2 ADL	5.88	3.92	*56.86*	9.80	23.53
		3+ ADL	3.17	1.59	3.17	*66.67*	25.40
	85+	0 ADL	*81.38*	2.28	1.46	1.79	13.09
		1 ADL	7.14	*59.52*	2.38	10.32	20.63
		2 ADL	0.00	6.25	*54.17*	10.42	29.17
		3+ ADL	2.63	0.00	13.16	*57.89*	26.32
Females	65–74	0 ADL	*96.62*	0.67	0.19	0.30	2.21
		1 ADL	19.06	*62.81*	4.69	4.69	8.75
		2 ADL	10.94	8.59	*57.03*	13.28	10.16
		3+ ADL	4.49	3.21	3.85	*69.87*	18.59
	75–84	0 ADL	*90.78*	2.21	0.64	0.91	5.46
		1 ADL	16.20	*61.97*	3.05	7.98	10.80
		2 ADL	8.67	5.33	*58.67*	12.00	15.33
		3+ ADL	4.79	2.66	5.85	*70.74*	15.96
	85+	0 ADL	*81.44*	4.77	1.58	2.37	9.84
		1 ADL	10.49	*62.94*	3.50	7.69	15.38
		2 ADL	5.00	6.67	*57.50*	9.17	21.67
		3+ ADL	4.12	2.94	2.94	*64.71*	25.29

Source: Society of Actuaries Long-Term Care Valuation Insurance Methods Task Force (1995)

The dependence of death on disability shows the following features:

- The mortality rate increases with the level of disability.
- At the higher ages there does not appear to be much difference in the mortality rate between people failing 2 ADLs and people failing 3 or more ADLs.
- The ratio of mortality rates for those failing 3 or more ADLs to those failing no ADLs falls with age.

- The differences between the mortality rates of those failing 3 or more ADLs and those failing no ADLs are 17.1%, 17.5% and 13.2% for males (starting with the lowest age group) and 16.4%, 10.5% and 15.5% for females. Very roughly, this is consistent with a constant addition of 0.15 to the mortality rate each year, independent of age and sex.
- For females the difference in mortality rate between those failing 1 ADL and those failing none appears to be independent of age: it is 6.5%, 5.3% and 5.5% for the three age groups.

The following features relating to deterioration in ability are shown in Table 6:

- Deterioration is less frequent than death.
- People who fail no ADLs are less likely to fall into the 2 ADL category than those who already fail 1 ADL. This applies to all ages and both sexes.
- People who fail no ADLs are less likely to fall into the 3+ ADL category than those who already fail 1 ADL, and they in turn are less likely to fall into the 3+ ADL category than those who already fail 2 ADLs. This applies to all ages and both sexes.
- Deterioration from no ADL failure increases with age.
- For males, deterioration from 1 ADL failure to 2 ADL failure decreases with age while the deterioration from 1 ADL failure to 3+ ADL failure increases with age.

The following features relating to improvements in ability are shown in Table 6:

- Improvements from 1 ADL are more frequent than deaths for males aged 65 to 74 and females aged 65 to 84.
- Improvements rates to 0 ADLs are higher for people who had failed 1 ADL than people who had failed 2 ADLs and, generally, are higher for those failing 2 ADLs than for those failing 3+ ADLs.
- Most improvement probabilities decrease with age but there are some exceptions to this.
- Some improvements are very great, i.e. those from failing 3+ ADLs to failing none.

The existence of a significant number of improvements is consistent with UK population data.

As well as using the information on transitions which we have described in this section, it is possible to use prevalence rate data to determine transition rates. Under a given set of assumptions it is possible to derive transition rates from prevalence rate data. This is, in fact, the approach we have adopted. The approach is described in detail in section 3. Some of the "shape" of the transition rate model is determined by the data in this section. An example of this is the requirement that the probability of a moderately disabled person becoming severely disabled should be higher than the probability of a non-disabled person becoming severely disabled in the next year. This "rule" is inferred from the US data, but in our model we include a parameter which describes just how great the difference is. The value for this parameter is determined by looking at UK prevalence rate data.

2.3 *Trends data*

We can use prevalence rate data as a starting point for our projections of the number of people requiring long-term care and we can use the transition rate model to move this population forward. However, there are likely to be changes in the transition rates over time.

We have looked for evidence of what changes have happened in the recent past to determine what trends should be included in our model.

The trends assumptions we adopt are important because the number of people who are projected to require long term care according to our model is very sensitive to them.

The main type of trend information concerns healthy life expectancy (HLE). Just as life expectancy gives a measure of the time someone may expect to live, healthy life expectancy gives a measure of the time someone expects to live and to be healthy. Like life expectancy, it can be determined by a snapshot of the population rather than actually involving any forecasting. We will be considering this type of HLE. We will also consider disabled life expectancy (DLE) which is a measure of the time someone expects to live whilst in a state of disability.

HLE depends on age and sex. It also depends on the definition of "healthy". If the definition is very narrow, so that many conditions count as unhealthy, HLE will be relatively short. On the other hand, if a wide definition is used, many people will be classed as healthy and HLE will be relatively long, and will tend towards the total life expectancy if very few people are counted as unhealthy.

The data which we discuss relate only to people aged 65 and over. We concentrate on these ages because they are the most important in terms of the number of people needing care.

It is important to note that, because of the way HLE is calculated, the time spent unhealthy depends both on how many people ever become unhealthy and on how long they live once they are unhealthy. This matters most for definitions in which anyone counted as unhealthy is in a severe state. It is quite plausible that improvements in medicine and care act both to prevent people ever reaching this severe state and also to prolong the life of anyone who does reach the state. These two effects work in opposite directions in terms of DLE — the former decreases it and the latter increases it.

Before we discuss the data on trends in HLE we will describe how we can use information on HLE trends. HLE is not an input for our projection model but it may be derived from the populations produced by the model. For a given set of input assumptions, including trends in, say, the probability that someone becomes severely disabled, we can examine how HLE changes over time. By adjusting the input trends, we can find a set which is compatible with the externally available HLE trend data.

The HLE data we use are taken from the booklet *Health Expectancy and Its Uses* (Bone et al, 1995) and the discussion paper *Healthy Life Expectancy in England and Wales: Recent Evidence* (Bebbington & Darton, 1996). The main set of data considered in both of these publications is derived from the General Household Survey. Both publications only consider data for England and Wales. (Some of the data are for 1976 and these are from the Elderly at Home Survey which only covered England.) The two publications are not independent, being based on the same raw data; however, the more recent publication also considers data from a more up-to-date survey.

We will principally be looking at two definitions of "healthy", but will also make some comments on other definitions. We use the phrases "free from any disability" and "disability free" to refer to people who do not have any limiting long-standing illness. We use the phrases “free from severe disability” and “severe-disability free” to refer to people who are unable to perform ADLs.

Although the HLE estimates are derived from GHS data, Bone et al (1995) and Bebbington & Darton (1996) have adjusted the data to allow for the fact that part of the population is not resident in households.

The analysis contained within both papers suggests that for both males and females the disability free life expectancy has been increasing and the ratio of disability free life expectancy to total life expectancy has been roughly constant.

As indicated, there is some uncertainty surrounding the interpretation of the trends in healthy life expectancy based on a catch-all definition of disability. The situation is, however, far more confusing as regards severely disabled life expectancy. Bone et al (1995) examine HLE from the Elderly at Home Survey of 1976 and the GHS surveys of 1980, 1985 and 1991. Three definitions of severe disability are considered.

The trends apparent for the three definitions differ in the following ways:

- The time spent severely disabled appears to have been falling if failure of an ADL is used to identify severe disability.
- The time spent severely disabled appears to have been rising if inability to manage stairs and steps is used to identify severe disability.
- The time spent severely disabled shows an erratic pattern if inability to get out doors is used to identify severe disability.

In summary, the trends in HLE shown by data from the General Household Survey are:

- Life expectancy free from any disability has been slowly increasing.
- The proportion of life spent free from any disability has been roughly constant.
- Severe-disability free life expectancy has been increasing according to an ADL based definition of severe disability.
- The proportion of life spent free from severe disability has been increasing.
- The severely-disabled life expectancy may have been falling, but this is far from clear.

It is important to recognise that all this trend information relates to disabilities recorded in the General Household Surveys. We mentioned in section 2.1 that there are difficulties in aligning the GHS disability categories with those used in the OPCS disability surveys. In discussing Table 5, we suggested that there are several types of disability captured by the OPCS definitions which are not measured by the GHS questions. It is quite possible that some of these disabilities, such as those related to behaviour and intellectual functioning, do not follow the same trends as the physical disabilities measured in the GHS. If this were the case, the HLE trend data would not be so useful.

3. A TRANSITION RATE MODEL

3.1 *Outline*

In section 2, we explained that we used the OPCS survey of disability in Great Britain (Martin et al, 1998) to provide the initial data for the number of people with disabilities. We did this by combining the prevalence rate data from the OPCS survey with the number of males and females at each age to give us the number of people at each of the ten disability levels, and the number healthy, in 1986. We need a transition rate model to project this population forward. Each year some people will show improvements in their abilities, some will show no change, some will deteriorate and some will die.

There are many possible transitions, all of which may depend on age and year. We have separate models for males and females. One thing we do not allow for in our model is duration: the probability that a transition takes place is taken to apply to all people in a particular sex/age/year/disability category; we do not take into account how or when someone arrived in that category.

All of the probabilities we use are annual. So, for example, a process that involves deteriorating from healthy to a category 3 disability and then deteriorating further to category 4 during the same year will be regarded as a single healthy-to-category 4 transition.

Thus, the model is a discrete time multiple state model. For a full description of such models and discussion of applications to disability insurance, see Haberman and Pitacco (1999).

3.2 *Mortality*

3.2.1 *Overall mortality*

We use the Government Actuary's Department (GAD) central population projection for the period 1996 to 2036 (Government Actuary 1998). This gives the projected total number of deaths each year at each age. Our model matches these numbers exactly. Note that the GAD projections include migration as a transition and we also include migration so that the numbers match.

In theory, it might be reasonable not to reproduce the GAD projected population. Future death rates will be closely related to the prevalence of disability in the future. Since we are producing a new model for the prevalence of disability it would be possible to use it to derive the number of deaths in each future year under certain assumptions about the link between mortality and disability. However, we decided that it would be undesirable to produce a population projection which differed from the GAD central projection. Thus, we use the GAD central projection as a constraint on the output of our model.

Since the prevalence rate data apply to 1985 and 1986 there is a ten year gap to fill before the start of the period covered by the current GAD projection model. (We actually assume that the prevalence rate data all apply to 1986.) During these years we use mortality rates which are interpolated between those of English Life Tables No.14 (ELT14) (OPCS, 1987) which are taken to apply in 1980 and the GAD 1996 rates. These rates are used to determine the total population each year (working back from 1996) and also the total number of deaths each year during the ten year period.

3.2.2 *The dependence of mortality on disability*

The mortality rate is higher for people in the severe disability categories and we split the total mortality into two components in order to model this. One of the components applies equally to all healthy and disabled people of a given age and sex in particular year. The other component is higher for people with severe disabilities.

This second component was set by reference to the US data described in section 2.2. Note that the US data only relate to people over 65. The US data were useful in suggesting an overall "shape" for the dependence of mortality on disability and how this relates to age. We have not attempted to include any of the detail from the US data in our model. The features that we incorporate in our model regarding the disability-related component of mortality are:

- There is only weak age dependence (above age 65) in the disability-related addition to healthy mortality.
- The extra mortality is low at younger ages. This is needed because applying the 65+ rates to the disabled population aged around 35 produces too many deaths. In fact the number of disabled people dying would be more than the total number of deaths according to the GAD model.
- There is no extra mortality compared with healthy people for those with disabilities in category 5 and lower. The description of these disabilities suggests they are not life threatening conditions.
- The extra mortality increases linearly starting with category 6. The US data do not fully support this, but we feel that we do not have enough information to justify a more complex category dependence.
- The maximum extra annual mortality is 0.20.
- The model is the same for males and females.

Once the extra mortality has been chosen, the other mortality component is determined by the requirement that the total number of deaths should match the GAD projection numbers.

The formula we use to express the extra mortality for someone aged x in disability category n (where $n = 0$ means healthy) is:

$$ExtraMort(x, n) = \frac{0.20}{1 + 1.1^{50-x}} \cdot \frac{\mathrm{Max}(n-5, 0)}{5}$$

The form of "reciprocal of one plus an exponential" is the same as we use for modelling deterioration (see section 3.3). The choice of the pivotal age 50 and the steepness factor 1.1 effect the extra mortality at younger ages. The following table shows illustrative values for this function at a range of ages and disability levels.

Table 7. Annual addition to mortality due to disability

Age	Category 6	Category 8	Category 10
20	0.00	0.01	0.01
30	0.01	0.02	0.03
40	0.01	0.03	0.06
50	0.02	0.06	0.10
60	0.03	0.09	0.14
70	0.03	0.10	0.17
80	0.04	0.11	0.19
90	0.04	0.12	0.20
100	0.04	0.12	0.20
110	0.04	0.12	0.20

The extra mortality might change with time. We discuss trends in section 4.

3.3 *Deterioration*

3.3.1 *Outline*

Healthy people can become disabled and the condition of disabled people can become worse. Both of these come under the heading of deterioration. In our model, deterioration is allowed from any state to any more severely disabled state. This results in a huge number of transitions. Owing to the complexity, the model for deterioration is split into three parts, which are dealt with in the next three sections. One part relates to the probability of a healthy person becoming disabled, another relates to the distribution of the severity of new disabilities amongst previously healthy lives and the final part relates to deterioration amongst people who are already disabled.

There are parameters for each part of the deterioration model. The parameter values are chosen so that the transition rate model is able to reproduce the prevalence rate data closely.

In making the comparison between the observed prevalence rates and those produced by the model, we start with twenty-year olds with disabilities matching the OPCS rates. This population is projected forward to produce the model prevalence rates at higher ages. The transition model includes mortality and improvements in health as well as deterioration but these other components are fixed separately — they are not chosen for their ability to reproduce the prevalence rate data.

Note that this approach assumes that there is a stationary population, i.e. transition rates have been constant in the past. This is clearly not correct. We refer to this problem in section 6. For convenience, we use a single mortality table during this comparison process (rather than using time dependent rates). The mortality table we use is ELT14.

Table 8 presents the ability of the model to reproduce the crude prevalence data. It shows the difference between the disability prevalence rates according to the OPCS survey (i.e. those shown in Table 2) and those produced by the transition rate model.

Table 8a. Difference in prevalence rate for females, *data – model* (per thousand)

Age	Able	OPCS Disability Category									
		1	2	3	4	5	6	7	8	9	10
20–29	–2	0	0	0	1	0	1	0	0	0	0
30–39	4	0	–3	–1	1	0	0	0	0	0	0
40–49	5	0	–3	–3	1	–1	0	0	1	0	0
50–59	–5	2	–2	0	2	2	0	0	2	2	–1
60–69	0	0	3	–1	0	0	–3	–2	1	3	–2
70–79	4	–4	7	0	–2	–6	3	–4	3	0	–1
80+	–1	0	0	1	0	0	0	0	0	0	0

Table 8b. Difference in prevalence rate for males, *data – model* (per thousand)

Age	Able	OPCS Disability Category									
		1	2	3	4	5	6	7	8	9	10
20–29	–3	0	1	1	1	0	1	0	0	0	0
30–39	2	0	–2	0	0	0	0	0	0	–1	0
40–49	3	–1	–1	–1	0	0	1	0	0	–1	0
50–59	–5	0	0	2	0	1	1	0	1	0	0
60–69	–10	3	8	1	0	–1	–2	–1	1	1	1
70–79	15	–8	9	0	–5	–8	1	–4	2	–2	0
80+	0	0	0	0	0	0	0	0	0	0	0

Note that the structure of the data that we are trying to model (i.e. those shown in Table 2) is very complex. The prevalence rates do not vary smoothly across categories and the dependence of the prevalence rates on age is quite different for the low disability and high disability categories.

Both parts of Table 8 are encouraging as the differences between the data and the model are not large. There are some systematic errors but there appear to be no major problems at the highest categories, which are the more important categories as far as care costs are concerned.

The reason why the values in the table are small is that the model of deterioration is complicated. There may be a case for simplifying the model and accepting a poorer fit to the data.

3.3.2 *The probability of becoming disabled*

We use formulae to express the probability of becoming disabled. The probability of becoming disabled is primarily constrained by the observed proportion of people who have no disability. There are only seven age bands for the published disability survey data but we find that a complex model is needed to provide a good fit to the data. The formula we use has four parameters for females and there is an additional one for males. For females, the formula we use is:

$$NewDisab(x) = A + \frac{D - A}{1 + B^{C-x}}$$

where the four parameters are *A*, *B*, *C* and *D* and *NewDisab(x)* is the probability that a female aged x becomes disabled in a year. We note that this formula is logistic in form and was first proposed by Perks for the graduation of mortality rates (See Benjamin & Pollard, 1993).

For males, the formula we use is:

$$NewDisab(x) = \left(A + \frac{D - A}{1 + B^{C-x}} \right) \times \left(1 - \frac{1}{3} \cdot \exp\left[-\left(\frac{x - E}{4} \right)^2 \right] \right),$$

where the additional parameter is *E*.

The parameter *A* is the limit of the probability of becoming disabled at young ages. *D* is the limit of the probability of becoming disabled that would apply at extremely high ages. The pair of parameters *B* and *C* determine how rapidly the probabilities change between the two extreme values. The extra parameter, *E*, gives the age at which there is a "kink" in the *NewDisab(x)* function.

Figure 1 shows the logarithm (base 10) of the annual probability of becoming disabled, for males and females. The parameter values used in the figure are the same as were used to produce Table 8.

Figure 1: (log) Annual Probability of becoming Disabled

The shapes of the curves in the figure are quite complex. The continual oscillations, which show females having the higher probability of becoming disabled at young ages, followed by males in their fifties, followed by further changes, may be traced directly to the data. To get sufficient flexibility in the shapes, an extra parameter was added for fitting the males' data (which is not needed for the females' data).

The parameter values that we use are given in Table 9.

Table 9. Parameter values for $NewDisab\,(x)$

Parameter	Males	Females
A	0.0017	0.0017
B	1.1063	1.0934
C	93.5111	103.6000
D	0.6591	0.9567
E	70.3002	(Not used)

The behaviour of the $NewDisab(x)$ formula above the age of 85 or so is not well constrained. Since the highest age group in the data we use to constrain the model includes all people over 80 and these have an average age of around 85, the probability of becoming disabled could be very different at the highest ages without noticeably changing the prevalence rates in the crude data.

We define the probability of becoming disabled in such a way that it only applies to people who survive the year. This was done for numerical convenience: because mortality and disability rates become high at old ages some technique is needed to avoid total transition probabilities exceeding 1. The device of defining transitions in sequence, i.e. with mortality first, followed by deterioration (which is followed by improvement), achieves this.

3.3.3 *The severity of new disabilities*

Someone becoming disabled from healthy may enter any of the ten disability categories. The relative probability of joining each category may change with age, with the likelihood that the disability is severe increasing for older people. The transition rate model has three parameters covering this age dependence.

An examination of the prevalence rates at ages over 80 shows that the progression is erratic. The rate is higher in category 1 than in category 2, category 2 has a lower rate than category 3 and so on. In fact the rate in every category is either higher than in both the neighbouring categories or lower than in both. A simple model cannot replicate such a pattern. We decided to adopt a model which could reproduce the observed pattern closely. This involves having a separate parameter to represent the “width” of each category. This approach is not unreasonable given the complex definitions used for each category. Because of the complexity of the definitions, some categories may include more people than others — this is the aspect of the disability prevalence rates that the width parameters are intended to mimic.

The formula for the probability that a person who becomes disabled at age x will have a disability in severity category n is given by:

$$Severity(x, n) = W(n) \cdot f(x)^{n-1} / Scale(x)$$

$$f(x) = A + \frac{1-A}{1+B^{C-x}}$$

$$Scale(x) = \sum_{n=1}^{10} W(n) \cdot f(x)^{n-1}$$

The category widths are given by $W(n)$. The *Scale* term ensures that the probabilities add up to 1 and its inclusion means that we can arbitarily set W(1)=1. The three parameters relating to the age dependence are *A*, *B* and *C* (they are distinct from the parameters used in the formulae for $NewDisab(x)$).

Figure 2 illustrates the age dependence of the relative severity of new disabilities. The figure shows the probability that someone newly disabled will be in category 6 or worse at the end of the year. The shapes of the curves are similar for other categories.

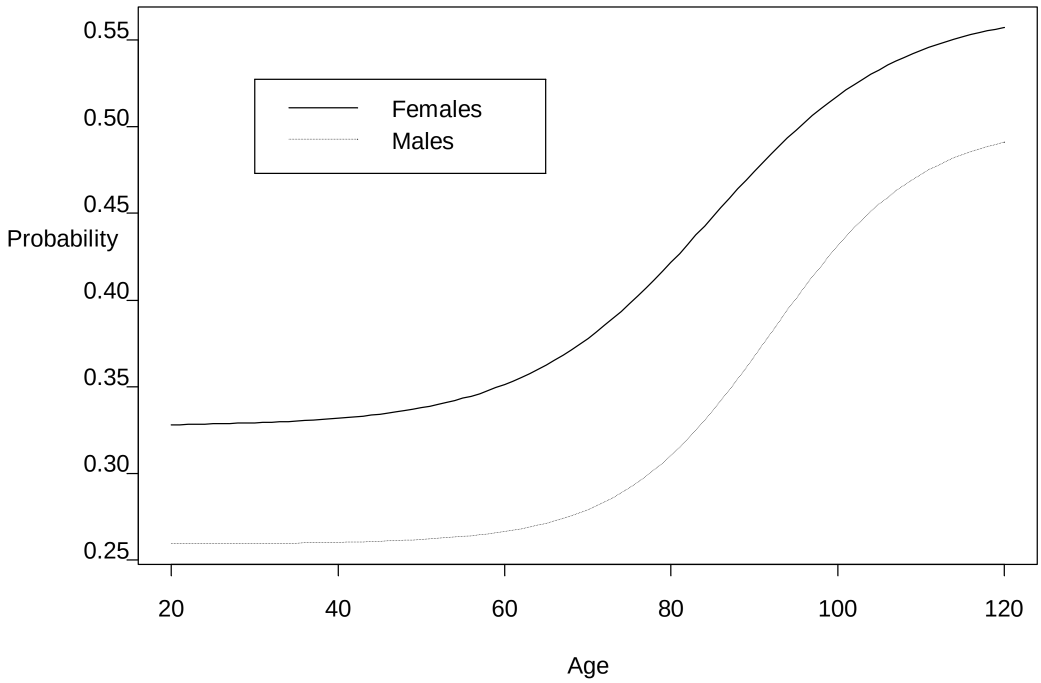

Figure 2: Probability of a new disability being category 6 or worse

Figure 2 shows that there is a difference between the probabilities for females and males. This was derived from fitting the prevalence rate data. However, it would be plausible to find slightly poorer fits in which there was little difference between the probabilities for males and females (by, for example, changing the likelihood of disabled people deteriorating).

The parameters we use are given in Table 10. Note that $W(1) = 1$ is fixed for both males and females.

Table 10. Parameter values for *Severity*

Parameter	Males	Females
A	0.8246	0.8180
B	1.1146	1.0911
C	91.7127	85.5099
$W(2)$	0.5250	0.6823
$W(3)$	0.4632	0.8166
$W(4)$	0.4622	0.6656
$W(5)$	0.6066	1.1749
$W(6)$	0.4205	1.0426
$W(7)$	0.6299	1.4203
$W(8)$	0.6370	0.9399
$W(9)$	0.9004	1.2222
$W(10)$	0.4874	1.0674

3.3.4 *Deterioration from disabled states*

People in any disability category can get worse and their new disability level could be any of the more severe categories. These transitions are included by relating them to the probability of deteriorating from healthy (i.e. becoming disabled). We use the following rule: the probability of someone in disability category *m* deteriorating to category *n* is F^m times the probability that a healthy person deteriorates to category *n*. This may be expressed by the following pair of equations:

$$Deteriorate(x,m,n) = Deteriorate(x,0,n) \times F^m$$
$$Deteriorate(x,0,n) = NewDisab(x) \times Severity(x,n).$$

The parameter F is required to be greater than 1 in order to reflect the fact that disabled people are more likely to become severely disabled than healthy people. For males we use F = 1.1561 and for females we use F = 1.1830.

3.3.5 *The fitting procedure*

We have said in section 3.3.1 that the parameters are set so that the transition rate model can generate a set of prevalence rates that closely matches the OPCS disability survey prevalence rates. In this section we specify how we define “close matching” and how we obtain a satisfactory fit.

We are trying to model prevalence rates for seven age bands and ten disability categories. This gives 70 “cells”. We simply try to minimise the sum of the absolute values of the differences between the prevalence rates in the data and the prevalence rates produced by our model. In other words, we take the numbers in a table like 8a or 8b, remove the minus signs and add them up. (The prevalence rate in the “able” category is automatically 1,000 minus the sum of the other ten prevalence rates at each age, and we do not include it in our error statistic.) Other statistics could have been chosen. For example, extra weighting could have been given to the high ages or high disability categories, or some weights relating to the uncertainties in the cells could have been used.

Our deterioration model has 17 parameters for fitting the females' data and 18 for fitting the males' data. It is difficult to obtain an optimal fit to the data when there are so many parameters to be considered. This is especially true when there are so many local minima encountered in the fitting process. However, we believe that, overall, we have obtained a good fit to the data.

We make further reference to the fitting process and the uncertainties involved in section 6.

3.4 *Improvements*

As noted in section 2.2, there is evidence that a significant number of disabled people improve to some extent. The US data show some dramatic improvements. It is not clear whether these represent recoveries from long-term disabilities or from temporary disabilities caused by, say, breaking a bone.

We decided not to include a full range of improvements in our transition rate model and, instead, we have adopted a simple assumption: all people, at all ages and in all disability categories have a 10% chance of improving by one category over the course of a year. This 10% probability only applies to those who survive the year and do not deteriorate during the year. The figure of 10% is broadly consistent with the UK data (Goddard, 1998). The approach is not consistent with what is shown by the US data unless those data include some short-term disabilities.

4. ASSUMED TRENDS

In section 2.3 we discussed data relating to trends in healthy life expectancy (HLE). We want our projection model to be able to reproduce trends similar to those indicated by the data. In the projection model, trends are included by changing transition rates over time. The procedure we adopt to identify which transition rate changes correspond to the observed HLE trends is:

- Calculate the healthy life expectancies in 1986 using the definitions of "healthy" which are related to the disability categories of the OPCS survey (Martin et al, 1988).
- Project the population forward for ten years using a range of assumptions for changes to the transition rates.
- Calculate the healthy life expectancies in 1996 for the various projections.
- Compare the changes in HLE produced by the model with those shown by the data and decide which trends to continue with for projections up to the year 2036.

The reason why we stop in 1996 is because that is the year when the GAD population projections start. The projection model becomes more complicated when it is built around the GAD population model because it must include migration. The year 1996 is therefore a natural break point for the projections.

Table 11 shows the healthy life expectancies in 1986. To calculate these, prevalence rates and a life table are needed. We have used the prevalence rates produced by the transition rate model described in section 3. (The model provides prevalence rates at individual ages unlike the published data that give the rates in ten-year age bands.) The life table is an interpolation between ELT14 and the life table corresponding to the 1996 mortality rates in the GAD population projection model. The ELT14 table is taken to apply to 1980.

Table 11. Life expectancies in 1986

		HLE(0)	HLE(0)/*e*	HLE(7)	HLE(7)/*e*	DLE(7)
Males	65	7.70	56.95%	12.58	93.09%	0.93
	70	5.17	49.19%	9.57	90.98%	0.95
	75	3.07	38.40%	6.98	87.24%	1.02
	80	1.56	25.99%	4.88	81.19%	1.13
	85	0.68	15.09%	3.26	72.20%	1.26
Females	65	9.14	52.84%	15.61	90.21%	1.69
	70	6.24	45.60%	11.99	87.65%	1.69
	75	3.89	37.16%	8.78	83.85%	1.69
	80	2.15	27.85%	6.03	78.03%	1.70
	85	1.03	18.47%	3.87	69.13%	1.73

The columns in Table 11 have the following meanings.

- HLE(0) is the life spent free from any disability, measured in years. HLE trend data suggest that this quantity should increase over time.
- HLE(0)/*e* is the ratio of the time spent free from any disability to the life expectancy *e*. This should stay roughly constant over time.
- HLE(7) is the time (in years) spent free from severe disability. Here, “severe disability” means the OPCS categories worse than category 7. HLE trend data suggest that this quantity should increase over time.
- HLE(7)/*e* is the ratio of the time spent free of severe disability to the future life expectancy. The ratio appears to have been increasing for males. It may have been either increasing or constant for females.
- DLE(7) is the severely disabled life expectancy, i.e. total life expectancy minus HLE(7). The evidence for trends relating to severely disabled life expectancy is unclear, as discussed in section 2.3. Some data indicate that it has been falling and others indicate it has been rising.

The comments made above about trends indicated by the data for severe disabilities relate to the ADL based definition of severe disability. As noted in section 2.3, different definitions of severe disability show different trends. In terms of inability to manage steps and stairs, the time spent disabled has been roughly constant for males but has lengthened for females. In terms of mobility outdoors, there appears to have been deterioration for both males and females.

The following definitions of life expectancies have been used. Let l_x be the number of lives aged x in a life table and let $l_x^{(n)}$ be the number of lives who are healthy or who have a disability of category n or less. This means that $l_x^{(0)} < l_x^{(1)} <\ldots< l_x^{(9)} < l_x^{(10)} = l_x$. Then, we define:

Complete expectation of life: $$\overset{\circ}{e}_x = \frac{1}{l_x} \cdot \left\{ \left(\sum_{y \geq x} l_y \right) - \frac{l_x}{2} \right\},$$

Complete expectation of life spent in disability categories *0-n* inclusive:

$$\text{HLE}(x,n) = \frac{1}{l_x} \cdot \left\{ \left(\sum_{y \geq x} l_y^{(n)} \right) - \frac{l_x^{(n)}}{2} \right\}$$

Complete expectation of life spent in disability categories more severe than *n*:

$$\text{DLE}(x,n) = \overset{\circ}{e}_x - \text{HLE}(x,n)$$

It should be noted that in Table 11, and the tables which follow, we have used the following abbreviated expressions: “HLE(0)”, “HLE(7)” and “e” for HLE(0,x), HLE(7,x) and $\overset{\circ}{e}$, respectively.

Changes in the total life expectancy directly affect the healthy life expectancies. The changes in total life expectancy between 1986 and 1996 depend only on the mortality rates in those two years and not on the transition models or trends. These life expectancies are given in Table 12.

Table 12. Life expectancy (years)

		1986	1996
Males	65	13.51	14.57
	70	10.51	11.37
	75	8.01	8.67
	80	6.01	6.49
	85	4.52	4.85
Females	65	17.30	17.93
	70	13.68	14.27
	75	10.47	11.03
	80	7.73	8.23
	85	5.59	6.04

The transition rate model has six components — total mortality, extra mortality due to disability, the probability of becoming disabled, the severity of new disabilities, the extra likelihood of disabled people deteriorating as compared with healthy people, and improvements in health. Changes in any of these can affect healthy life expectancies.

For overall mortality we have adopted the central projection of the GAD model produced in 1998. We have not explored the effect of varying this. The GAD projection assumes reductions in the rates of mortality and therefore an increase in life expectancy. If there are no changes to disability prevalence rates, this leads to increases in disabled life expectancy. It also leads to a decrease in the ratio of healthy life expectancy to total life expectancy because the disability prevalence rates are highest at the high ages, so the extra years being gained are *ceteris paribus* years of below average health.

If the extra mortality due to disability declines, perhaps as a result of medical breakthroughs or an improvement in care provision for disabled people, then people will live longer once they become disabled. If there are no other changes, in particular no reduction in the number of people becoming disabled and no increase in the probability of people recovering from their disabilities, then people will spend a greater proportion of their lives with a disability. This would cause the disabled life expectancy and especially the severely disabled life expectancy to rise.

If the opposite happened, i.e. improvements in mortality rates applied more to the total population than to the disabled population, the effect on disabled life expectancy would be to tend to reduce it. It seems unlikely that there could be a substantial widening of the difference between the mortality rates of disabled people and the mortality rates of healthy people. This is because there is not very much "room" for improvement in the mortality rates of healthy people, so that a significant widening would actually require the mortality rate for disabled people to get worse over time.

We have analysed the effect of changes in the level of extra mortality in two models. In one (model E) the gap between the mortality of healthy people and the mortality of severely disabled people widens and in the other (model F) it narrows. The way the trends are implemented is to replace the quantity 0.20 in the equation for *ExtraMort* (x,n) (see section 3.2.2) in year t by the expression $0.20+\Delta\cdot(t-1986)/10$. In model E, $\Delta = 0.02$ and in model F, $\Delta = -0.02$.

Neither of these trends could continue indefinitely. Where Δ is positive it will eventually lead to a worsening of the mortality of disabled people. Where Δ is negative it will eventually lead to the mortality of disabled people being less than that of healthy people.

If fewer people become disabled then this will tend to increase the healthy life expectancy and decrease the disabled life expectancy. We introduced the probability *NewDisab* in section 3.3.2 to represent the probability of becoming disabled. We can change the parameters in this function to effect changes in the probability of becoming disabled.

We use expressions such as "1 in 10" to describe the changes made to *NewDisab*. A rate of 1 in 10 means that the probabilities that apply to someone aged x in year t will also apply to someone aged $x + 1$ in year $t + 10$, to someone aged $x + 2$ in year $t + 20$ and so on (so, for example, the probability that a 71 year-old becomes disabled in 2010 is the same as the probability that a 70 year-old becomes disabled in 2000). Table 13 indicates what a rate of 1 in 10 means in terms of percentage reductions in the probability of becoming disabled. The table shows, for example, $R - 1$ (expressed as a percentage) where R is the ratio of the probability of a sixty year old becoming disabled in year t to the probability of a sixty year old becoming disabled in year $t + 1$. The probabilities in year t are determined by the parameters in Table 9.

Table 13. Annual reduction in the probability of becoming disabled implied by a "1 in 10" change in *NewDisab(x)*

Age	Males	Females
20	0.19%	0.22%
30	0.39%	0.40%
40	0.64%	0.59%
50	0.83%	0.73%
60	0.90%	0.81%
70	0.74%	0.82%
80	0.81%	0.79%
90	0.59%	0.69%
100	0.34%	0.52%

$NewDisab(x)$ is assumed to affect all of the probabilities of deterioration, including the deterioration from one disabled state to another more severely disabled state (see section 3.3.4). Hence a reduction in $NewDisab(x)$ will reduce the number of people who become severely disabled in two ways: fewer people become disabled and fewer of these deteriorate to severe categories.

Trends in the probability of becoming disabled are included in most of the models we consider. The trends are expressed as rates such as "1 in 10" in Table 14.

The severity of new disabilities is one of the components of our transition rate model. If the average severity of new disabilities reduces, this should have a greater impact on severely disabled life expectancy than on disabled life expectancies based on a lower disability threshold. As there is some indication from the healthy life expectancy trend data that there has been an increase in the proportion of life spent free from severe disability but no increase in the proportion of life spent free of all disability, this component could help the model to match the observed trends.

We include trends in the *Severity* formula in the same way as in the $NewDisab(x)$ formula. That is we introduce changes at a rate of 1 in 10, say, so that the probabilities that apply to someone aged x in year t apply also to someone aged $x + 1$ in year $t + 10$ and so on (so that the distribution of the severity of new disabilities for 71 year olds in 2010, for example, is the same as the distribution of the severity of new disabilities for 70 year olds in 2000). Trends in *Severity* are included in models G to J. The trends are given as rates, such as "1 in 10", in Table 14.

In section 3.3.4 we introduced a parameter, F, which relates the probability of deterioration for a person who is disabled to the probability that a healthy person becomes disabled. If this parameter decreases then fewer people should become severely disabled. Its effect should therefore be similar to making new disabilities less severe. Trends in this parameter are included in models K to M.

Changes to the parameter F of the deterioration-from-disabled model are incorporated in a different way to changes in *NewDisab(x)* or *Severity*. Since F ought to be at least 1, we have used the following form for changes to F:

$$F(t) = 1 + \left[F(1986) - 1\right] \times \alpha^{t-1986}.$$

The value of *F* in 1986 is 1.156 for males and 1.183 for females (see section 3.3.4). When α = 0.99 the value of *F*(1996) is 1.141 for males and 1.166 for females, and the value of F(2036) is 1.094 for males and 1.111 for females. The trends in F are given in Table 14 in terms of α. (The absence of a trend means α = 1.)

A reduction in the relative likelihood of deterioration for a disabled person might be the result of the targeting of health care resources towards people who are already disabled.

The other ingredient in the transition rate model is the probability that disabled people improve slightly. We consider one model, model P, in which the probability of a disabled person improving increases steadily from 10% per year in 1986 to 12% per year in 1996.

We have considered sixteen combinations of trends in the transition rate model. The trends which we have assumed are listed in Table 14. A dash indicates that no trends are included for the component.

Table 14. Transition rate trends in the models

Model	*ExtraMort*	*NewDisab*	*Severity*	*Deteriorate*	*Improve*	To 2036?
A	—	—	—	—	—	Yes
B	—	1 in 20	—	—	—	Yes
C	—	1 in 10	—	—	—	Yes
D	—	1 in 5	—	—	—	Yes
E	+2%	1 in 10	—	—	—	No
F	–2%	1 in 10	—	—	—	No
G	—	—	1 in 10	—	—	No
H	—	1 in 10	1 in 10	—	—	No
I	—	1 in 10	1 in 5	—	—	No
J	—	1 in 10	1 in 2	—	—	No
K	—	—	—	0.99	—	Yes
L	—	1 in 20	—	0.99	—	Yes
M	—	1 in 10	—	0.99	—	Yes
N	—	1 in 5	—	0.99	—	Yes
O	—	1 in 10	—	0.97	—	No
P	—	1 in 10	—	—	+2%	No

The meaning of the final column will be explained after the healthy life expectancies have been discussed.

Table 15 shows the healthy life expectancies in 1996 according to Models A, C and N. The form of each table is the same as Table 11 which relates to healthy life expectancies in 1986. By comparing Table 11 with Table 15, we can establish how the trend assumptions contained within models A, C and N alter the computed healthy life expectancy figures between 1986 and 1996.

The reason why these three models have been chosen for illustrative purposes is that Models A, C and N represent the most pessimistic, the central and the most optimistic assumptions, respectively, out of the sixteen models under consideration.

Table 15A. Life expectancies in 1996, Model A

		HLE(0)	HLE(0)/*e*	HLE(7)	HLE(7)/*e*	DLE(7)
Males	65	8.10	55.58%	13.48	92.50%	1.09
	70	5.44	47.87%	10.27	90.31%	1.10
	75	3.24	37.30%	7.50	86.50%	1.17
	80	1.64	25.26%	5.22	80.43%	1.27
	85	0.71	14.71%	3.47	71.52%	1.38
Females	65	9.32	51.95%	16.07	89.63%	1.86
	70	6.38	44.71%	12.41	86.97%	1.86
	75	4.00	36.31%	9.16	83.04%	1.87
	80	2.23	27.12%	6.35	77.11%	1.88
	85	1.08	17.94%	4.11	68.16%	1.92

Table 15C. Life expectancies in 1996, Model C

		HLE(0)	HLE(0)/*e*	HLE(7)	HLE(7)/*e*	DLE(7)
Males	65	8.24	56.58%	13.54	92.90%	1.04
	70	5.58	49.10%	10.33	90.85%	1.04
	75	3.37	38.88%	7.57	87.28%	1.10
	80	1.72	26.55%	5.28	81.38%	1.21
	85	0.76	15.62%	3.53	72.70%	1.32
Females	65	9.48	52.87%	16.16	90.12%	1.77
	70	6.52	45.71%	12.49	87.58%	1.77
	75	4.12	37.37%	9.24	83.83%	1.78
	80	2.32	28.16%	6.43	78.14%	1.80
	85	1.14	18.87%	4.20	69.51%	1.84

Table 15N. Life expectancies in 1996, Model N

		HLE(0)	HLE(0)/*e*	HLE(7)	HLE(7)/*e*	DLE(7)
Males	65	8.38	57.53%	13.61	93.40%	0.96
	70	5.71	50.23%	10.41	91.53%	0.96
	75	3.51	40.43%	7.66	88.30%	1.01
	80	1.81	27.85%	5.37	82.75%	1.12
	85	0.80	16.53%	3.62	74.58%	1.23
Females	65	9.63	53.73%	16.29	90.83%	1.64
	70	6.66	46.66%	12.62	88.49%	1.64
	75	4.23	38.37%	9.38	85.04%	1.65
	80	2.40	29.15%	6.57	79.78%	1.66
	85	1.19	19.74%	4.33	71.77%	1.70

Model A includes no trends in the transition rates other than in the overall mortality. This results in a reduction in the ratio of life expectancy free of any disability to total life expectancy. This contradicts the findings of Bebbington & Darton (1996). The severely disabled life expectancy increases. This appears to contradict the healthy life expectancy data, at least where disability is defined in terms of ADLs (Bone et al (1995)). A full analysis of the results for all sixteen models can be found in Rickayzen & Walsh (2000).

5. PROJECTIONS BASED ON THE TRANSITION RATE MODEL

5.1 *The projection method*

In section 4 we described nine different sets of trend assumptions which we decided to incorporate in our model. Before presenting the results arising from some of these sets of assumptions, we provide some details of the projection method used.

For the initial population (in 1986) we need to consider the number of men or women in each disability category at each individual age. Such data are not available for individual ages. To provide the individual age populations we use the prevalence rates derived from the transition rate model discussed in section 3. The population is not fully consistent with the OPCS prevalence data but, as Table 8 shows, the differences are small.

Twenty-year-olds are treated differently in the projection model from people of other ages. The disability prevalence rates for twenty-year-olds in each year must be included as assumptions. The assumption that we adopt is that these prevalence rates stay constant — we use the OPCS disability prevalence rates for people aged 16 to 19 as the rate appropriate to twenty-year-olds in all years. This assumption is of no great consequence as there are few disabled twenty-year-olds.

The Government Actuary's Department (GAD) population projection includes migration and we include it in our model too in order to reproduce the same total population as the GAD projection. Migration is included in the GAD projection in the following way:

- Half of the migrations are assumed to occur at the start of the year and half at the end.
- Those immigrating at the start of the year are "exposed" to the same mortality rates as the rest of the population during the year.

We take the same approach. The immigrants at the start of the year are also "exposed" to the possibility of deterioration or improvement in health.

We assume that the migrants at age x share the same level of disability as the rest of the population at that age. In the GAD central projection the number of migrants per year does not change beyond 1998. The number does vary with age. In total, there is assumed to be a net immigration per year of roughly 19,500 men aged 20 to 59, 1,250 men aged 60 and over and 22,500 women aged 20 to 59. There is assumed to be a net emigration of roughly 1,500 women aged 60 and over each year.

The following equations describe how the population is moved forward. The equations apply separately to males and females.

Let *Lives*(x, t, n) be the number of lives aged x in year t with a category n disability, where category 0 is taken to mean "healthy" and let *Migrants*(x, t, n) be the corresponding number of immigrants. *Lives*(x, t, n) is determined by the following equation:

$$
\begin{aligned}
Lives(x, t, n) = {} & \left[Lives(x-1, t-1, n) + Migrants(x-1, t-1, n)/2\right] \times \\
& \left[1 - Mortality(x-1, t-1, n)\right] \times \\
& \left[1 - DeteriorateFrom(x-1, t-1, n)\right] \times \\
& \left[1 - ImproveFrom(x-1, t-1, n)\right] + \\
& DeteriorateTo(x, t, n) + \\
& ImproveTo(x, t, n) + \\
& Migrants(x, t-1, n)/2
\end{aligned}
$$

The quantity $Mortality(x, t, n)$ represents the probability that a person aged x in year t who is in disability category n dies during the next year.

This quantity can be written as:

$$Mortality(x, t, n) = Mortality(x, t, 0) + ExtraMort(x, t, n).$$

The extra mortality due to disability is given by a formula (section 3.2.2) and the mortality rate that is independent of disability is set so that the number of deaths in year t at age x agrees with the GAD projection (see section 3.2.1).

The quantity *DeteriorateFrom* represents a probability. It is related to the expressions in section 3.3 in the following way:

$$DeteriorateFrom(x, t, 0) = NewDisab(x, t) \text{ and}$$

$$DeteriorateFrom(x, t, m) = \sum_{n=m+1}^{10} Deteriorate(x, t, m, n).$$

where *NewDisab* (x, t) and *Deteriorate* (x, t, m, n) are defined in the following way:

NewDisab (x, 1986) is the same as *NewDisab* (x), as defined in section 3.3.2.

NewDisab (x,t) differs from *NewDisab* (x, 1986) in models that include time dependence in the probability of becoming disabled. Similarly, *Deteriorate* (x, 1986, m, n) is the same as *Deteriorate* (x, m, n), which is defined in section 3.3.4. *Deteriorate* (x, t, m, n) differs from this in models that include time dependence in the probability of becoming disabled or in the extra likelihood of disabled people deteriorating.

The quantity *ImproveFrom* represents the probability that a person who survives a year, and does not deteriorate during the year, improves by one disability category during the year. As explained in section 3.4, in the current projection model this probability is set at 0.1 for all ages and disability classes (but not category 0) and both sexes.

The quantity *DeteriorateTo*(x, t, n) represents the number of persons aged x in year t who made a transition to disability category n from a lower disability category during the last year. The number is given by:

$$DeteriorateTo(x,t,n) = \sum_{m=0}^{n-1} \{ ExposedToDet(x-1, t-1, m) \times Deteriorate(x-1, t-1, m, n) \}$$

where

$$ExposedToDet(x, t, n) = [Lives(x, t, n) + Migrants(x, t, n) / 2] \times [1 - Mortality(x, t, n)].$$

The quantity *ImproveTo* represents the number of persons aged x in year t who made a transition from disability category $n+1$ to n during the last year. The number is given by:

$$ImproveTo(x, t, n) = ExposedToImp(x-1, t-1, n+1) \times 0.1,$$

where

$$ExposedToImp(x, t, n) = [Lives(x, t, n) + Migrants(x, t, n) / 2] \times [1 - Mortality(x, t, n)] \times [1 - DeteriorateFrom(x, t, n)].$$

(The 0.1 is the probability of improvement from one year to the next)

In Appendix 1, we present the results of the projections of the disabled population for three of the models: Model A, Model C, and Model N. As mentioned in section 4, these models represent the most pessimistic, the central and the mmost optimistic trend assumptions of the sixteen models under consideration. The results for all nine models are shown in Walsh and Rickayzen (2000b).

Since the number of people in each disability category is closely dependent upon the total number of people, we include the totals in Table 16. In this table and those shown in Appendix 1, the age category “All” refers to ages 20 and upwards.

For the five years shown in the table, the adult population under 60 peaks in 2016 and the population aged 60-69 peaks in 2026, reflecting the baby boom generation. For higher ages the size of the population is highest in 2036.

The projected results for the nine models vary a great deal from one model to another. However, we believe that the assumptions in the models are generally plausible. Also, as discussed in section 2.3 and section 4, it is hard to rule out models by using data on trends because these data point in two different directions — more time spent severely disabled according to some data and less time according to others. This means that it is not possible to be confident that the results of one model are more realistic than those from another unless some other constraints can be provided on the trend assumptions. We are not aware of any other constraints.

Table 16. Projected population (thousands) according to the GAD Model

Age Group	Year	Males	Females
20 – 59	1996	16,097	15,801
	2006	16,578	16,188
	2016	16,680	16,204
	2026	15,867	15,430
	2036	15,266	14,906
60 – 69	1996	2,597	2,822
	2006	2,878	3,039
	2016	3,484	3,634
	2026	4,123	4,163
	2036	3,862	3,855
70 – 79	1996	1,800	2,435
	2006	1,882	2,310
	2016	2,204	2,588
	2026	2,708	3,116
	2036	3,278	3,624
80 – 89	1996	659	1,370
	2006	772	1,386
	2016	890	1,395
	2026	1,126	1,683
	2036	1,400	2,037
90+	1996	67	273
	2006	104	340
	2016	139	374
	2026	184	430
	2036	258	577
All	1996	21,220	22,701
	2006	22,214	23,262
	2016	23,398	24,196
	2026	24,008	24,822
	2036	24,064	25,000

We can comment on the results shown in Appendix 1 as follows:

Model A has no trends and is therefore the most pessimistic model (in the sense that it is likely to project relatively high numbers of severely disabled lives). The main features of the projection are as follows:

- For adults aged less than 60 the number who are healthy is projected to fall and the number in each of the disability categories is roughly constant.
- For the higher ages, the number of people in all categories of disability is expected to increase, as is the number who are healthy.
- The number of adult males who are severely disabled (categories 8, 9 and 10) is projected to increase by 321,000 from 384,000 in 1996 to 705,000 in 2036. This increase is made up from a decrease of 1,000 males aged less than 60 and increases of 32,000, 76,000, 131,000 and 82,000 at the higher age groups (60 to 69, 70 to 79, 80 to 89 and 90 plus).
- For adult females the projected increase in the number who are severely disabled is 380,000 — from 689,000 to 1,069,000. This comprises a decrease of 3,000 aged under 60 and increases of 28,000, 75,000, 131,000 and 149,000 at the higher age groups. (These numbers differ from those in Appendix 1 due to rounding.)
- The overall increase in the number severely disabled is larger for females than males in this projection. The difference is entirely due to the 90 plus age category.

Model N has the strongest trends and is therefore the most optimistic model. The main features of the projection are as follows:

- In the 20 to 59 age group the number of males and females in each disability category, as well as the number who are healthy, is projected to fall between 1996 and 2036.
- In the 60 to 69 age group, the number of healthy people is projected to rise while the number of disabled people is expected to fall (this applies to all disability categories). The changes in numbers in each category over time are not monotonic.
- In the 70 to 79 age group, the number of healthy males and the number of males in disability categories 1 to 7 are projected to rise while the number of males in disability categories 8 to 10 is projected to stay roughly constant. For females in this age group, there is projected to be an increase in the number who are healthy and in the number in disability categories 1 to 4 and a decrease in the number in the higher categories.
- In the 80 to 89 age group, the number of healthy males and the number of males in disability categories 1 to 7 are projected to rise while the number of males in disability categories 8 to 10 is projected to fall. For females in this age group, there is projected to be an increase in the number who are healthy and in the number in disability categories 1 to 5 and a fall in the number in the higher categories.
- For males aged 90 and over, there is projected to be an increase in the number healthy and the number in each disability category. For females there is projected to be an increase in the number who are healthy and the number in disability categories 1 to 8 and a decrease in the number in category 10.
- Combining all of these age groups, there is projected to be an increase in the number of males who are healthy or who are in disability categories 1 to 6 and a decrease in the number of males who are more severely disabled. For females there is projected to be an increase in the number who are healthy or who are in disability categories 1 to 4 and a decrease in the number who are more severely disabled.

6. UNCERTAINTIES

It should be noted that there are various uncertainties surrounding the projection model. The main ones are the following:

- The ambiguous trend data.
- The model incorporates only published data for the OPCS disability survey. Such published data for the population over the age of 80 have not been sub-divided into age bands. This means that the model has few constraints at the oldest ages, which are the ages when the disability prevalence rates are at their highest.
- The assumption that the population is stationary in deriving transition rates from the prevalence rate data.

A full discussion of these uncertainties can be found in Walsh and Rickayzen (2000b).

7. CONCLUSION

We draw two main conclusions from the results projected in this paper. The first of these is a cause for optimism. However, it may unfortunately be swamped by the second conclusion.

- Although there will be a large increase in the number of elderly people in the UK the implications for the number of people needing long-term care will be ameliorated to some extent by a reduction in the proportion of older people who are severely disabled.
- The data that have shown changes in the prevalence of severe disabilities among the elderly do not present a clear picture of what has been happening in the recent past. As a result of this lack of clarity, there is a large amount of uncertainty surrounding the results of our projections and it is quite plausible that the first conclusion is wrong.

Fundamentally, the number of people with severe disabilities in 40 years' time will depend on what happens to the probabilities of deterioration and improvement in health and on what happens to the mortality rate of people with severe disabilities. These influences are all included in our projection model. We have tried to make sense of the data on healthy life expectancies as measured at intervals over the past two decades in order to input appropriate trends to the model. The data, however, do not provide a unique message. It is possible to take from them the view that people are spending less time, on average, with severe disabilities. On the other hand, the opposite view can also be taken.

Although we are not experts at interpreting healthy life expectancy data, we have consulted people who are and have read what has been published in this area regarding British data. The conclusions of these researchers, who are more familiar with life expectancy data than we are, seems to be that the situation is improving. At worst, people are spending the same proportion of their lives severely disabled — so gains in life expectancy are split between time spent healthy and time spent in poor health. At best, the trend over the last twenty years has been for the increase in life expectancy to lead to an equal increase in healthy life expectancy and no change in disabled life expectancy.

If we choose assumptions for trends that reflect this optimistic view, the result is that disability prevalence rates fall and consequently the disabled population does not rise in line with the total number of elderly people, and may even fall.

The range for the projected number of severely disabled adults in 2036 (according to one particular definition of severity) is between 0.8 million and 1.8 million for the models we have run. Moreover, some more extreme models may also be compatible with existing trends data. Such a wide funnel of doubt is inevitable when projecting forward for 40 years on the basis of inconclusive data.

There are many other aspects of the projection model which could be refined or even overhauled. However, we do not feel that the model itself is an important source of uncertainty. Indeed, apart from the doubts over trends, the most important shortcoming of the projections is probably the lack of data on the prevalence rates of disability for people over the age of 85. If such data, which do exist, are published it may be possible to improve the reliability of the output from the projection model.

Another theme which underpins the work described in this paper is the lack of reliable data. For example, we described in section 3 how we derived the transition rates for our multiple state model from prevalence rate data applicable to 1985 and 1986. Future research in the area of long term care would be greatly assisted if regular national surveys were undertaken which enabled longitudinal data to be collected (i.e. an appropriate cross section of the UK population could be tracked at each survey date so that transition rates could be computed directly from the data). Ideally, the surveys should be undertaken at least biennially since we are most interested in calculating probabilities of transition from one year to the next.

Finally, we have projected, under various assumptions, the disabled population over the next 40 years. The next step would be to assess the care needs of this population, being careful to distinguish between formal and informal provision.

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APPENDIX 1

Table 1(M). Number of males with disabilities (thousands), Model A

Age Group	Year	Able	OPCS Disability Category 1	2	3	4	5	6	7	8	9	10
20–59	1996	15,123	255	143	121	111	102	70	63	50	41	18
	2006	15,502	283	160	135	123	112	77	69	54	44	19
	2016	15,568	294	166	140	127	115	79	71	55	46	19
	2026	14,809	280	158	133	121	110	75	68	53	44	18
	2036	14,271	262	148	125	114	103	71	64	50	41	17
60–69	1996	1,987	167	97	79	70	62	38	36	28	24	9
	2006	2,209	183	107	87	76	68	42	39	30	26	10
	2016	2,657	226	132	108	95	84	52	49	38	33	12
	2026	3,165	263	153	125	109	97	60	56	43	38	14
	2036	2,936	253	147	121	106	94	58	54	42	37	14
70–79	1996	1,077	177	109	93	84	78	48	47	38	35	14
	2006	1,114	186	116	98	90	83	51	50	41	38	15
	2016	1,310	217	135	114	104	96	60	59	47	44	18
	2026	1,583	271	168	143	131	121	76	75	60	57	23
	2036	1,946	323	200	171	155	143	89	87	71	66	26
80–89	1996	194	76	53	50	50	53	37	42	40	44	20
	2006	228	89	62	58	59	63	43	50	46	51	23
	2016	257	102	72	67	68	72	51	58	55	60	27
	2026	327	129	91	85	86	91	64	73	69	76	35
	2036	392	158	112	106	108	115	81	94	89	99	45
90+	1996	5	4	4	4	5	6	5	7	8	11	6
	2006	8	6	6	6	7	9	8	11	13	18	10
	2016	10	9	8	8	10	13	11	15	18	25	14
	2026	13	11	10	11	13	16	14	20	24	33	19
	2036	19	15	14	15	18	23	20	28	34	47	27
All	1996	18,387	679	406	348	321	301	199	195	163	155	66
	2006	19,061	748	450	385	355	334	221	219	184	178	77
	2016	19,803	848	511	437	404	381	252	251	213	208	90
	2026	19,897	952	579	497	460	436	288	291	249	249	109
	2036	19,564	1,012	621	536	500	479	319	327	285	291	130

APPENDIX 1 (CONTINUED)

Table 1(F). Number of females with disabilities (thousands), Model A

Age Group	Year	Able	OPCS Disability Category 1	2	3	4	5	6	7	8	9	10
20–59	1996	14,693	212	154	151	138	142	104	86	56	45	22
	2006	14,980	232	170	166	150	154	112	93	59	48	24
	2016	14,975	238	173	169	152	157	114	94	60	49	24
	2026	14,264	225	164	160	145	149	108	89	57	46	23
	2036	13,799	213	155	152	137	142	103	85	54	44	22
60–69	1996	2,149	132	99	94	82	86	60	51	29	26	15
	2006	2,323	140	105	100	87	91	64	54	31	27	16
	2016	2,761	170	128	122	106	111	78	67	38	34	20
	2026	3,182	192	144	137	119	125	88	75	43	37	22
	2036	2,922	182	136	130	113	119	84	71	41	36	21
70–79	1996	1,406	168	131	130	119	135	102	95	58	56	35
	2006	1,324	160	125	124	113	130	98	92	56	54	34
	2016	1,493	179	139	138	126	144	108	102	62	60	38
	2026	1,772	217	169	168	154	177	134	126	77	75	47
	2036	2,089	250	195	194	176	202	152	143	87	84	53
80–89	1996	441	100	83	90	89	117	102	113	80	89	65
	2006	448	101	85	91	90	118	103	114	81	90	65
	2016	446	102	85	91	91	119	105	116	83	92	67
	2026	541	122	102	110	109	143	126	139	99	110	81
	2036	636	147	123	132	132	175	154	172	124	139	102
90+	1996	31	12	11	13	14	22	24	34	31	43	39
	2006	35	14	12	15	16	26	29	42	39	57	54
	2016	39	15	14	16	18	29	32	46	43	63	60
	2026	44	17	15	18	20	33	36	52	50	73	70
	2036	58	23	21	24	27	43	49	70	67	99	95
All	1996	18,719	624	477	477	441	503	392	379	254	259	176
	2006	19,111	648	496	495	457	520	407	394	267	276	192
	2016	19,713	704	538	536	493	560	437	424	287	297	208
	2026	19,803	774	594	593	547	627	492	481	327	342	243
	2036	19,504	815	630	632	586	680	542	541	374	402	293

APPENDIX 1 (CONTINUED)

Table 2(M). Number of males with disabilities (thousands), Model C

Age Group	Year	Able	OPCS Disability Category 1	2	3	4	5	6	7	8	9	10
20–59	1996	15,141	249	140	119	110	100	69	62	49	40	17
	2006	15,562	266	151	128	117	106	73	65	50	41	17
	2016	15,675	264	151	128	116	105	72	64	49	40	17
	2026	14,949	240	137	117	107	96	66	58	45	37	16
	2036	14,432	217	124	106	97	88	60	53	41	33	14
60–69	1996	2,002	163	95	78	68	60	37	35	27	23	9
	2006	2,261	170	100	81	71	62	38	35	27	23	9
	2016	2,768	199	116	95	83	72	44	40	31	27	10
	2026	3,350	216	127	103	89	77	47	43	32	28	10
	2036	3,164	196	115	93	81	70	42	38	29	25	9
70–79	1996	1,097	174	108	91	83	75	47	45	36	33	13
	2006	1,170	177	110	93	84	76	47	45	35	32	13
	2016	1,417	199	123	104	93	83	51	48	38	34	13
	2026	1,777	238	147	123	110	98	60	56	44	40	15
	2036	2,228	273	167	139	124	110	66	62	48	43	17
80–89	1996	204	76	53	50	50	52	36	41	38	41	18
	2006	263	90	62	57	57	58	40	44	40	43	19
	2016	327	103	70	64	63	64	43	47	43	46	20
	2026	455	128	86	78	76	76	50	54	48	51	22
	2036	599	157	105	94	91	90	59	64	56	59	26
90+	1996	6	5	4	4	5	6	5	7	8	11	6
	2006	10	7	6	7	8	10	8	11	12	16	9
	2016	16	11	9	9	11	13	11	14	16	20	11
	2026	24	15	12	13	14	17	14	18	20	25	13
	2036	39	22	18	18	20	24	18	24	26	33	17
All	1996	18,449	667	400	343	316	295	194	189	156	148	63
	2006	19,265	711	429	367	337	313	205	200	165	156	66
	2016	20,203	775	469	400	366	338	220	214	176	167	71
	2026	20,554	838	509	434	396	365	236	229	189	181	77
	2036	20,462	865	528	451	412	381	246	241	200	193	83

APPENDIX 1 (CONTINUED)

Table 2(F). Number of females with disabilities (thousands), Model C

Age Group	Year	Able	OPCS Disability Category 1	2	3	4	5	6	7	8	9	10
20–59	1996	14,709	208	152	149	136	140	102	84	55	44	22
	2006	15,037	221	163	159	144	147	107	87	56	45	22
	2016	15,076	218	160	156	142	144	104	85	54	43	21
	2026	14,398	199	147	143	130	132	95	77	50	40	19
	2036	13,957	183	135	132	120	122	88	71	46	36	18
60–69	1996	2,165	129	97	92	80	84	59	49	28	25	14
	2006	2,374	132	100	94	82	84	58	49	28	24	14
	2016	2,869	153	116	109	95	97	67	55	31	27	15
	2026	3,353	164	124	116	101	102	70	57	32	28	16
	2036	3,130	148	112	105	90	91	62	51	29	24	14
70–79	1996	1,429	167	130	129	117	133	99	91	56	53	33
	2006	1,390	155	120	119	108	121	89	82	50	47	29
	2016	1,623	166	129	127	114	126	92	83	50	47	29
	2026	1,999	195	151	148	133	146	106	95	57	53	33
	2036	2,424	215	166	161	144	156	112	99	59	54	33
80–89	1996	456	101	84	90	90	116	101	110	77	85	61
	2006	496	103	86	91	90	114	97	104	72	78	55
	2016	532	104	86	91	89	112	94	98	68	72	51
	2026	691	125	103	107	104	129	106	110	74	79	55
	2036	875	150	123	128	123	151	123	127	85	90	62
90+	1996	33	12	11	13	15	23	24	33	30	41	37
	2006	43	16	14	16	18	28	30	41	37	51	46
	2016	54	18	17	19	21	31	33	44	38	52	46
	2026	71	23	20	23	25	36	37	49	42	56	49
	2036	108	32	28	32	34	49	49	63	53	69	60
All	1996	18,792	617	474	473	438	495	384	368	246	247	166
	2006	19,341	627	482	480	442	495	382	362	242	244	166
	2016	20,153	660	508	502	461	511	389	366	242	242	163
	2026	20,512	706	544	538	493	545	414	388	255	255	171
	2036	20,494	727	563	558	512	569	434	410	271	274	186

Table 3(M). Number of males with disabilities (thousands), Model N

Age Group	Year	Able	OPCS Disability Category 1	2	3	4	5	6	7	8	9	10
20–59	1996	15,158	244	138	118	108	99	68	61	47	39	17
	2006	15,614	251	144	123	112	101	69	61	47	38	16
	2016	15,760	240	138	118	108	97	66	58	44	35	15
	2026	15,050	212	123	105	96	86	59	51	39	31	14
	2036	14,539	187	109	94	86	77	53	46	35	28	12
60–69	1996	2,017	160	94	77	67	59	36	33	25	22	8
	2006	2,310	158	93	76	66	57	35	31	24	20	7
	2016	2,867	174	103	84	72	62	37	33	24	21	8
	2026	3,500	178	105	86	73	62	37	32	24	20	7
	2036	3,334	152	90	73	62	52	31	26	19	16	6
70–79	1996	1,114	171	106	90	82	74	45	43	34	30	12
	2006	1,214	170	106	90	80	71	43	40	31	27	10
	2016	1,500	184	114	95	85	74	44	40	31	27	10
	2026	1,917	211	129	108	95	82	49	44	34	29	11
	2036	2,445	228	138	114	99	85	50	45	34	30	11
80–89	1996	213	77	54	50	50	52	35	39	35	38	16
	2006	299	90	62	57	55	55	36	38	33	34	14
	2016	399	100	68	61	58	56	36	37	31	31	13
	2026	580	120	80	71	66	61	38	37	30	29	12
	2036	786	142	94	82	75	68	41	40	32	30	12
90+	1996	6	5	4	5	5	7	5	7	8	10	5
	2006	12	8	7	8	9	10	8	10	11	13	7
	2016	22	13	10	11	12	14	10	13	13	15	7
	2026	38	18	15	15	16	18	13	15	14	16	7
	2036	68	27	21	20	21	23	16	18	17	18	8
All	1996	18,507	657	396	339	312	290	190	183	150	139	58
	2006	19,449	678	412	353	322	295	191	181	146	132	55
	2016	20,548	711	434	370	335	302	194	180	143	128	53
	2026	21,086	738	452	384	346	309	195	180	141	126	51
	2036	21,172	735	451	383	344	305	191	175	137	122	49

Table 3(F). Number of females with disabilities (thousands), Model N

Age Group	Year	Able	OPCS Disability Category 1	2	3	4	5	6	7	8	9	10
20–59	1996	14,725	205	150	147	135	138	101	82	54	43	21
	2006	15,087	212	157	153	139	141	102	82	53	42	20
	2016	15,158	202	150	147	134	134	96	77	49	39	19
	2026	14,499	180	134	131	120	120	85	68	44	34	16
	2036	14,066	161	120	118	109	108	77	61	40	31	14
60–69	1996	2,180	127	96	91	79	82	57	47	27	23	13
	2006	2,420	125	95	90	78	79	53	43	24	20	11
	2016	2,959	139	106	99	86	85	57	46	25	21	12
	2026	3,486	142	108	101	87	84	56	44	24	20	11
	2036	3,282	122	93	87	74	71	46	36	20	16	9
70–79	1996	1,451	165	129	128	117	130	96	87	53	49	30
	2006	1,451	150	117	116	105	114	82	72	42	39	23
	2016	1,736	155	122	118	106	112	78	67	39	35	21
	2026	2,187	174	136	132	117	121	83	70	40	36	21
	2036	2,687	182	142	136	119	120	81	67	38	33	19
80–89	1996	471	102	86	92	92	117	100	106	73	78	54
	2006	541	105	89	94	93	113	92	93	61	63	42
	2016	611	105	89	93	90	106	83	81	52	51	34
	2026	831	124	103	106	102	116	88	82	51	49	32
	2036	1,094	144	119	122	115	128	94	86	53	50	32
90+	1996	35	13	12	14	16	24	25	33	29	38	32
	2006	51	18	16	19	22	32	32	40	34	42	34
	2016	71	22	21	24	26	37	35	41	32	37	29
	2026	101	28	26	29	32	42	38	42	31	35	26
	2036	165	40	36	41	43	55	47	50	35	38	27
All	1996	18,862	612	472	472	438	492	379	356	236	231	151
	2006	19,549	609	474	472	437	479	361	331	215	205	131
	2016	20,535	624	487	481	442	474	349	311	197	183	113
	2026	21,103	647	507	499	456	483	350	306	191	174	106
	2036	21,294	649	511	503	459	482	346	300	185	169	102