Appendix B: Methods: supply projection model

This section describes in detail the inputs and the components of the standard supply projection.

Supply projection model

The framework underlying the projection of practising dental professionals in Australia conceives the labour force as a dynamic system of stocks and flows. The stock of dental service providers is equivalent to the number of registered dentists, therapists, hygienists and prosthetists. Movement into the stock of dental practitioners (recruitment) consists of practitioners who were educated in Australian educational institutions, practitioners who have migrated into Australia, and practitioners who return to practice after a period of cessation from practice. Attrition (wastage) from the stock of practitioners is associated with migration out of Australia, retirement, death and cessation of practice. Cessation of practice may be permanent (e.g. to pursue another career) or short-term (e.g. prolonged parental leave, study leave).

To ensure accurate representation of the stock of practitioners in Australia, dentists were categorised into sex and age groups, and allied dental professionals into age groups. Each element of the inflows and outflows were followed through each age and sex group, as shown in Figure 25.

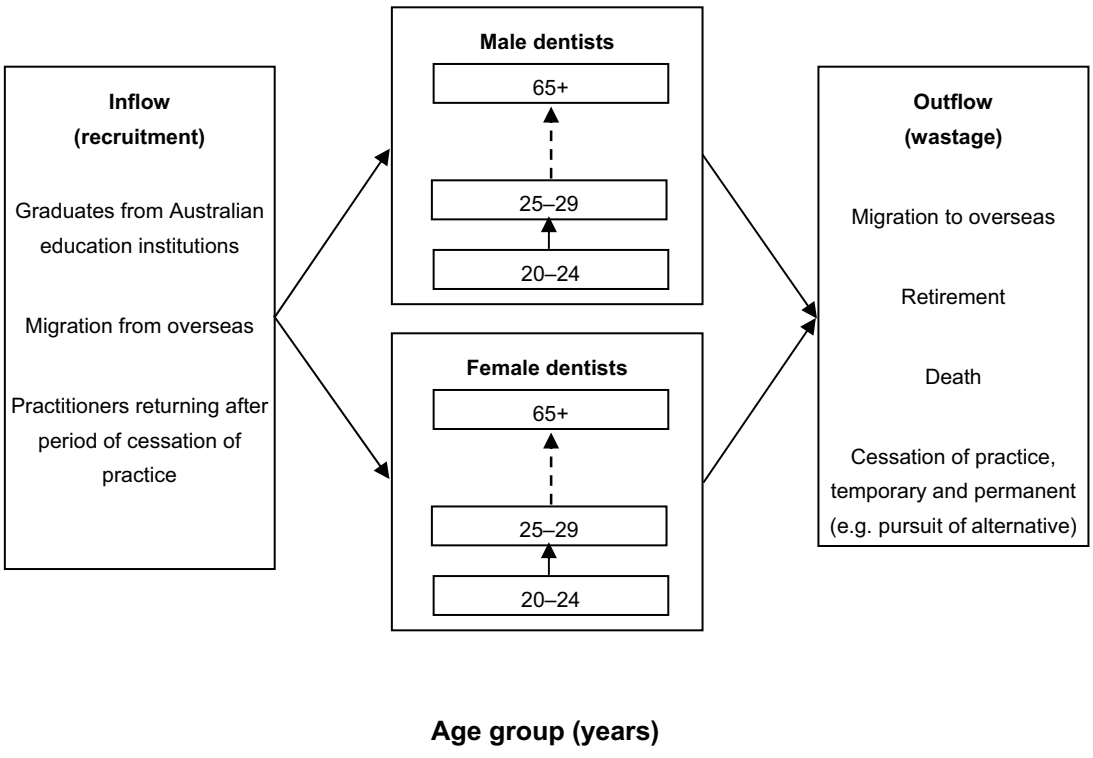


Figure 25: Framework of the labour force projection model

The baseline stock of dentists was divided into male and female dentists and then grouped into 12 age categories, i (i = 1, 2,…12). The baseline stock of allied dental professionals was divided into 10 age categories. There was no categorisation by sex as these groups are highly gendered, the prosthetists dominated by males and the therapists and hygienists by females.

A basic Markov chain model was adopted; the model assumes that dentists flow in and out of age categories independently and with identical probabilities that do not vary over time (Bartholomew & Forbes 1979). Each dentist with the passage of time has a given probability of staying in the same age group (P_{ii}) or of making a transition into an older age group ($P_{i,i+1}$). The transitional probabilities between each of the age groups are set out in an array as follows:

P_{11}	P_{12}	…	…	…	W_1
…	P_{22}	P_{23}	…	…	W_2
…	…	P_{33}	P_{34}	…	W_3
…	…	…	P_{II}	P_0	W_I

Each element $\mathbf{P}_{ii}$ is the probability that a member of the age category i at the start of the time interval remains in that age category at the end, and $\mathbf{P}_{i,i+1}$ is the probability that a member of age category i at the start of the time interval is in age category i+1 at the end. $\mathbf{W}_i$ is the probability that a member of age category i at the start would no longer contribute to the stock of dentists at the end of the time interval. Because each dentist must either stay in the same age group, move to the next age group or no longer contribute to the stock of dentists, each row sums to 1:

$$P_{ii} + P_{i,i+1} + W_i = 1$$

(Note: As there are only 12 age categories, dentists who are 75 years or older cannot move into the next age category—they can only stay in the current age category or be wasted out of the stock of dentists.)

The matrix **P** is the transition matrix, and the row vector **W** (W_1, W_2…W_I) is the wastage vector. It is implicit in this model that time is discrete, typically one year. The elements of **P** and **W** are assigned numerical values by estimating the probabilities from past data.

The Markov chain model is completed by an estimation of the flow of new recruits. The number of recruits at year T and for age category i is denoted by $R_i(T)$, referred to as the recruitment vector. The recruitment vector is set out in an array as follows:

$R_1(2001)$	$R_1(2002)$	…$R_1(T)$
$R_2(2001)$	$R_2(2002)$	…$R_2(T)$
…	…	…
$R_I(2001)$	$R_I(2002)$	…$R_I(T)$

The following notation specifies the calculation for each age category, with the total number of practising dentists in an age category for year T denoted by $D_i(T)$:

$$D_i(T) = R_i(T) + D_i(T–1) \times P_{ii} + D_{i-1}(T–1) \times P_{i-1,i}$$

$$i = 12, T>2000$$

For example, the notation for the calculation of the number of practising dentists in age category 2 (i = 2, 25–29 years) in 2003 would be:

$$D_2(2003) = R_2(2003) + D_2(2002) \times P_{22} + D_1(2002) \times P_{12}$$

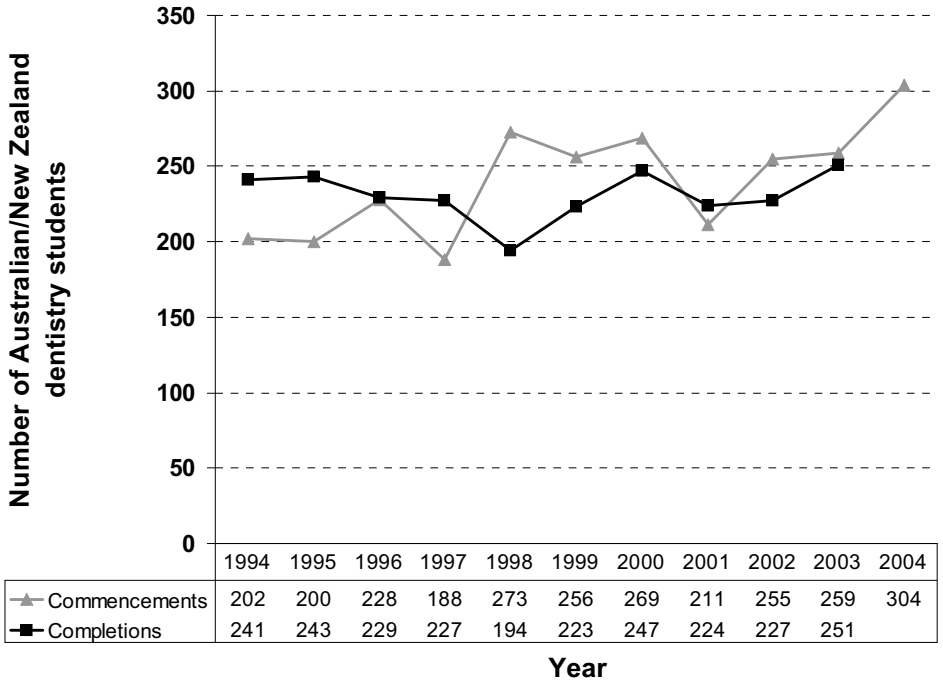
Dentist recruitment vector

The recruitment vector consists of several components each described in some detail below. There are varying degrees of confidence in each component, their accuracy being contingent upon the availability of data and the degree of potential overlap between components.

Australian university graduates

In 2003 there were five universities in Australia that provided Bachelor of Dental Science courses. In addition to these, Griffith University established a Dental School in 2004. Data on course commencements and completions were obtained from the Department of Education, Science and Training (DEST). There has been a marginal increase in the number of graduate completions in the decade to 2003 (Figure 26). The number of commencements has increased since 2001, suggesting continued growth in the number of completions until approximately 2009, when the first year of commencements from Griffith are expected to graduate.

Estimates for the number of completions were obtained by taking the average number of completions between 2000 and 2003. This estimate was validated by comparing it with the number of students currently enrolled in dental courses. It was estimated that 237 graduates per year would enter the dental labour force between 2003 and 2008, increasing to 307 per year in 2009. From 2009 the additional 70 graduates accounts for Griffith University graduates and for incremental increases in completion numbers from other institutions.



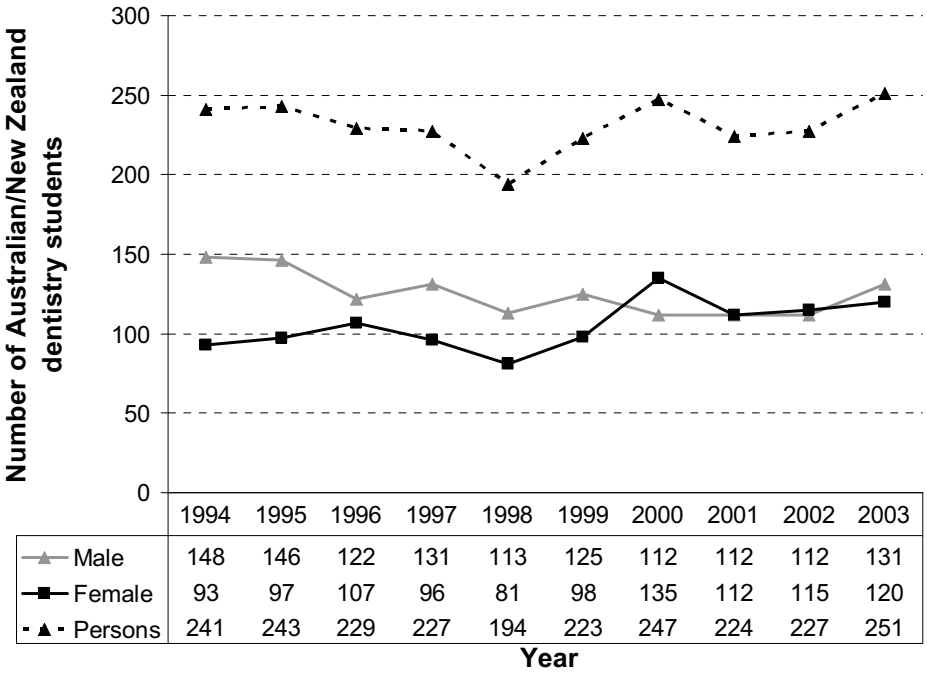
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Commencements	202	200	228	188	273	256	269	211	255	259	304
Completions	241	243	229	227	194	223	247	224	227	251	

Note: The number of completions for 2004 was not available at time of publication.

Sources: Tables C.1, C.2.

Figure 26: Australian/New Zealand citizens and permanent residents commencements and completions in dentistry by year, 1994 to 2004

The proportion of graduates that were female has increased from approximately 40% in the mid 1990s to approximately 50% since 2000 (Figure 27). This has implications in terms of attrition rates and supply of visits. For development of an appropriate recruitment vector, the sex and age distribution of the graduate component is based on the average age and sex distribution for Australian citizens and permanent residents completing courses in dentistry between 2000 and 2003.



	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Male	148	146	122	131	113	125	112	112	112	131
Female	93	97	107	96	81	98	135	112	115	120
Persons	241	243	229	227	194	223	247	224	227	251

Source: Table C.3.

Figure 27: Australian/New Zealand citizens and permanent residents completions in dentistry by sex, 1994 to 2003

Overseas entrants

Overseas entrants to the dentist labour force enter the pool of dentists from two main pathways. Dentists who obtained their qualifications in the United Kingdom, Ireland or New Zealand are automatically recognised and are granted registration. Dentists who trained in other countries are required to undertake an examination process with the ADC.

Information on the number of dentists entering the labour force through the automatic recognition pathway is difficult to obtain because not all state and territory registration boards are able to provide qualifications data of registrants. Information on this group is obtained from immigration data on overseas arrivals into Australia. An estimate can be made by looking at the number of entrants into Australia from the United Kingdom, Ireland and New Zealand who recorded dentistry as their occupation and intended to stay for 12 months or more (Table B.1). It should be emphasised that these figures are indicative only because it cannot be determined whether all these entrants will apply for recognition and subsequently work as a dentist in Australia. Also, these entrants may have obtained their qualification from other countries and may therefore not be eligible for automatic recognition.

In addition to the uncertainties of intention to practise, the number of overseas entrants fluctuates from year to year (as shown in Table B.1). Consequently, the number of entrants was averaged over the years 2000 to 2006 and then multiplied by the employment rate for the Australian dentist labour force from the 2003 survey (84.9%).

Table B.1: Long-term overseas arrivals to Australia of entrants with United Kingdom, Ireland or New Zealand citizenship and stated dentistry as their profession, 2000 to 2006

Age group (years)	2000	2001	2002	2003	2004	2005	2006 (as at Nov 2006)	Average
20–29	21	41	43	47	39	35	27	36
30–39	15	8	26	22	33	26	28	23
40–49	3	5	5	5	8	5	5	5
50+	—	3	7	3	3	3	3	3
Total	**39**	**57**	**81**	**77**	**83**	**69**	**63**	**67**

Source: ABS—DIMA overseas arrivals and departures unpublished data.

The number of successful ADC candidates has progressively increased since 2002 (Dental Board of Queensland Bulletin 2006). There were 37 successful candidates in 2002, increasing to 48 in 2003, 61 in 2004, 110 in 2005 and 158 in 2006. The number of overseas-trained dentists sitting final clinical exams increased from 50–60 per year in 2000 to 299 in 2006.

While the numbers of ADC candidates are expected to continue to increase in the coming years, numbers are sensitive to changes in local and world events as well as changes in migration policies. However because it is unlikely that the number of successful candidates will drop below 100 per year in coming years, consequently a conservative estimate of 100 successful ADC candidates per year was applied in the recruitment vector for 2007 and onwards.

Information on sex and age of dentists completing ADC examinations was not available. As a proxy, the Victorian Dental Board's data (2000–2006) on qualifications and age collected at first registration was used to estimate a representative age distribution of ADC candidates.

Return to practice

The final component of the recruitment vector is the group of dentists who return to practise (RTP). This component includes dentists who return to Australia after an extended visit overseas (longer than 12 months) and those that return to dentistry after cessation of practice for other reasons (e.g. career break, family responsibilities).

There are a number of difficulties in capturing accurate return to practice data, including the inability to match registration details across jurisdictions; the inability to consistently match registration data across time within each state and territory; and the possible double counting of registrations for dentists who have travelled overseas for an extended period yet have kept their registration active. Given the difficulties in this component of the model, estimates for return to practice were derived by the addition of two estimates from different sources.

First, return from an extended visit overseas (greater than 12 months) was derived from the overseas arrivals data collected by the Department of Immigration and Multicultural Affairs (DIMA). The numbers of Australian citizen arrivals who indicated that they were dentists between 2000 and 2006 are shown in Table B.2. An average of the 6 years was used as an estimate of return to practice from an extended visit overseas. These estimates were then multiplied by the employment rate for the Australian dentist labour force from the 2003 survey (84.9%).

Table B.2: Australian citizen dentists arriving in Australia after a long-term stay abroad, by age group, 2000 to 2006

Age group (years)	2000	2001	2002	2003	2004	2005	2006 (YTD)	Average (2000–06)
20–29	31	32	23	29	19	25	20	26
30–39	29	37	29	44	35	43	38	36
40–49	26	25	21	31	34	28	18	26
50+	16	19	26	22	26	27	14	21
Total	**102**	**113**	**99**	**126**	**114**	**123**	**90**	**110**

Note: YTD–year to date totals (as at November, 2006).
Source: ABS—DIMA overseas arrivals and departures unpublished data.

The second component of the return to practice vector is return to dentistry after a cessation of practice of 12 months or more. Obtaining an estimate for this group is problematic due the inability to track the practice status of dentists over time—not all state/territory datasets can be linked from year to year. Where it is possible to perform longitudinal analysis, the ability to track changes in practice status is inhibited by the numerous dentists that do not respond in consecutive surveys.

Given these difficulties, an estimate for return to practice was derived by tracking the change in work status across years and weighting for consecutive non-response. For state/territory datasets that could be linked, the proportion of dentists who indicated they were not working in a given year and were employed in the following year was determined (Table B.3). This component is a rate rather than a fixed estimate. The RTP percentage is multiplied by the estimated number of dentists practising/employed in a given year of the projection in order to calculate the RTP component of the recruitment vector for the following year of the projection.

Table B.3: Percentage of practising dentists returning to practice after a cessation of practice

	Age groups (years)										
	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65+	Total
Males	3.2	2.5	0.9	1.7	0.8	0.8	0.9	1.1	1.4	2.3	**1.2**
Females	4.8	3.1	4.5	3.4	1.7	1.0	0.8	2.0	0.6	2.4	**2.6**

Note: Cessation of practice is for a period of 12 months or more.

Dentist recruitment summary

The components of the recruitment vector are presented in Table B.4. With the exception of the numbers of Australian university graduates (which increase to 307 in 2009) and the RTP component, estimates were kept constant through the course of the projection.

Table B.4: Dentist recruitment vector (standard projection) by age group and sex

Age group (years)	Grads	ADC	RTP (base)	RTP (expat.)	UK/NZ	Total
			Male			
20–24	94	—	4	5	7	110
25–29	14	6	12	5	7	43
30–34	5	16	6	8	5	41
35–39	1	11	13	8	5	39
40–44	3	8	7	8	2	27
45–49	1	8	9	8	2	27
50–54	—	—	9	5	1	15
55–59	—	1	10	5	1	16
60–64	—	—	7	3	1	11
65+	—	—	7	3	—	10
Total	117	50	85	57	29	338
			Female			
20–24	99	—	6	6	9	120
25–29	12	11	15	6	9	52
30–34	4	15	22	7	5	53
35–39	3	14	14	7	5	42
40–44	2	5	7	3	1	18
45–49	1	3	3	3	1	11
50–54	—	1	2	1	—	4
55–59	—	1	2	1	—	4
60–64	—	—	—	—	—	1
65+	—	—	—	—	—	—
Total	121	50	70	36	28	304
			Persons			
20–24	193	—	10	11	15	229
25–29	26	17	27	11	15	96
30–34	9	31	28	15	10	94
35–39	4	25	27	15	10	81
40–44	4	13	14	11	2	45
45–49	1	11	12	11	2	38
50–54	—	1	11	6	1	18
55–59	—	1	12	6	1	20
60–64	—	—	7	4	1	12
65+	—	—	7	3	—	11
Total	237	100	155	93	57	643

Dentist attrition (wastage vector)

The attrition component of the model includes dentists who leave the profession either permanently or for an extended break (12 months or more). In order to estimate attrition, labour force collection data sets, where possible, were linked from year to year, and the following dentists were identified as having ceased practice in Australia:

- dentists who were practising in Australia in 1998 and 1999 but not practising in the following year (numbers were weighted up to account for non-response).

- dentists who became unregistered in a given year but had reported practising in the previous year. In order to limit the number of dentists migrating interstate from being included in this group, only dentists working solely or mainly in their state of registration were included as attrition. For those dentists whose work status was mainly or solely in another state and who then became unregistered, it was assumed that their un-registered status was a result of permanent interstate migration and therefore they were included as attrition.

The attrition rates were used to calculate the matrix of transition probabilities. Attrition rates by age and sex, and the resulting probabilities of remaining in the same age group (P_{ii}) in the following year of the projection and of moving into the next age group ($P_{i-1,I}$) are presented in Table B.5.

Table B.5: Dentist attrition rates and transition probabilities by age group and sex (standard projection)

	Male			Female		
Age group (years)	**Wastage**	**P_{ii}**	**$P_{i-1,i}$**	**Wastage**	**P_{ii}**	**$P_{i-1,i}$**
20–24	5.45%	0.1891	0.7564	5.69%	0.1886	0.7545
25–29	4.21%	0.7663	0.1916	5.00%	0.7600	0.1900
30–34	2.80%	0.7776	0.1944	5.29%	0.7577	0.1894
35–39	1.81%	0.7855	0.1964	5.04%	0.7597	0.1899
40–44	0.91%	0.7927	0.1982	2.59%	0.7793	0.1948
45–49	0.73%	0.7941	0.1985	3.71%	0.7703	0.1926
50–54	1.89%	0.7849	0.1962	3.92%	0.7686	0.1922
55–59	4.21%	0.7663	0.1916	7.33%	0.7413	0.1853
60–64	8.06%	0.7355	0.1839	9.10%	0.7272	0.1818
65–69	12.54%	0.6997	0.1749	20.00%	0.6400	0.1600
70–74	12.10%	0.7032	0.1758	21.73%	0.6262	0.1565
75+	24.18%	0.7582	0.0000	21.73%	0.7827	0.0000

Notes

1. Wastage rates determined using the following AIHW DSRU dentist labour force data sets: Victoria 1998, 1999; South Australia, 1998, 1999, 2000; New South Wales 1998, 1999, 2000.
2. Wastage is proportionally applied to P_{ii} and $P_{i-1,I}$, e.g. P_{22} =0.8– (0.8 x 0.0421), P_{23} = 0.2 – (0.2 x 0.0421).
3. There was no observed wastage in the 75+ years age group for female dentists due to extremely low numbers of female dentists in that age group. The wastage rate for the 70–74 years age group was applied to the 75+ years age group.

Estimation of dentist visits supplied

To estimate the projected supply of dentist visits by dentists in 2020, the numbers of practising dentists were multiplied by age-and sex-specific supply rates (Table D.2). Over the past 40 years, the length of a visit has been increasing, as has the number of services supplied at a visit. Because the number of hours worked per week has remained stable, the number of visits supplied has declined substantially over that period (Brennan & Spencer 2006). It is unlikely that this decline in productivity, in terms of visits supplied per annum, will suddenly discontinue, and it is also uncertain that it can continue at the previous rate. Hence, the standard supply projection assumes that the number of visits supplied per annum per dentist will continue to decline at half the rate that was observed over the period 1983–84 to 2003–04. The low supply projection presented in Section 6.4 presents a scenario in which productivity is assumed to decline at 100% of the previous rate of decline. The age by sex supply rates for this scenario are presented in Table D.5.

Total aggregated supply of visits is calculated by the summation of projected dentist supply and allied dental practitioner supply. Estimation of allied supply is outlined in the following section.

Allied dental practitioner recruitment

Estimation of future allied dental practitioner recruitment is complicated by several factors. The numbers of students graduating from allied dental courses will increase substantially over the next decade. In addition, the proportions of graduates completing a dual qualification who will practise principally as a hygienist rather than a therapist is unknown. The resulting recruitment vector shown in Table B.6 was based solely on estimates of recruitment of domestic graduates plus a small RTP component (1.3%) for therapists and hygienists.

Table B.6: Allied dental recruitment vector by age group and sex

	2003 (baseline)			2020		
Age group (years)	Dental prosthetists	Dental therapists	Dental hygienists	Dental prosthetists	Dental therapists	Dental hygienists
20–24	0	27	58	0	26	59
25–29	9	27	59	9	28	63
30–34	9	13	34	9	14	39
35–39	6	14	18	6	13	21
40–44	6	5	1	6	2	3
45–49	0	4	1	0	2	2
50–54	0	1	1	0	2	1
55–59	0	0	0	0	1	1
60–64	0	0	0	0	1	0
65+	0	0	0	0	0	0
Total	**30**	**90**	**172**	**30**	**90**	**190**

Note: RTP percentage included in recruitment for therapists and hygienists, rate set at 50% of overall female dentists RTP rate (1.3%).

Allied dental practitioner attrition (wastage vector)

Due to the inability to link annual allied dental labour force datasets and the relatively small numbers in those groups, the calculation of occupation specific wastage rates was considered to be not viable. Therefore, dentist wastage rates were used to develop the allied dental wastage vectors. The dental hygiene and dental therapy projections used female dentist attrition rates with a 50% loading. The dental prosthetist projection used male dentist attrition rates (Table B.7).

Table B.7: Allied dental practitioner attrition rates and transition probabilities by age group and sex (standard projection)

	Prosthetists			Dental therapists / dental hygienists		
Age group (years)	Wastage	P_{ii}	$P_{i-1,i}$.	Wastage	P_{ii}	$P_{i-1,i}$.
20–24	5.45%	0.1891	0.7564	8.54%	0.3658	0.5488
25–29	4.21%	0.7663	0.1916	7.5%	0.7400	0.1850
30–34	2.80%	0.7776	0.1944	7.9%	0.7366	0.1841
35–39	1.81%	0.7855	0.1964	7.6%	0.7395	0.1849
40–44	0.91%	0.7927	0.1982	3.9%	0.7689	0.1922
45–49	0.73%	0.7941	0.1985	5.6%	0.7555	0.1889
50–54	1.89%	0.7849	0.1962	5.9%	0.7529	0.1882
55–59	4.21%	0.7663	0.1916	11.0%	0.7120	0.1780
60–64	8.06%	0.7355	0.1839	13.7%	0.6908	0.1727
65–69	12.54%	0.6997	0.0000	45.2%	0.5485	0.0000

Notes

1. Wastage rates determined using the following AIHW DSRU dentist labour force data sets: Victoria 1998, 1999; South Australia, 1998, 1999, 2000; New South Wales 1998, 1999, 2000.
2. Dental therapist and dental hygienist wastage rates are based on female dentist wastage rates increased by 50%.
3. Wastage is proportionally applied to P_{ii} and $P_{i-1,I}$, e.g. P_{22} =0.8– (0.8 x 0.0421), P_{23} = 0.2 – (0.2 x 0.0421).
4. Due to small numbers the allied dental labour force was categorised into 10 age groups, unlike dentists who were categorised into 12 age groups.

Estimation of allied dental visits supplied

To estimate the projected supply of dental visits by allied dental practitioners, the numbers of practising allied dental practitioners were multiplied by the occupation specific supply rates (Section 3.2, Table 3). There were no additional assumptions relating to changes in productivity over time.

For aggregation with dentist supply dental therapist and dental hygienist supplies were discounted to enable an appropriate comparison to demand estimates.

Use of services data (demand) is sourced from the NDTIS. This survey collects data on dental visiting patterns and does not discern between visits supplied by dentists and other oral health service providers. Hence, the community typically report a single visit when they see a dentist and hygienist or therapist at the same visit, but each supplier counts the visit in their visits supplied. For the purposes of reconciliation with demand projections, only allied visits supplied without contact with a dentist at the same visit are counted towards total aggregate dental labour force supply. This is achieved by estimating the proportion of allied visits supplied which would be single provider visits. For hygienists it was estimated that 20% of all visits supplied would be independent of a visit to the dentist. The total number of visits supplied by dental therapists was reduced by 135,000 visits per year, which was an estimate of 50% of visits supplied by all school dentists.