TDB ADVISORY | Corporate Finance & Economics Expertise

The Costs and Benefits of a National Tooth Brushing Education Programme for Children

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Abbreviations	
DMFS	number of decayed, missing, filled permanent tooth surfaces
dmfs	number of decayed, missing, filled primary tooth surfaces
DMFT	number of decayed, missing, filled permanent teeth
dmft	number of decayed, missing, filled primary teeth
DS	number of decayed tooth surfaces
DT	number of decayed teeth
DT+dt	number of decayed permanent and primary teeth
FS	number of filled tooth surfaces
FT	number of filled teeth
MT	number of missing teeth
NPV	net present value

1. Executive summary

The incidence of dental caries in New Zealand is still high despite a number of government-funded interventions. Dental visits and treatment for children from birth until year 8 are government funded while under the Talk Teeth programme, adolescents get free basic care for their teeth from year 9 until their 18th birthday. Nevertheless, almost half of New Zealand children and adolescents have some dental caries. Dental caries experience refers to both decayed and filled teeth, as well as teeth that have been extracted (missing) because of decay.

This report proposes a new preventative programme that aims to educate children through supervised tooth brushing, increased engagement with parents and caregivers over oral hygiene, and increased dental health checks.

In overseas trials, effective tooth-brushing education is shown to have a big effect on reducing dental caries in children and adolescents. Programmes in Scotland and Denmark provide an evidential basis for making estimates of the expected net benefits from implementing a similar such programme in New Zealand. The common elements of the overseas programmes have been education of parents and children about understanding dental caries is a disease; training of parents and children in the techniques of proper tooth brushing; instilling the habit of regular oral hygiene as recommended by the Ministry of Health; and early identification of at-risk children for professional treatment.

The Ministry of Health's 2009 Oral Health Survey[1] showed that about two in three children and adolescents brushed their teeth twice a day; however, less than one in two children and adolescents brushed twice daily with fluoride toothpaste, as the Ministry recommends. This suggests improved teeth cleaning has some potential to improve oral health outcomes at relatively low cost.

The purpose of this report is to provide an economic assessment of the costs and benefits of a national tooth-brushing education programme for pre-school and primary school-age children using operational models trialled and adopted overseas. The report addresses two questions:

- what is the cost of a national tooth-brushing education programme for children aged 12 and younger? and
- what are the likely range of dental health effects and associated treatment savings for under 18-year olds (whose dental treatment costs are funded) resulting from such a programme?

The total cost to operate the programme is estimated at $12 million p.a. or around $11 p.a. per child in the programme. The cost of the programme would be incurred by the government via the Health budget. It is possible that this fiscal cost might be reduced to around $7.3 million p.a. ($7 p.a. per child) if sponsorship was available for the tooth-brushing supplies.

Against that background we provide estimates of the expected dental-health benefits from the reduced need for dental treatment using three scenarios. These scenarios are based on the measured impacts of programmes undertaken in Scotland and Denmark, and impact estimates based on shifting the current practices in New Zealand District Health Board (DHB) regions (the "reduced-disparities

[1] Ministry of Health, Our Oral Health: Key findings of the 2009 New Zealand Oral Health Survey.

model"). The dental-health benefits measured are the avoided treatment costs for under 18-year olds whose dental care is currently subsidised by the government, and the life-long private costs of replacing dental fillings at regular intervals.

These scenarios show a potential range of expected benefits of between $51 million p.a. and $61 million p.a. with a central estimate of around $57 million p.a. The Health budget benefits from the reduced need to treat dental caries in children and adolescents.

In addition to the benefits of reducing the number of cavities and the need for dental treatment, the Government would reduce expenditures in the Health budget with a central value of $45 million p.a. These reductions in expenditures arise from the cost saving from not having to treat dental caries minus the cost of the running the programme. That saving could be passed on to other health priorities. There is also a continuing benefit of sound teeth in the form of avoided replacements that would have a value of around $13 million p.a. This is a private benefit to people 18 years and over who would not need to have replacement treatment on fillings first installed on their permanent teeth as an adolescent.

Table 1 below summarises the estimated costs of the programme, compares them with the estimate of the benefits from avoided treatment costs and presents a range of expected net benefits for a national tooth-brushing education programme.

Table 1: Summary of cost and benefits using scenario simulations models

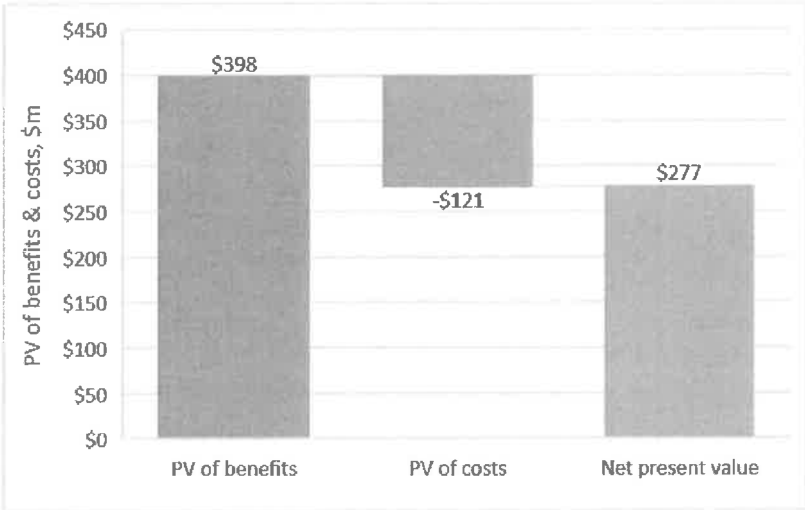
Annual recurring costs and benefits	Scotland Childsmile model	Nexø model	Reduced disparities model	Central estimate
	$m	$m	$m	$m
Savings from avoided treatment				
<5 years	$23.8	$6.1	$19.2	$16.4
Primary 5 -12	$22.6	$28.8	$29.4	$27.0
Secondary 13-17	$8.2	$18.2	$12.1	$12.9
Total financial benefits	$54.7	$53.1	$60.8	$56.2
Continuing savings for adults	$8.2	$18.0	$11.7	$12.7
Total national benefits	$62.9	$71.1	$72.5	$68.9
Programme costs				
Staff & related costs		$6.8		
Toothbrushes and toothpaste		$4.3		
Materials & supplies		$0.6		
Total fiscal & resource costs		$11.7		
Net benefits				
Financial	$43.1	$41.4	$49.1	$44.5
National	$51.3	$59.5	$60.9	$57.2

In national cost benefit terms, the annual estimated net benefit range is $51 million to $61 million p.a. with a central estimate of $57 million. This represents a benefit: cost ratio (B/C) of 5.9x for the central range.

At a minimum level, for the costs of the proposed programme to equal the savings from not having to treat dental caries, would require a sustained 4 percentage point improvement in child and adolescent dental health (as measured by the percent with "no obvious decay"). The 4 percent level would be the breakeven on the cost of the programme measured by avoided dental restorations and extractions. For comparison, the number of Scottish 5 year olds with "no obvious decay" rose from 44.6 percent in 2006 to 67 percent in 2012.

A value can be placed on the tooth-brushing and education programme over a 20-year horizon by discounting the costs and benefits at the discount rate mandated by the Treasury for national cost-benefit analysis of 7 percent pre-tax real. In Figure 1 we show the net present value (NPV) of the benefits and costs is $277 million (in 2013$ terms). This results from $398 million of present value benefits and $121 million of present value costs (a 3.3x benefit: cost ratio).

Figure 1: Present value of net benefits over 20 years (7% p.a. real)



2. Introduction

2.1 A proposal to improve the dental health of children

The purpose of this report is to provide an economic assessment of the costs and benefits of a national tooth-brushing education programme for pre-school and school-age children. The proposed programme is based on operational models trialled and adopted overseas.

It is proposed that a new programme be introduced for supervised tooth brushing for pre-school and primary school children. This New Zealand tooth-brushing education programme would consist of volunteer parents conducting supervised tooth brushing of pre-school and primary school children. Under the proposed programme, volunteer tooth brushing supervisors (carers and parents) would be provided with training on effective tooth brushing and dental hygiene by professional dental educators employed by the District Health Board.

A national pre-school and primary-school tooth-brushing education programme

Child enrolled at birth:

- linked to 20 hours' free early childhood care;
- parents of the children would be screened and deliver morning tooth-brushing sessions
- training of parents and carers in correct brushing techniques;
- provision of infant-sized toothbrushes and toothpaste;
- supervised brushing daily in early childhood care centres; and
- revised health target for sound teeth for five year olds.

Five to eight 8 year olds, early school:

- trained volunteers and teachers conduct daily supervised brushing;
- provision of toothbrushes and toothpaste;
- on-going education on correct tooth-brushing technique, infection control and healthy diets;
- higher frequency of dental hygienists visiting to schools;
- an annual review for all children;
- children identified as at risk recalled more frequently; and
- a new health target for eight year olds sound teeth.

Eight to 12 year olds, core primary-school years:

- increased frequency of dental hygienists visiting schools; and
- in areas of poor dental health, increased resources and an extension of the early school programme.

12 to 18 year olds, intermediate and secondary school:

- higher frequency of dental hygienists visiting schools; and
- in areas of poor dental health, increased resources and extension of early school programme.

At daily tooth-brushing sessions supervisors would guide the children through correct brushing, provide basic dental hygiene information and identify children that may need referral to trained professionals for further examination. Each child would be provided with his/her own toothbrush and at each brushing session an appropriate amount of toothpaste. Toothbrushes and fluoride toothpaste would be provided under the programme at no cost to the parents or school. Each session would take in the order of 15 minutes and one supervisor might control several sessions.

The DHB dental educators would provide leadership, oversight and monitoring of the volunteers and would act as a source of advice and assistance. They would be the immediate point for referral for professional treatment.

2.2 Background

From the 1930s until 1990, the rates of dental caries among five year olds in New Zealand fell dramatically. In the 1930s a child starting school might have been expected to have dental caries in over half his or her teeth. By 1990, the average for five year olds was just two teeth affected by dental caries. The rate of dental caries in five year olds has remained virtually unchanged since (dmft=1.88 in 2013).

Current figures indicate there are considerable disparities in dental health among New Zealand children starting school. Around 57 percent of children starting school have no dental caries, For the other 43 percent, levels of dental caries are on average high. The children with dental caries have on average over four affected teeth (dmft=4.4). In some parts of the country, such as Northland, two in three children start school with dental caries.

Dental caries is a health problem in most industrialised countries, second only in prevalence to the common cold (according to the World Health Organisation).

The causes of dental caries are well understood. Decay is caused by the action of acids produced in the mouth attacking the enamel tooth surface. The acid is produced when carbohydrates (sugars) in food and drink react with bacteria naturally present in the mouth. Bacteria is deposited as plaque on tooth surfaces and produces acid leading to a loss of calcium and phosphate from the enamel, a process called "demineralisation"[2]. The early manifestation of decay is a small patch of soft enamel just below the tooth surface, often hidden from sight in the grooves or in between the teeth. If left unchecked, decay spreads into the soft, part of the tooth beneath the enamel called the dentine. The weakened enamel then collapses to form a cavity. Cavities can only be restored by a dentist. Cavities, even in young children who do not yet have their permanent teeth, can have serious and lasting complications such as pain, abscess, tooth loss, and infection resulting in hospital admissions.

Following the introduction of fluoride to community water supplies from the 1950s, and the introduction of fluoride-containing toothpaste during the 1980s, dental caries rates among five year olds in New Zealand has continued to decline. Fluoridated drinking water now reaches almost 60 percent of the population[3] and fluoride toothpaste is practically the universal kind purchased by consumers. Dental-caries rates continued to fall among populations receiving and not receiving fluoridated drinking water.[4]

Despite a number of health interventions, dental caries rates remain stubbornly resistant to further decline. Further, hospitalisation for treatment of dental disease is rising. Over the period 1990 to 2009 hospital admissions for dental treatment have increased from 0.76 per 1,000 population to 3.01 per 1,000 population, a four-fold increase. Children aged between age three and eight years have had the

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[2] Enamel demineralises and remineralises continuously but it is when this balance is upset that decay progresses to a cavity. Saliva dilutes and neutralises the acid and is an important natural defence against decay. Aside from buffering plaque acids, saliva contains minerals that can "heal" an affected tooth.

[3] The differences in dental caries between five year olds living in fluoridated and non-fluoridated areas are 59.5 percent caries-free versus 55.2 percent, on average in 2013.

[4] Ministry of Health, Age 5 and Year 8 oral health data from the Community Oral Health Service, 2013.

greatest rates of increase in hospital admissions for dental treatment. Dental caries accounted for approximately 76 percent of all the hospital admissions for dental treatment.[5]

Extending drinking-water fluoridation to currently unserved communities is a possible preventative approach. But as we have seen, there is not a marked difference in the levels of dental caries experienced by those accessing fluoridated drinking water and those that do not (differences at year eight, i.e., roughly 12 years of age, are 56 percent sound teeth in fluoridated areas versus 52 percent in un-fluoridated areas, and dmft+DMFT=2.6 versus dmft+DMFT=2.4 affected teeth respectively on average). There is a cost of extending fluoridation, estimated by a recent government-funded study[6] at $144 million (in present value terms over 20 years at a 3.5 percent discount rate) to extend fluoridation to communities of 500 and above.

A perhaps more significant consideration than the financial cost of extending fluoridation is political controversy over water fluoridation within communities on technical, ethical and safety grounds. Both proponents and opponents of fluoridation have been criticised for exaggerating the benefits and risks. Several important systematic reviews have cited the lack of quality research into the effects of water fluoridation.[7] Gaps in the scientific literature add fuel to the political controversy. All of which begs the question of what else might be done to obtain and maintain higher levels of sound teeth using the fewest resources possible.

The Ministry of Health recommends tooth brushing twice-daily with fluoride toothpaste. Yet the 2009 Oral Health Survey showed that less than one in two children and adolescents brushed as the Ministry recommends. This suggests improved teeth cleaning has some potential to improve oral health outcomes if it could be encouraged at relatively low cost.

As is discussed in Section 4 below, in Denmark and in Scotland dental-hygiene education programmes have achieved significant and verifiable reductions in dental caries among school-age children at very modest cost. The common elements of the programmes have been:

(a) education of parents and children in understanding dental caries is a disease;

(b) training of parents and children in the techniques of proper tooth brushing and instilling the habit of regular oral hygiene; and

(c) early identification of at-risk children for professional, non-invasive treatment.

The intervention logic is based on how regular teeth cleaning inhibits the development of dental caries. The transmission mechanism is by controlling and disrupting plaque and bacteria through

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[5] Whyman RA, Mahoney, EK, Stanley, J and Morrison, D, Admissions to New Zealand Public Hospitals for Dental Care, A 20 Year Review. A report prepared for the New Zealand Ministry of Health, 2012.

[6] Sapere Research Group, Review of the benefits and costs of water fluoridation in New Zealand, September 2015, Ministry of Health.

[7] Introduction to the SCHER opinion on Fluoridation. European Commission Scientific Committee on Health and Environmental Risks (SCHER). 2011.
Centre for Reviews and Dissemination, What the 'York Review' on the fluoridation of drinking water really found, University of York, United Kingdom, 2003.
Iheozor-Ejiofor, et al. Water fluoridation for the prevention of dental caries. The Cochrane database of systematic reviews, June 2015.

mechanical force, and by introducing agents to the saliva that can assist to re-mineralise teeth in the early stages of enamel attack. Regular tooth brushing and associated oral-hygiene practices are demonstrably associated with better oral health.

2.3 Purpose of the report

2.3.1 National tooth brushing education programme

The purpose of this report is to provide an economic assessment of the costs and benefits of a national tooth-brushing education programme for pre-school and school-age children using operational models trialled and adopted overseas.

The report addresses the following questions:

- what are the dental-educator workforce requirements and the associated costs of a national tooth-brushing education programme for children aged 12 and younger? and
- what are the likely range of dental-health effects and associated treatment savings resulting from such a programme?
- Is the programme likely to be value for money?

2.3.2 Outline of the tooth-brushing education programme

The proposed New Zealand programme has as its focus pre-school and primary school children. This is the age when children are developing their primary (infant) and permanent teeth. It is also the age where lifelong dental hygiene habits can be developed and permanent teeth erupt.

Daily supervised tooth brushing in pre-schools or primary schools would be organised to meet established practice standards:

- informed consent would be obtained from parents (carers) for each child participating in the tooth-brushing education programme;
- all volunteer supervisors would receive training from dental educators in effective tooth-brushing technique and dental hygiene;
- children would brush their teeth daily under supervision;
- performance against the standards would be monitored by a dental educator on a regular basis and findings on areas for improvement would be discussed with the responsible person in the pre-school or school;
- toothbrushes would be individually identifiable for each child and replaced once a term, or sooner if required due to wear or other factors;
- volunteer supervisors would be trained to regulate the amount of toothpaste used (a smear of toothpaste would be used for children under 3 years and a pea-sized amount for children 3 years and over) and to discourage children from swallowing toothpaste;

- where toothpaste is shared, the supervisor would dispense it onto a clean surface; and
- after tooth brushing, brushes would be rinsed individually and replaced in a storage system to allow them to air dry in the upright position and to avoid contact with each other.

Critical to any health intervention a robust monitoring framework would be put in place to measure the impact of the programme.

2.4 Structure of the report

2.4.1 Assessment methodology

The methodology section (Section 3) explains what cost-benefit analysis is and how it is used to assist decision makers to make public policy choices. It then sets out the specific methods, principles and assumptions used to assess the costs and benefits of the proposed tooth-brushing education programme.

2.4.2 Overseas experience

The overseas experience section (Section 4) examines two examples of similar programmes used overseas. The two examples, from Denmark and Scotland, are relevant because they provide evidence on the possible effects of tooth-brushing education programmes on dental hygiene. The examples also have the advantage of having been subject to robust academic studies with the results of those studies published in recognised peer-reviewed journals.

2.4.3 Estimating the programme cost

Section 5 of this report outlines the proposed program for pre-school and primary school-age children. The section includes estimates of the required volunteer and professional dental educator workforce and the costs of the proposed programme.

2.4.4 Assessment of potential dental health effects

Section 6 presents the potential dental-health benefits arising from reduced levels of dental caries. The breakeven reduction in dental caries in the benefit population (aged under 1 year to 17 years) is estimated. Four scenarios are presented on possible expected benefits. The scenarios are based on experiences in Scotland and Denmark and on achieving median and best-practice levels of sound teeth among New Zealand DHBs. We have used Scotland and Denmark because they have successfully implemented similar programmes and have published, high-quality research on the impacts of the programmes.

2.4.5 Cost benefit analysis conclusions

Finally, the concluding section (Section 7) summarises the results of the cost benefit analysis and presents a sensitivity analysis of the results.

3. Methodology

3.1 National cost-benefit analysis[8]

National cost-benefit analysis (NCBA) is a systematic process for calculating benefits and costs to society of a government policy to see whether the benefits outweigh the costs, and by how much.

Any policy process starts with defining a problem and the potential need for a programme to address the problem. Having established the potential need, the next thing to do is to clearly define the policy, alternative solutions, and the counterfactual. The counterfactual is the situation that would exist if the policy does not go ahead (the "do nothing" or "without" the policy scenario). Only those costs and benefits directly attributable to the policy should be included in the NCBA. If something would occur anyway, regardless of the policy under consideration, then it is part of the counterfactual scenario.

There are different perspectives in any cost benefit analysis. Analysis from a national perspective, looks beyond private individuals, firms and government agencies at whether there is a better or worse use of the nation's resources as a result of the policy decision. Decision makers are usually keenly interested in the impact of policy decisions on the government's financial position. It is not uncommon, for example, for policy changes to differentially affect more than one government agency. For example, in-school tooth brushing might indirectly impose costs on the Education budget that contribute to savings in the Health budget. The overall financial impact on the government's finances is of interest.

Costs and benefits need to be identified as comprehensively as possible. As a general principle, only "real" costs and benefits are taken into account i.e., representing changes in the level of available resources to the nation. It is usual practice to ignore transfer payments such as taxes and subsidies that do not represent changes in the level of national resources but merely their transfer from one group to another. Care is needed to avoid double counting (such as of capital investment and depreciation and of financial charges and the discount rate).

An important issue over which there is often confusion is the question of whether costs and benefits represent incremental level changes or timing changes (or a combination of both). We come back to this issue in Section 6 below. Studies of preventative dental care typically claim benefits in treatment avoided (teeth or surfaces "saved"), a level change. However, we do not know whether the proximate effect of prevention is to permanently save a tooth from decay or to defer to the future the development of decay. Deferment is a benefit nevertheless, since incurring the cost of treatment is postponed, but it is a lesser benefit than a permanent saving where the treatment cost is never incurred. Dental health effects are often measured using this "tooth saved" approach which almost certainly overstates the practical effect of preventative care.

In many instances NCBA considers externalities resulting in common goods, club goods and public goods. Put most simply, an externality is a cost or benefit that affects someone who did not choose to incur that cost or benefit. While the concept of externalities is not controversial in economics, its application is controversial. Prevention and treatment of contagious disease has clear externalities,

[8] See Sugden, R and Williams, A, The Principles of Practical Cost-Benefit Analysis, Oxford University Press, 1978.

but most health care is not an externality as the benefits accrue to the patient. Concepts of social justice and the special meaning of good health as an intrinsic human value lie behind public funding for public health services.

Society places a higher value on benefits and costs that occur in the near future, compared with those that occur at a later date. For example, if it is known that $1.00 invested today will return $1.07 in a year's time (based on a seven percent per annum return), then we can say that $1.07 in a year's time has a present value (PV) of $1.00. The time value of money is treated in cost benefit analysis by discounting benefits and costs to present values to provide a common unit of measurement. The discount rate represents the rate at which present benefits and costs can be exchanged for future benefits and costs.

NCBA makes explicit the assumptions about what matters to the decision maker and what does not by using a decision rule that simultaneously considers dollar-denominated sums of costs and benefits. Cost benefit decision rules usually take one of three forms:

- the maximum available benefit subject to some cost or budget constraint;
- the maximum excess of benefit over cost (B – C); or
- the maximum ratio of benefits to costs (B/C).

Proposals that satisfy the threshold test are expected to be implemented because they represent a better use of scarce resources (greater value for money. Frequently decision makers over-ride the NCBA recommended course of action. This may be a result of the analysis not fully reflecting what matters most to the public policy decision maker.

3.2 Measurement of costs

The proposed tooth-brushing education programme uses resources that are assumed to be additional to the current community oral health programme.

The resources employed are a team of dental educators whose job it is to train parents, caregivers and teachers about oral health, effective tooth brushing and hygiene. Dental educators also monitor tooth-brushing activity and provide feedback to ensure a high standard of performance is achieved.

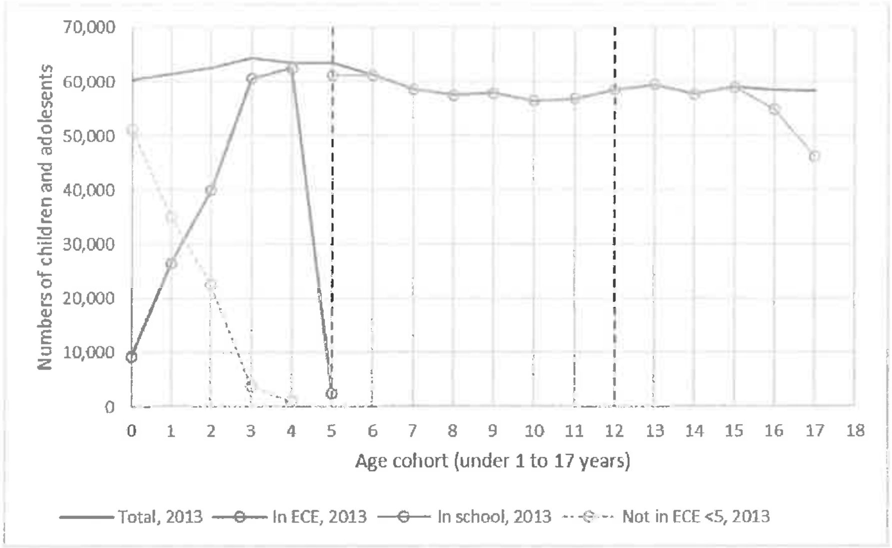
The framework for the measurement of costs is a standard budgetary model. Using data on the population of children in early childhood education, in the community, and in primary school, we estimate the required number of volunteer supervisors and the resulting required number of dental educators based on certain assumptions.

In Figure 2 below, we show the numbers of children and adolescents (under age 18) by age[9] [10] segmented into the numbers in primary and secondary school, in early childhood education (ECE) and not in ECE. This segmentation of the population is used to calculate the required number of volunteer brushing supervisors and dental educators. It is also the population that benefits directly from the

[9] Ministry of Education, Annual Childhood Education Census Report 2014.
[10] Ministry of Education, School Rolls 2010-2015, Time Series for Student Numbers.

tooth-brushing education programme and on whose behalf DHBs incur dental care costs.

Figure 2: Population cohorts under age 18 and educational attendance



Dental educators are assumed to be salaried employees of District Health Boards (DHB) and under this proposal are provided with a car. Meetings, professional development and other administrative jobs are expressly allowed for as programme leadership and management costs.

Voluntary brushing supervisors are assumed to be parents, grandparents or other caregivers who stay on to assist with supervising of daily tooth-brushing sessions. There is likely to be a naturally high turnover of volunteer supervisors necessitating on-going training of new volunteers.

Key variables that have to be determined and addressed by assumptions, include:

- the ratio of children to each volunteer;
- the turnover of volunteers;
- the training time and group size for new volunteers and monitoring and refresher training;
- the dental-educator workforce salary, overheads and vehicle running costs and programme management and administration staff requirements; and
- the supplies of publicity materials, toothbrushes and toothpaste.

The monetary costs of the programme (salaries, overheads and expenses, materials and tooth-brushing supplies) are resource costs to the nation and fiscal costs to the government falling within the Health budget.

No allowance is included for costs that might arise if school facilities are inadequate and additional school facilities need to be built.

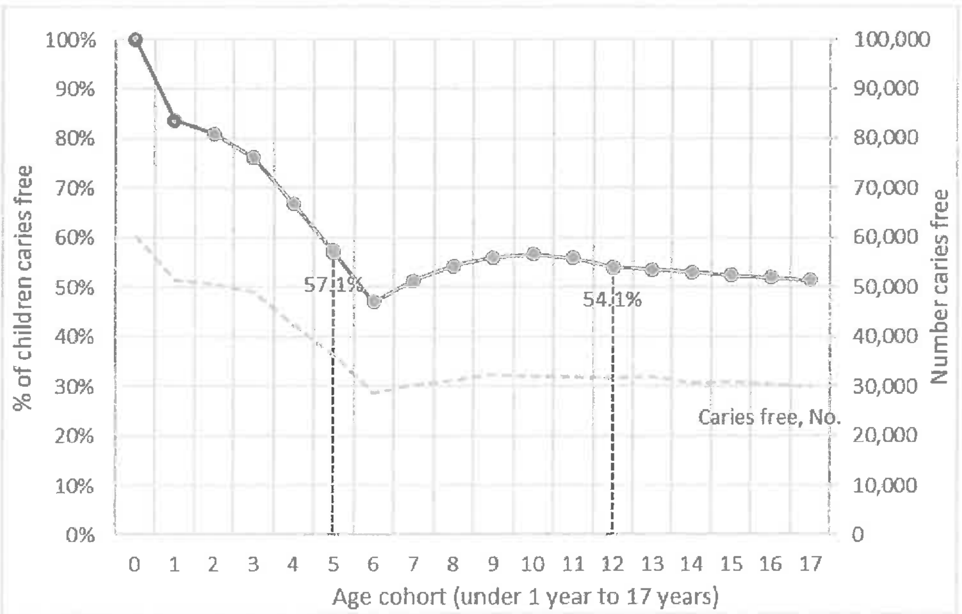
3.3 Measurement of benefits

The approach used in this report is to measure the benefits of the programme based on extrapolation of the expected reduction in dental treatment as shown in results from clinical and field trials. There are a number of methodological challenges in attempting to apply a NCBA framework in this context. These factors are common to all analyses of this nature and in undertaking this assessment we have used generally accepted practices consistent with those used in other similar analyses, taking a more conservative approach in some situations. In summary, these factors are:

- the way dental-health statistics are reported;
- causality, what caused the change; and
- the distinction between the prevention and delay of the onset of dental caries.

The first matter relates to the way dental-health statistics are reported. These are typically reported as averages of individual teeth or tooth surfaces affected at age five or in year eight of school (roughly corresponding to age 12 years), or for broad age group ranges (e.g., for under five year olds and five to 11 year olds). Studies of the effects of preventative dental care are also reported in a similar way. Such studies report, for example, such factors as a level of change in the percentage of five-year olds without visible dental caries. In this analysis we have created a synthetic system of weights that align to the point averages and broadly align to the multi-year averages (see Figure 3). This provides a mechanism to scale reported effects such as the effects on age five children in Scotland or age 15 year adolescents in Denmark onto the New Zealand population. Figure 3 below sets out a chart of the system of scalars adopted that relate to the imputed rates of children and adolescents that are free of obvious dental caries by age cohort (in the range from under-one years to 17 years of age).

Figure 3: Age cohort scalars relating to observed caries-free at age 5 and year 8 (2013)



Note: Orange dots are actual caries-free rates. Blue dots are imputed caries-free rates for the age cohort.

The second matter relates to causality. Dental caries is the result of many influences including hereditary, diet and other diseases affecting the individual, as well as oral hygiene. Extrapolation on the basis of the number of teeth (or surfaces) saved can be fraught by these contextual factors as they influence the susceptibility of individuals to dental caries.

The third matter for consideration, as previously referred to, is the distinction between prevention and delay of the onset of dental caries. The distinction is important as each has a different economic value. By delaying what may be an inevitable cost of treatment, preventative care reduces the present value of the future treatment costs. Further, future treatment costs may be quite different if treatment technology changes. The expected time at which the tooth becomes affected and the discount rate applied to future treatment costs are therefore relevant to the comparative economic value of preventative treatment. Using *tooth saved* measures are inherently short term, as the same tooth may later experience decay. In other words, the preventative care programme may not have saved the tooth at all, but merely delayed the on-set of decay (by an unknown amount of time). There is currently no accepted methodology that translates tooth-saved measures to treatment deferred.

Moreover, we cannot know that the benefits of a preventative dental health programme will persist into adulthood. There is some evidence that oral-hygiene practices deteriorate with age, to a greater degree in males than females. So, if after leaving school, adolescents who have been exposed to the programme return to background tooth-brushing habits, their level of dental caries may well return to background levels as well. In this scenario, there is little or no lasting benefit beyond the treatment deferral savings that have accrued to the government.

Taking the above limitations into account, we have done three things in this report to ensure the benefit assessment is conservative. We have:

- adopted a conservative approach to extrapolating differences in tooth-saved measures;
- focussed effect measures on the population aged 17 years and under who receive subsidised dental treatment; and
- avoided assuming the effects can be simply extrapolated to the adult population at large.

The main measure of benefit used in the literature on preventative dental programmes is avoided treatment. There are several measures of this effect: the number or percentage of an age group that is (observably) caries free; the average numbers of teeth affected; and the average numbers of tooth surfaces affected. The measures also account for teeth extracted (missing) due to decay. There is potential distortion if surface measures are used. This is because there is no way of comparing the missing surfaces of an extracted tooth with filled surfaces. Extraction is a cheaper option than a complex filling. The decision to repair or extract an affected tooth is a conscious decision on the part of the tooth's owner, parent or caregiver. For this reason, we have focussed on "teeth" (DMFT or dmft) and used weighted average treatment costs that include simple and complex repair costs as well as extraction costs.

Another issue of some importance is to quantify how many teeth are saved if one individual is free of dental caries. As noted above, in New Zealand, in 2013, 57 percent of five year olds (2013) had no dental caries (dmft=0). The median rate of dental caries for five year olds was 1.88 (dmft=1.88); an average of the dental caries in the children with decay (43 percent) and those without decay (57 percent). By dividing 1.88 by (100% – 57.5%) we are able to calculate an implicit number of teeth with dental caries among five year olds with dental caries. On average the "with dental caries" children have 4.41 teeth affected. Thus, preventing the development of dental caries in one five-year-old child reduces the need for treatment of 4.41 teeth (for children in year eight the corresponding figure is 2.28 teeth (DMFT+dmft=2.28) per child with decay).

This only gets us part of the way to establishing the potential number of teeth saved by preventative care. A further matter is the pattern of eruption and loss of primary and permanent teeth. The number of teeth in a child's mouth is changing year by year until about age 14 years. Children entering early childhood education from age 3 will typically have their full set of 20 primary teeth. Between ages 6 and 14, primary teeth are progressively lost and replaced with erupting permanent teeth. We have used a standard pattern for eruption of and loss of each tooth to provide a model of the mix of primary and permanent teeth at each age. Table 2 below shows our estimate of the number of teeth saved from treatment when a child or adolescent is free from dental caries.

Table 2: Mean averted teeth treated per child or adolescent

	Under 18 year olds	<5 years	Primary 5 – 12 years	Secondary 13-17 years
Weighted average dmft & DMFT	3.68	4.41	3.93[1]	2.48

1. Weighted average reflects the changing number of primary (dmft) and permanent (DMFT).

Dental restorations have a finite lifespan: an average of 12.8 years for amalgam and 7.8 years for composite resins[11]. With a 62:38[12] mix of composite and metallic fillings this is a weighted average replacement time of 9.7 years. Thus, a child or adolescent who receives a restoration to a permanent tooth at age 15 years could expect to have that restoration replaced six times in his or her lifetime (from age 25). Avoiding a restoration thus avoids the present discounted value of the six future restorations as a private benefit to the individual. In line with statistics on missing teeth in adults, we assume that at each repair, 2.7 percent of teeth are extracted.

3.4 Monetising the benefits

To ascribe a monetary value to teeth saved from decay or extraction we need an estimate of the cost of treatment avoided. Sapere[13] provides a weighted average treatment cost for children of $84 for restorations, $58 for simple extractions and $1,900 for a hospitalisation (2013$). Sapere based its cost estimates on government funding for dental care to under 18 year olds. Dentists are paid by DHBs for a package of oral health services including preventative treatments and basic restorations. In addition, DHBs provide a tariff for extractions and more complex restorations by dentists that do not require prior approval. The tariff ranges from $58 for an extraction under local anaesthetic to $99.99 for a non-metallic restoration in more than one surface. The resulting $84 per avoided tooth (in 2013$) was

[11] Van Nieuwenhuysen JP, et al "Long-term evaluation of extensive restorations in permanent teeth". J Dent. 31 (6) 2013.
[12] Sapere, op. cit., page 35.
[13] Ibid page 37.

derived from 40:60 single surface/ multi-surface fillings and a 62:38 mix of composite and metallic fillings.

Sapere also reports the costs of dental treatment for adults from the New Zealand Dental Association's fee survey[14]. Sapere notes a considerable variation in the costs of treatment reported by dental practices and settles on $200 per extraction and $247 per restoration (in 2013$). We use the same avoided cost in our estimate of the continuing private benefit.

3.5 Monetary amounts

Unless indicated otherwise, all monetary amounts are expressed in real 2013 money's worth (2013$).

3.6 Discounting and discount rate

In an analysis where costs and benefits fall in different time periods it is necessary to use the technique called discounting to allow for the observable fact that money (and resources) has more value today than in the future. Discounting to a present value is achieved by multiplying a future dollar amount by a discount factor that is calculated from the discount rate.

Discounting future costs in a cost-benefit analysis is uncontroversial. Applying discounting to health-related benefits is controversial. The main reason for controversy is that it is not possible to "invest" avoided detrimental health. Many economists nevertheless hold the view that future health gains should be discounted.

The Treasury[15] provides specific guidance on the discount rates to be used in cost-benefit analysis in public sector decisions. The default rate is 7 percent per annum in real pre-tax terms. This recommended discount rate is used in this report.[16] In most cost-benefit analyses the choice of discount rate will not affect the relative ranking of the options unless there are differences in technology resulting in different patterns of short-run and long-run costs and benefits. However, it is good practice to establish whether the results are affected by the discount rate by a sensitivity analysis using different discount rates.

Overseas studies of tooth-brushing education programmes show that benefits arise almost immediately the programme commences. Evidence from Scotland shows, for example, declining decay rates among five year olds occurring almost simultaneously with widening coverage of the programme. This is reasonable since at the onset tooth brushing both retards the development of soft spots into caries and prevents the formation of new soft spot that could progress into future caries. No lumpy capital costs are incurred. So, it is reasonable to compare steady state annual costs and annual estimated benefits.

For completeness, we provide a start-up scenario evaluated over 20 years that compares the evolution of benefits over time with the start-up and on-going programme costs.

[14] Ibid, page 36.
[15] The Treasury, Current Discount Rates retrieved from www.treasury.govt.nz
[16] See for ample, Sapere, op cit, page 28 which used a 3.5 percent p.a. discount rate.

3.7 Social investment approach

The proposed national tooth-brushing education programme is an example of a social investment approach. Social investment is intended to put the needs of people who rely on public services at the centre of decisions on planning, programmes and resourcing. The proposed national tooth-brushing education programme is consistent with the social investment principles through:

- a particular focus on children at risk of dental caries;
- investing up-front to support people most at risk of poor health outcomes later on in life;
- commissioning services within communities; and
- interacting with households through a trusted relationship with the school or ECE centre.

The upshot of the social investment approach is early investment and intervention to achieve better long-term results for people and reducing overall reliance on health or social services with their attendant cost to taxpayers.

In terms of the role of the volunteers, if we look at volunteer service through the lens of an economist there is both economic value created and an economic cost incurred:

- there is an opportunity cost for the volunteers of spending time (a limited resource) on unpaid work as opposed to paid work, household work or leisure; and
- there is economic value from the social capital generated, i.e., the intangible benefits associated with volunteering such as social cohesion, social awareness, trust, goodwill, and improved socio-economic outcomes.

Work is valued by what it is paid. Statistics New Zealand provides an estimate of the value of volunteer time of $22.10 per hour in 2013[17]. Measuring the economic value from the social capital generated by volunteer work is more problematic[18]. The one thing we can be confident about is that the value of volunteer work to the volunteer is worth at least as much as the opportunity cost. Economists frequently use "willingness to pay" as a substitute for economic value in cost-benefit analysis when there is no other means of measurement.[19] Rather than add the same amount to benefits and costs we instead omit the value and costs of volunteer time from the cost-benefit analysis and include it instead as a memorandum item.

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[17] Statistics New Zealand (2015). Non-profit institutions satellite account: 2013.

[18] See Spellerberg, A. Framework for the Measurement of Social Capital in New Zealand, Statistics New Zealand, 2001.

[19] See Adler, MD and Posner EA, New Foundations of Cost-Benefit Analysis, Cambridge Mass: Harvard University Press, 2006.

4. Overseas experience

Overseas examples of preventative dental health improvement programmes provide relevant insights for New Zealand.

While each case is different contextually, and in approach, they all provide valuable lessons. Below we describe the programmes developed in Scotland and in Denmark, and where similar programmes have been adopted. The impacts from the Scottish and Nexø programmes have been measured and the result published in authoritative peer-reviewed journals.

4.1 Scotland's Childsmile programme

Since 2011 the Scottish National Health Service has been delivering Childsmile to all Scottish children and their families[20]. The programme has also been implemented in Wales as *Cynllun Gwên* (Designed to Smile). University of Glasgow researchers working in the field of community dentistry were central to the establishment of Childsmile.[21] In the late 1990s, the University of Glasgow Community Oral Health group employed a community-based approach for a programme of dental-health improvement for children in some of Glasgow's most deprived areas. From this beginning developed a programme now called Childsmile.

Childsmile has the following three elements:

- the Childsmile Core programme. Every child is provided with a dental pack containing a toothbrush and a tube of fluoride toothpaste on at least six occasions by the age of five. Three and four year olds attending nursery have daily, supervised tooth brushing according to national tooth-brushing standards;
- the Childsmile Nursery and Childsmile School programmes deliver fluoride varnishing for children aged 3 and upwards who are identified as living in the most deprived areas; and
- in addition, the Childsmile Practice programme is being developed to provide a universally accessible child-centred dental service. Contact with children is from the age of three months. Additional support is given to the children and families most in need through home visiting, community initiatives and primary care dental services. Oral health advice includes advice on healthy weaning, diet, teething and tooth-brushing instruction.

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[20] National Health Scotland website.

[21] See Blair Y, et al, Glasgow nursery-based caries experience, before and after a community development-based oral health programme's implementation, Community Dental health 2004.
Macpherson LMD, et al, National supervised tooth brushing program and dental decay in Scotland, J Dent Res 2013.
McMahon AD et al, Reductions in dental decay in 3-year old children in Greater Glasgow and Clyde: repeated population inspection studies over four years. BMC oral health 2011.
Macpherson LMD et al, Childsmile: the national child oral health improvement programme in Scotland. Part 1: establishment and development, British Dental Journal 2010.

Childsmile stands out because it is an evidence-based preventive care programme that evolved in the field and has been rolled out nationally[22] with measurable impacts on the target population group.

Before the widespread introduction of Childsmile, dental caries was present in 54 percent of Scottish 5-year-olds (2000), rising to 79 percent among those from the most deprived backgrounds. These figures are roughly comparable to the current New Zealand situation for five-year olds. Since the introduction of the national tooth-brushing initiative (2001), and later the start of the Childsmile programme (2006), levels of dental caries have decreased dramatically in 5-year-olds. Dental caries was evident in 42 percent in 2008, 36 percent in 2010 and 33 percent in 2012. Dental caries in the most deprived children reduced from 79 percent (2000) to 55 percent (2010)[23]. 55 percent is roughly the level of dental caries in New Zealand for five year olds living in non-fluoridated areas.

In 2011, in direct response to the demonstrated benefits, Childsmile was formally extended to cover all children from birth to 12 years of age in Scotland.

In the 2012 oral health survey[24], 67 percent of five year olds were free of dental caries and the average number of affected teeth was 1.35 (dmft=1.35). A decade earlier the corresponding figures were 44.6 percent and 2.76 (dmft=2.76). Scottish health authorities report no decrease in childhood obesity rates or in deprivation[25], suggesting that it is the dental health programme that is making the difference.

4.2 "Nexø Method"[26]

A related programme to Childsmile is the Danish dental health programme called the "Nexø Method". This started as a demonstration project from 1987 to 2005 by the Nexø Public Dental Health Service. Nexø is a low socio-economic area of Denmark where dental caries was high at that time. The "Nexø Method" consisted of a non-operative caries treatment programme with the following components:

- access from 8 months of age;
- early education of parents using principles of motivational interviewing to establish good habits from the very beginning instead of changing inadequate ones later;
- non-operative caries treatment for at-risk children;
- tooth-brushing training; and
- a focus on tooth brushing during the eruption period of permanent molars, generally between age 6 and age 14.

[22] Although Scotland's total population is 5.3 million compared to 4.6 million in New Zealand, Scotland has 30 percent fewer children than New Zealand aged 12 and under.
[23] Minister for Public Health Michael Matheson, media statement 10 November 2013, The Scottish Government.
[24] The Scottish Government, Health of Scotland's population – Dental Health 2014.
[25] The Scottish Government, Scottish Health Survey 2014, Topic Report Obesity and Topic Report Equality Groups.
[26] See Ekstrand K, A Non-operative Caries treatment Programme Nexodent – the Nexø Method. Caries data from Denmark National Board of Health.

This strategy led to a remarkable decline in dental caries, especially amongst teenagers, compared to the background Danish national experience. Later, the Nexø Method was integrated into the Danish public dental health services. In 1986/87, 15 percent of Nexø 15 year olds were free of dental caries and the mean number of affected teeth was DMFT=5.04. By 1999, 71 percent of Nexø 15 year olds had no obvious dental caries (mean affected teeth DMFT=0.68). In the same year, among the general population of 15 year olds in Denmark, 33 percent were free of obvious dental caries (DMFT=2.42). By 2004 the difference was 79 percent and 40 percent respectively.

The Nexø experiment provided a rare opportunity to compare the "before and after" and "with and without" effects of the programme.

The Nexø programme was tested on a group of children in Moscow from 1994 to 1996 including a randomised control group. 18 years after the 2½ year intervention, a follow-up study found a long-term positive effect of the programme[27].

The Nexø programme was also adopted by Community Dental Services in Greifswald, Germany as preventive measures in kindergartens and schools. The combination of targeted brushing and fluoride toothpaste was promoted in parent meetings and in the training of kindergarten educators and school teachers, as well as during the weekly or daily brushing. The programme was mostly supported by the community preventive dental assistant for the institutions with the highest caries levels. Kindergarten teachers also helped children with special needs and teachers were responsible for the weekly brushing with fluoride toothpaste. Tooth decay in Greifswald dropped from exceptionally high levels to below the mean values in the federal state of Mecklenburg-Vorpommern and in the whole of Germany. Amongst 15-year-olds, a dental caries decline of 70 percent was recorded while representative data in the federal state only decreased by 50 percent[28].

In 2008, the mid-sized Finnish city of Laukaa launched a still on-going health education project called the "Tooth Brushing School". The "Tooth Brushing School" was based on methods used in Nexø. The aim of the project was to have all children under 12 years of age and their parents and care givers attend the "Tooth Brushing School." In addition, in all Laukaa schools, oral health lessons were, and still are, organised every year with a specific theme. The themes have varied from healthy diet to dental caries. Examples of earlier themes are Snacking; The Little Ones Follow the Big Ones' Example; and Good for Mouth, Good for You[29]. We are not aware of any studies evaluating the effectiveness of the Laukaa programme at this stage.

4.3 Discussion

Scotland and several places adopting the Nexø Method have achieved significant and verifiable reductions in dental caries among school age children. The common elements of the programmes have been:

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[27] Reported in Vermaire, E, Optimizing Oral Health. Towards a Tailored, Effective and Cost-effective Dental Care. Sourced from www.ivorenkruis.nl/userfiles/File/Proefschrift_Erik_Vermaire_final.pdf.

[28] Vermaire, E, op cit.

[29] See Gajanan K et al eds., Oral Health Promotion in Infants and Children: Models and Long-Term Effectiveness. International Journal of Dentistry 2014.

- education of parents and children in understanding that dental caries is a disease;
- training of parents and children in the techniques of proper tooth brushing and to instil the habit of regular oral hygiene; and
- early identification of at-risk children for professional non-invasive treatment.

The programmes are different in important ways. Childsmile focuses on pre-school and primary-school children while the Nexø Method concentrates on primary school and early adolescents during the phase of eruption of permanent teeth.

One matter raised by the overseas experiences that has implications for this analysis is whether there is a practical limit to the effectiveness of tooth brushing. In both the Scottish and European examples, the levels of dental caries free individuals increased dramatically. However, there seems to be a "ceiling" at around 80 percent caries free. One interpretation is that although in-school tooth brushing has the capability to make a difference to children and adolescent teeth, especially if background dental hygiene habits are poor, it is not of itself a complete solution to dental caries. In our analysis we have taken 80 percent caries free to be a practical limit on the effect of tooth-brushing education programmes in pre-school and school. This imposes a downward bias to the estimates of benefit from the which otherwise would reach above 90 percent caries free, above level observed overseas.

5. Estimating programme cost

5.1 Programme design assumptions

We have used a population-served approach to work out estimates of the number of dental educators required to train volunteer supervisors and to monitor tooth-brushing performance.

The number of pre-school and primary-school age enrolments for the year ended June 2013 was used as the base year to align with dental-health statistics. In that year, 192,000 children were enrolled in ECE, 122,000 aged under 5 were not in ECE, and 470,000 children were in primary school or intermediate. In total, there were 784,000 children aged between under 1 year and 12 years of age.

The additional dental educator workforce requirement of 50 educators was estimated using the following assumptions:

- new volunteer supervisors receive two hours initial training and all supervisors receive two half-hours of refresher training and/or supervision per annum from a dental educator;
- the dental educator training and supervision workload is determined by the number and turnover of volunteer supervisors;
  - one volunteer supervisor for 12 children in ECE, 1 for 8 children not in ECE and 1 for 30 in primary school;
  - a 33 percent annual turnover of volunteer supervisors for under 5 year olds and 20 percent for primary school;
- training occurs in groups of ten volunteers; and
- dental educators work standard public service hours with a weekly time allowance for administration and meetings as well as breaks and leave.

Tooth-brushing sessions are assumed to occur daily in ECE and primary schools and twice weekly for children not in ECE. Tooth-brushing sessions are assumed to take on average 30 minutes for children aged under 5 and 15 minutes for primary school children.

The required number of volunteer supervisors is 47,000 or one for every 17 children in the programme.

In addition, an estimated nine staff would be required to manage and administer the programme regionally and nationally.

5.2 Cost estimates

5.2.1 Staff and related costs

Staff and related costs for the dental educator workforce, programme management and administration were estimated using the following assumptions:

- dental educators receive an annual salary of $60,000, programme manager(s) receive $80,000 and administrators receive $53,000 and assistants $40,000;

- dental educators have access to a motor vehicle with annual running cost (including depreciation) of $6,500; and

- overhead costs are estimated at 85 percent of staff costs for dental educators and 100 percent for office staff.

Using the above assumptions, the annual staff and related cost of the tooth-brushing education programme is estimated at $6.8 million.

5.2.2 Publicity

$0.5 million is allowed annually to cover the cost of a website aimed at young children and their care givers as well as postage, publicity, advertising and other material (including obtaining consent).

5.2.3 Tooth-brushing supplies

The cost of tooth-brushing supplies is worked out from the following assumptions:

- all supplies are purchased at a 20 percent discount to wholesale cost;

- both regular and infant-sized toothbrushes are used as age appropriate;

- four toothbrushes per child are issued each year (at the start of each term) and a 25 percent wastage factor is included for toothbrushes that are discarded for having been dropped or otherwise contaminated; and

- toothpaste is issued in 25g "pea"-sized doses with 25 percent wastage.

The expected annual cost of toothbrushes is $3.0 million.

The expected annual cost of toothpaste is $1.4 million.

5.2.4 Volunteer time

The time of volunteer supervisors has both an opportunity cost and an economic value. Based on 2.1 million hours of volunteer time per annum, the imputed opportunity costs of this element is $47 million per annum. The economic value is not measurable, but based on the willingness to pay principles discussed in the section on methodology, the economic value created must be at least equal to this amount.

5.2.5 Costs summary

In Table 3 below we summarise the estimated annual costs of the national tooth-brushing education programme for pre-school and primary school children from different perspectives.

Table 3: Tooth-brushing education programme estimated costs

	Programme costs	
	$m	$ per child
Total Staff & Related Costs	$6.78	$6.39
Toothbrushes and toothpaste	$4.32	$4.07
Materials & supplies	$0.56	$0.53
Total financial & opportunity costs	**$11.66**	**$10.98**

From a national perspective, the resources absorbed by the programme amount to approximately $12 million p.a. or around $11 p.a. per child in the programme. This is also the estimated financial cost to the government via the Health budget. It is possible that this fiscal cost might be reduced to around $7.3 million p.a. ($7 per child p.a.) if sponsorship was available for the tooth-brushing supplies.

5.3 Cost allocation by DHB

In the following table, we allocate the dental educator workforce and programme cost by DHB based on the potential numbers of children and adolescents in the programme.

Table 4: Allocation of dental educators & annual programme costs by DHB

DHB		Dental educators	Annual programme costs: Dental educators	Admin	Tooth-brushes	Tooth-paste	Other	Total
		No.	$000	$000	$000	$000	$000	$000
Northland	3%	1	149	23	75	34	14	$295
Waitemata	11%	6	675	104	340	156	64	$1,340
Auckland	9%	4	507	78	255	117	48	$1,006
Counties Manukau	13%	6	773	119	389	179	74	$1,533
Northern region	36%	17	2,104	325	1,059	486	201	$4,174
Waikato	9%	5	529	82	267	122	51	$1,051
Lakes	2%	1	146	22	73	34	14	$289
Bay of Plenty	6%	3	328	51	165	76	31	$650
Tairawhiti	1%	1	84	13	42	19	8	$167
Taranaki	3%	1	174	27	87	40	17	$344
Midland region	21%	11	1,261	195	635	291	120	$2,502
Hawkes Bay	4%	2	249	38	125	57	24	$493
Midcentral	4%	2	230	36	116	53	22	$457
Whanganui	2%	1	116	18	58	27	11	$230
Hutt Valley1	3%	2	205	32	103	47	20	$406
Capital & Coast1	5%	3	314	48	158	72	30	$622
Wairarapa	1%	0	53	8	27	12	5	$105
Central region	20%	10	1,166	180	587	269	111	$2,313
Nelson-Marlborough	3%	2	180	28	91	42	17	$358
West Coast	1%	0	46	7	23	11	4	$92
Canterbury	12%	6	701	108	353	162	67	$1,391
South Canterbury	1%	1	81	13	41	19	8	$161
Southern	6%	3	338	52	170	78	32	$670
Southern region	23%	12	1,346	208	678	311	129	$2,671
New Zealand	100%	50	5,877	907	2,958	1,358	561	$11,660

5.4 Breakeven requirements

The first most logical question is to test the reasonableness of the breakeven position. In other words, what change in the level of children and adolescents under 18 years that are free of dental caries would justify the cost of the proposed programme?

The required change in the caries-free percentage among the benefit group is 3.7 percentage points.

Around a four percentage point reduction in the incidence of dental caries is necessary for the programme to be financially viable. The evidence on achievability from two programmes overseas is, as noted in sections 4.1 and 4.2 above:

- over two years after the introduction of the programme in Nexø (1989 to 1991) the dental caries free rate for 15 year olds increased from 25.5 percent to 48 percent. Four years later it stood at 65.5 percent; and

- in Scotland, a 6.1 percentage point improvement in the percentage of caries-free of five year olds was recorded between 2002 and 2004 while national tooth brushing was only partially implemented. The average two-yearly improvement in the dental health of five year-olds since 2002 has been 4.5 percentage points.

On the basis of this evidence, it seems fairly safe to conclude that breakeven on the costs of the programme could be achieved through the required 4 percentage points more children and adolescents being free of obvious dental caries.

In the next section we estimate the possible benefits of a national tooth-brushing education programme for pre-school and primary school children.

6. Assessment of potential dental health effects

In this section we assess the potential benefits of tooth brushing in pre-school and primary school (children age 12 and under) on the whole population of children and adolescents under age 18 (the benefit group). The benefit group is the 1,075,000 (2013) members of the population under 18 years who are in receipt of subsidised dental care. We have avoided extrapolating beyond this group as there is limited evidential basis for understanding how preventative care in children and adolescents affects the dental health of adults.[30]

We have, however, assumed that the benefit group experiences a lasting benefit for the rest of their lifetime from avoiding a filling in a permanent tooth during adolescence.

6.1 Oral health benefit simulation scenarios

We now turn to making estimates of the likely size of the resulting benefits to society as a whole of the tooth-brushing education programme.

The idea behind simulation scenarios is to establish systematic models about possible future states of the world (scenarios).

Scenario development starts by dividing our current knowledge into things we believe we know something about and elements we consider uncertain or unknowable. The first component casts the past forward. For example, we make assumptions about the benefit group and their dental health remaining unchanged in the absence of a tooth-brushing education programme. The second element is the outcome of a decision to introduce the tooth-brushing education programme in schools. The art of scenario development lies in blending the known and the unknown into a limited number of internally consistent views of the future that span a range of possibilities.

In the simulation scenarios we have developed, the estimated dental-health benefits are the avoided cost of treatment in children and adolescents that have lower rates of dental disease than observed in 2013. We take a conservative approach in estimating the benefits in that we focus exclusively on the benefits arising from avoided treatment costs and make no allowance for the other benefits such as avoided pain and suffering, time off school and time off work for parents and carers and resulting lost productivity.

6.2 Childsmile scenario

As noted above, the Childsmile programme resulted in the percentage of dental-caries-free children at age five increasing from 54 percent to 67 percent. This is a 13 percentage point improvement in caries-free five-year olds. The hypothetical question being answered here is: what if NZ five year olds had the same rate of improvement in dental caries as occurred in Scottish 5 year olds and this persisted across the benefit group? What would be the saving in treatment costs for the benefit group?

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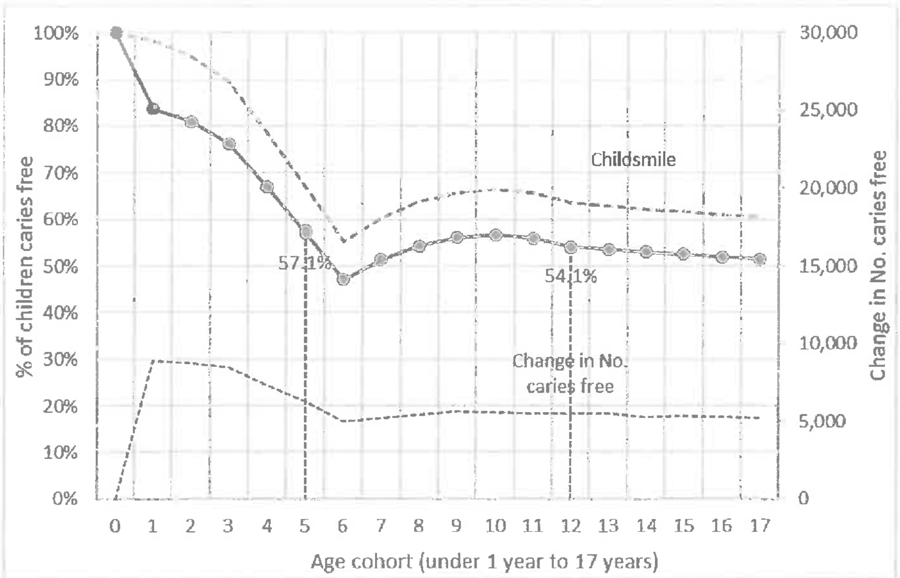
[30] Evidence for 18-year olds in the Nexø trial is patchy but indicated that the decay-free rate was lower than for 15-year olds by about one-third, but nearly twice as many 18 year olds were caries free compared to the background Danish population aged 18 years.

This scenario corresponds to sound teeth levels for New Zealand five year olds corresponding to the proportion obtained in Scotland in 2012, one year after Childsmile was rolled out nationally.

Figure 4 below shows the simulation of the Childsmile programme in a New Zealand context. In broad terms, the scenario being simulated is a fairly uniform vertical shift in the numbers of children and adolescents in the benefit group. The size of the vertical shift corresponds the shift in caries-free five-year olds that occurred in Scotland to 2012 (13 percentage points).

Figure 4: Simulation of Childsmile experience in New Zealand

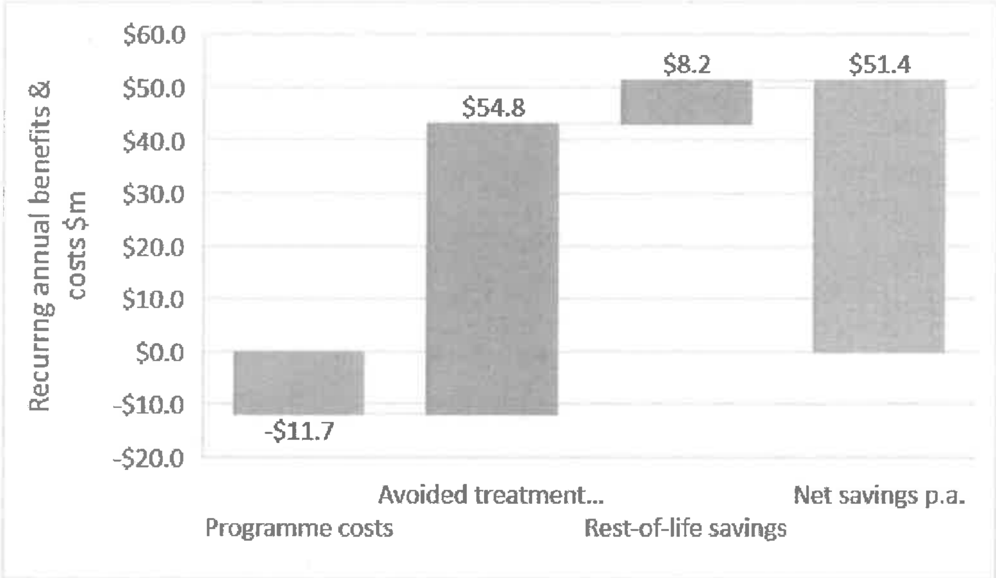


The vertical gap between the lime green and blue curve in Figure 44 represents the benefit in terms of the percentage of children in each age cohort who would have needed dental treatment if the programme has not been implemented. The blue dotted line shows the absolute number of children in each age cohort benefiting.

We estimate the total annual avoided treatment costs for the benefit group to be $53 million pa. This estimate includes 314 fewer infant hospital admissions each year for dental related issues. The benefits accrue differentially by age group: 44 percent to pre-school children, 41 percent in the treatment of primary school treatment (age 5 to 12 years), and 17 percent amongst 13 to 17 year olds.

In addition, over their lifetimes, the individuals save an additional $8 million p.a. from avoiding replacements or extractions as adults. After allowing for the $11.7m p.a. programme costs, the total expected national benefit from the programme has a present value of $51 million p.a. (refer Figure 5 below).

Figure 5: Recurring steady state benefits and costs of Childsmile scenario



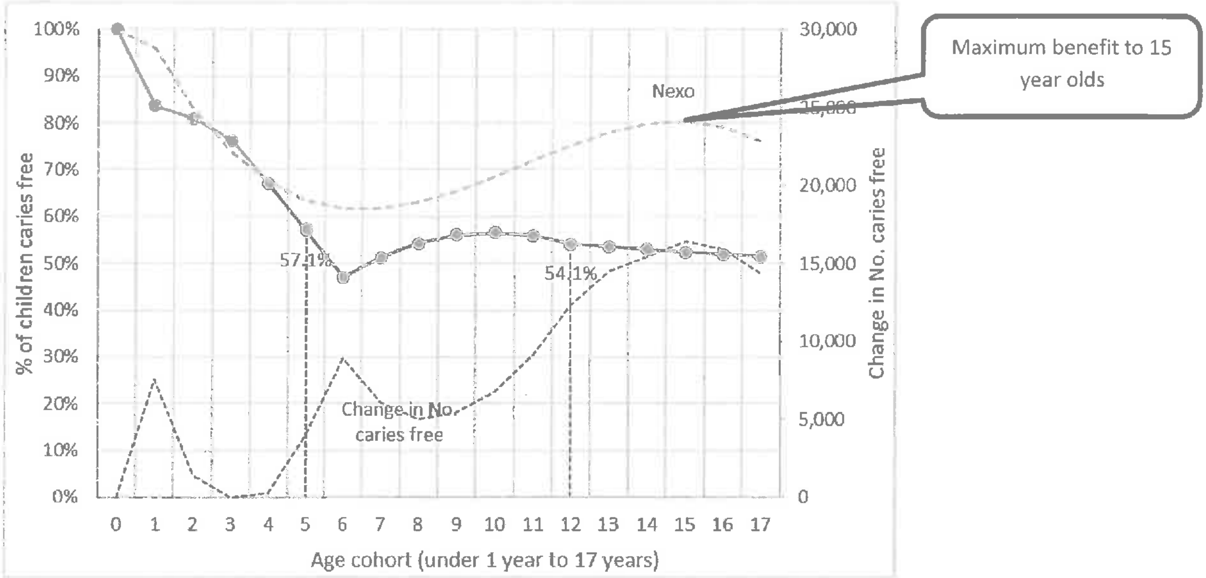
6.3 "Nexø Method" scenario

As noted above the Nexø programme resulted in the percentage of dental caries free 15 year olds increasing from 15 percent to 71 percent. This is a 56 percentage point improvement. The hypothetical question being answered is: What if New Zealand five and 15 year olds had the same improvement in dental caries as in Nexø after the method programme? What would be the saving in treatment costs?

Rather than applying the full 56 percentage point improvement, we have capped the level at 80 percent caries free. Otherwise the scenario would have almost all New Zealand adolescent caries free, with the improvement all attributable to the in-school tooth-brushing education programme. This seems implausible in the absence of other changes in dental hygiene and diet that could not be directly attributable to the programme.

Figure 6 below shows the simulation of the Nexø programme in a New Zealand context. In broad terms, the scenario being simulated is a differential vertical shift in the numbers of children and adolescents in the benefit group. The size of the vertical shift corresponds the shift in caries-free five-year olds and 15 year olds that occurred in Nexø relative to the background Danish population.

Figure 6: Simulation of the Nexø experience in New Zealand



In Figure 6 the gap between the lime green and blue curves represents the benefit in terms of numbers of children in each age cohort who do not require dental treatment. In the Nexø case, there was a greater improvement of the dental health of 15 year olds than for 5 year olds. However, the improvement tapered off by age 18. The blue dotted line shows the absolute number of children in each age cohort benefiting.

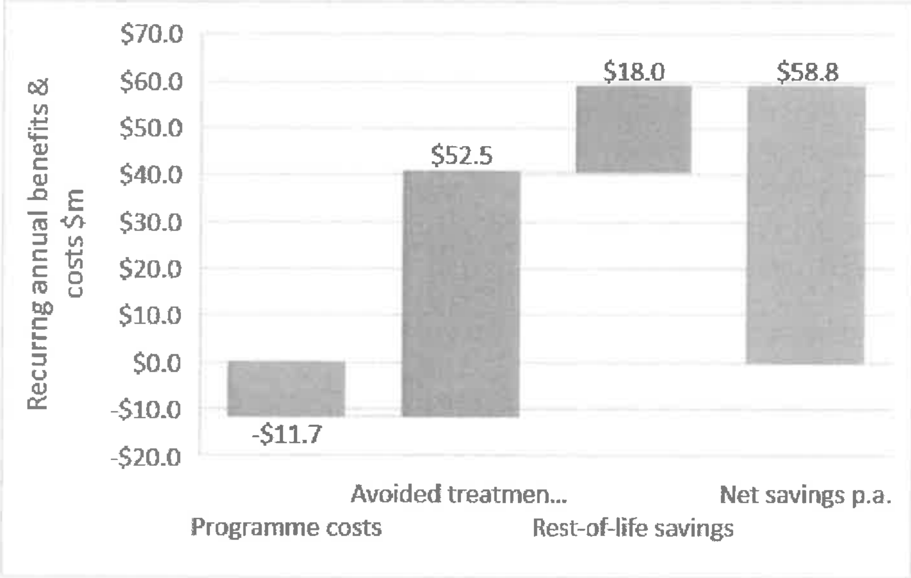
On the basis of the Nexø experience, we estimate the total annual avoided treatment costs at $53 million, including 70 fewer infant hospital admissions.

The benefits accrue differentially by age group: 10 percent to pre-school children, 55 percent in the treatment of primary school treatment, and 35 percent amongst 13 to 17 year olds.

In addition, over their lifetimes, the individuals save an additional $18 million p.a. in costs from avoiding replacements or extractions as adults.

Thus, after allowing for the programme costs, the total expected national benefit from the programme has a present value of $59 million.

Figure 7: Recurring steady state benefits and costs of Nexø scenario



6.4 Reducing disparities in New Zealand scenario

For this scenario we have considered how a tooth-brushing education programme might be rolled out across the country. The disparities amongst year 8 children (roughly 12 years of age) are not as great as for five year olds.

Figure 8: Changing rankings of DHBs between age five years old & year 8 caries free

5 year olds	Year 8	Rise	No change	Fall
Northland	Northland		x	
Nelson-Marlborough	Bay of Plenty	x		
Midcentral	Taranaki	x		
Counties Manukau	Canterbury	x		
Taranaki	Hutt Valley			x
Bay of Plenty	Tairawhiti			x
Canterbury	West Coast			x
Hutt Valley	Hawkes Bay			x
Tairawhiti	South Canterbury		x	
Wairarapa	Wairarapa		x	
Lakes	Lakes		x	
Waitemata	Waitemata		x	
Whanganui	Auckland	x		
Waikato	Nelson-Marlborough	x		
West Coast	Midcentral			x
Hawkes Bay	Counties Manukau			x
Southern	Whanganui	x		
Capital & Coast	Waikato	x		
Auckland	Southern			x
South Canterbury	Capital & Coast			x
		7	5	8

Figure 8 shows the changing rankings (worst to best) of the DHBs in terms of the dental health of 5 years old and year 8. The worst are better, the best are worse and the disparity range is 13 percentage points instead of 34 percentage points. There are disparities among the districts in the dental health status of 5-year olds, ranging from 34 percent caries free in Northland DHB district to 68 percent in

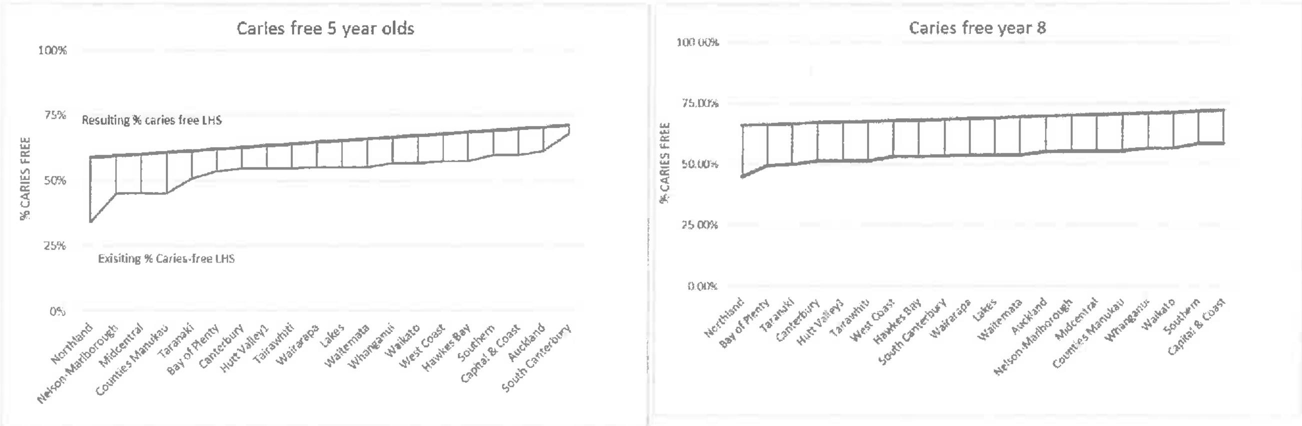
South Canterbury DHB district. In four DHB districts, the average dental health status is materially below the national average for caries-free five-year olds. Twelve DHB districts are clustered close to the mean and the remaining four DHB districts have five-year old caries-free rates over 60 percent.

Since background dental hygiene practice is a factor in the current regional disparities, it seems reasonable that the proposed programme will also have disparate effects. If children are not brushing regularly, or not brushing with fluoride toothpaste, then the introduction of daily brushing on school days is likely to affect these children more than the one in two children who brush according to Ministry of Health recommendations.[31]

We have matched this scenario to the Childsmile experience with an overall 13 percentage point improvement in caries free rates among five year olds. What this scenario seeks to illustrate is the differential effect on reducing disparities among children and adolescents around the country.

This scenario corresponds to a greater improvement in the children in the nine DHB regions that have poor dental health at age five and in year eight, or where their rankings deteriorate between age five and year eight. In Figure 9 below, the gold-coloured line shows the shift required to achieve the median level of sound teeth children in each DHB region. The grey line represents the shift required to meet the best practice amongst DHBs.

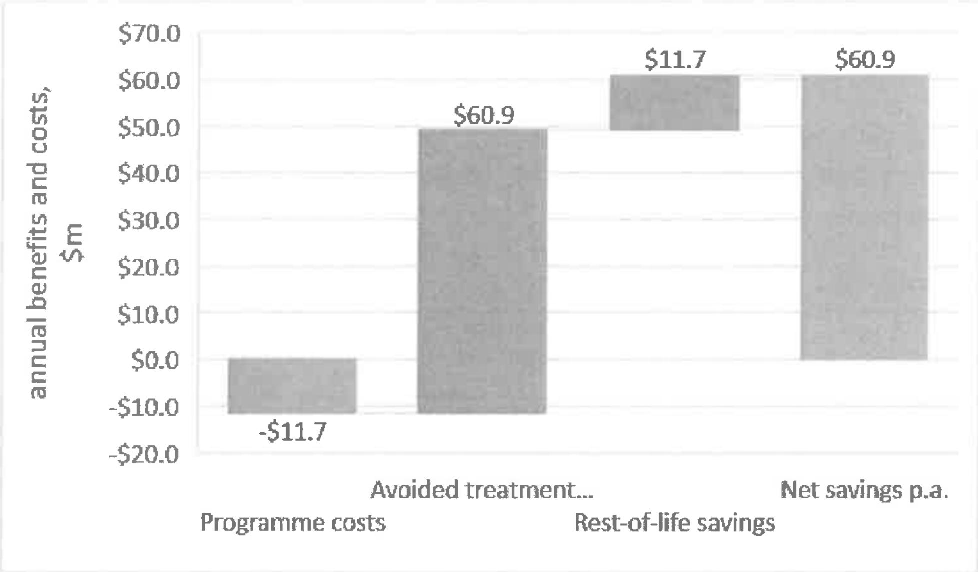
Figure 9: Simulation of reducing disparities in New Zealand



We estimate the annual avoided treatment costs from this targeting programme at around $61 million, including 253 fewer infant hospital admissions. This estimated net benefit includes a continuing benefit in adulthood of $12 million p.a..

[31] See Gowda, S, School-based tooth brushing programme in a high-risk rural community in New Zealand - an evaluation. Northland DHB, 2011.

Figure 10: Recurring steady state benefits and costs of reduced disparities scenario



6.5 Summary of estimated benefits

In sections 6.2 to 6.4 above we have presented scenarios on the possible effects arising from a tooth-brushing education programme. These scenarios are modelled on overseas experience with similar programmes. In summary, the scenarios show:

- Avoided treatment costs in under 18-year olds in the range $53 million p.a. to $61 million p.a. with a central estimate of $56 million p.a.. Avoided treatment costs accrue to the government via reduced expenditures on treating dental caries in children and adolescents.
- Consequential rest-of -life savings (for 18 year olds and older) in the range $8 million p.a. to $18 million p.a. with a central estimate of $13 million p.a.. Consequential rest-of -life savings accrue to private individuals.
- Aggregate benefit to society (public sector and private) are in the range $63 million p.a. to $73 million p.a., with a central estimate of $69 million p.a..
- Net benefits (after deduction of programme costs) in the range $51 million p.a. to $61 million p.a. with a central estimate of $57 million p.a..

As noted above, we are not imputing any additional private benefits that might arise from avoidance of pain and suffering and from any lasting effects of the programme on dental hygiene behaviours beyond age 17.[32]

[32] If there were lasting benefits from preventative tooth brushing, they would be in the range $1 million to $3 million per annum for 20 year olds (life expectancy of 62 years). These benefits, if they could reasonably be attributed to the programme, would accrue to the private individuals.

7. Cost benefit analysis conclusions

7.1 Principal findings

Summarising the estimated costs of the programme and comparing them with the estimate of the benefits from avoided treatment costs gives a range of expected recurring net benefits for a national tooth-brushing education programme.

Table 5: Summary of cost and benefits of scenario simulations

Annual recurring costs and benefits	Scotland Childsmile model	Nexø model	Reduced disparities model	Central estimate
	$m	$m	$m	$m
Savings from avoided treatment				
<5 years	$23.8	$6.1	$19.2	$16.4
Primary 5 -12	$22.6	$28.8	$29.4	$27.0
Secondary 13-17	$8.2	$18.2	$12.1	$12.9
Total financial benefits	$54.7	$53.1	$60.8	$56.2
Continuing savings for adults	$8.2	$18.0	$11.7	$12.7
Total national benefits	$62.9	$71.1	$72.5	$68.9
Programme costs				
Staff & related costs		$6.8		
Toothbrushes and toothpaste		$4.3		
Materials & supplies		$0.6		
Total fiscal & resource costs		$11.7		
Net benefits				
Financial	$43.1	$41.4	$49.1	$44.5
National	$51.3	$59.5	$60.9	$57.2

In summary, Table 7 shows the estimated net financial benefits to the government from a national tooth-brushing education programme is in the range of $41 million to $49 million annually with a central estimate of $45 million.

In national cost benefit terms, the annual estimated net benefit range is $51 million to $61 million p.a. with a central estimate of $57 million p.a. This represents a benefit: cost ratio of 5.9x.

7.2 Start-up scenario

In the foregoing we have provided estimates of the recurring benefits associated with the simulation scenarios and programme costs. The programme costs, however, may occur out of sequence from the benefit; and the benefits will evolve over time.

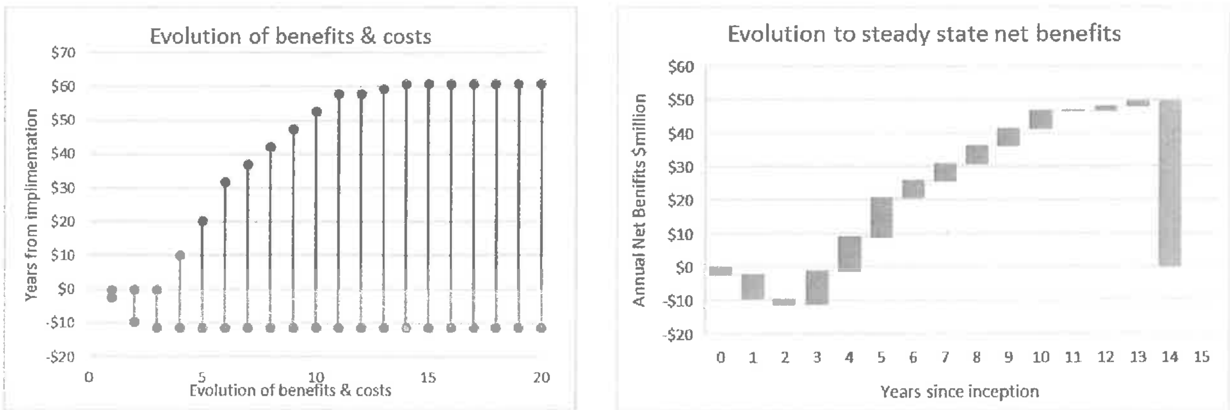
We have therefore constructed a start-up scenario which assumes:

- programme management costs commence 18 months before the programme is implemented;
- dental educators are recruited in "batches" over three years reaching full staffing levels in the second year after implementation;

- the benefits from avoided treatment in pre-schoolers emerge after two years and reach steady-state levels in the fifth year of the programme;
- the benefits from avoided treatment in primary school age children emerge after two years and reach steady-state levels in the tenth year of the programme; and
- the benefits from avoided treatment in secondary school adolescents emerge after four years and reach steady-state levels in the thirteenth year of the programme.

Figure 11 shows in the left-hand chart the evolution of the monetary benefits over time. The right-hand chart shows the evolution to steady stare in the fourteenth year of the programme.

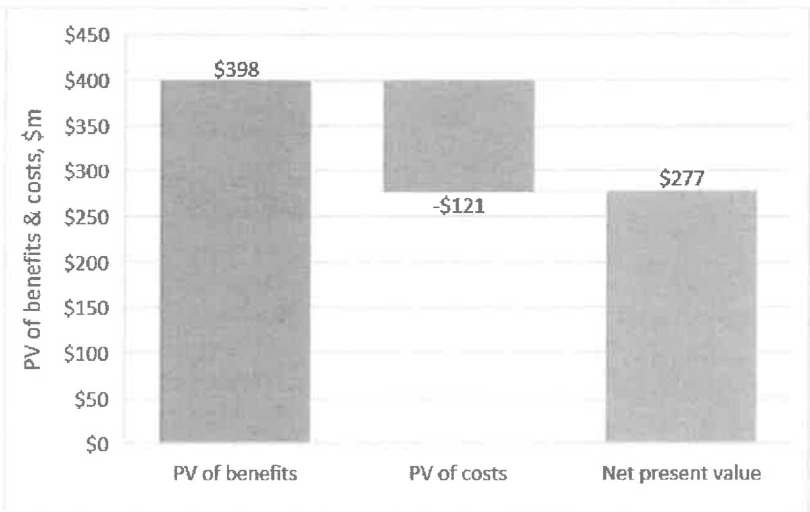
Figure 11: Start-up scenario characteristics



It can be discerned from the right-hand chart that the programme breaks-even in the fourth year.

A value on the programme over a 20-year horizon can be achieved by discounting the costs and benefits at the discount rate mandated by the Treasury for national cost-benefit analysis of 7 percent pre-tax real. In Figure 12 we show the NPV of the benefit cash flows and cost cash flows is $277 million (in 2013$ terms). This results from $398 million of present value benefits and $121 million of present value costs (a 3.3x benefit: cost ratio).

Figure 12: Present value of net benefits over 20 years (7% p.a. real)



7.3 Sensitivity analysis

Sensitivity analysis is the study of how sensitive the results of the analysis are to the uncertainty in individual assumptions such as the costs and benefits, and in the discount rate. The main purpose of a sensitivity analysis is to indicate where further work may be required on verifying assumptions made about a particular cost or benefit if the net benefits are particularly sensitive to it.

The usual way of determining which costs or benefits most affect the cost-benefit analysis result is to vary each one at a time, holding all other costs and benefits constant.

Table 6: Sensitivity analysis

Variable	Central value	Variation	Resulting change in net annual financial benefit	
		+/-	$m	
Mid-point financial B-C			$44.5	
Number of children in programme				
In ECE	191,733	+10%	-$0.4	-1%
		-10%	$0.4	1%
Primary school	470,322	+10%	-$0.6	-1%
		-10%	$0.5	1%
Number of volunteer supervisors				
Children per volunteer, ECE	12	+5	$0.7	2%
		-5	-$1.8	-4%
Children per volunteer, primary	30	+5	$0.4	1%
		-5	-$0.4	-1%
Annual turnover of volunteers, ECE	33%	+5%	-$0.4	-1%
		-5%	$0.4	1%
Annual turnover of volunteers, primary	20%	+5%	-$0.3	-1%
		-5%	$0.2	1%
Dental-educator workforce				
Salary	$60,000	+$5,000	-$0.3	-1%
		-$5,000	$0.6	1%
Overhead ratio	85%	+5%	-$0.2	0%
		-5%	$0.2	0%
Training group size	10	+5	$2.2	5%
Teeth-cleaning supplies				
Average discount on wholesale price	20%	+5%	-$0.3	-1%
		-5%	$0.2	1%
No. of toothbrushes per child per year	4	+2	-$1.6	-4%
Wastage rate toothbrushes	25%	+10%	-$0.2	-1%
Wastage rate toothpaste	25%	+10%	-$0.1	0%
Savings from avoided treatment costs				
Weighted average cost of treatment	$84	+$5	$3.3	7%
		-$5	-$3.3	-7%
Mean dmft 5 year olds in children with evident dental caries	4.41	+1	$8.7	20%
		-1	-$8.7	-20%
Mean of dmft+DMFT 12 year olds in children with evident dental caries	2.48	+1	$6.9	16%
		-1	-$6.9	-16%
% caries free at age 5	57%	+1%	-$0.4	-1%
		-1%	$0.4	1%

In Table 8 above, we have varied each central value as indicated to test the impact on the net national benefit estimate. Using an arbitrary threshold of 3 percent for materiality, the most important variables are:

- the mean number of decayed teeth in children with evident decay, especially of 5 year olds and to a lesser degree 12 year olds; and
- the weighted average cost of treatment.

Appendix 1: Comparison with extending fluoridation study

Introduction

Tooth brushing and education is an intervention for the purpose of preventing the development of dental caries in children and adolescents. However, it is not the only potential approach to dental caries prevention. As noted in the main body of this report, for 70 years fluoride has been added to community water supplies in New Zealand for the purpose of preventing tooth decay. Currently around 2.1 million people receive fluoride in this manner. Water is reticulated to around 85 percent of the population and around two-thirds is treated with the addition of chemical fluoride.

It is relevant to compare the economic costs and benefits of different approaches to the same policy question. In May 2016, the Ministry of Health released a report it had commissioned from the Sapere Research Group (Sapere) on the economic benefits and costs of water fluoridation in New Zealand. In order to validly compare Sapere's results with the results of the tooth brushing and education study, a number of adjustments must be made to standardise assumptions. This appendix is included for the purposes of allowing the reader to make an "apples for apples" comparison of the two proposals.

The Sapere report found a net present value (NPV) saving from water fluoridation over 20 years of $1,401 million, made up of a present value cost of fluoridation of $177 million and offsetting benefits of $1,578 million from reduced dental-decay treatment costs. In addition, the report estimated the costs of extending water fluoridation to communities with over 500 residents to be $144 million with offsetting benefits of $789 million, and net benefits with a NPV of $645 million over 20 years. The extension would cover an additional 1.1 million individuals (3.2 million individuals in total), leaving 1.3 million without access to fluoridated water supplies. The basis for the extension to communities with over 500 residents is the estimated costs of providing fluoridated water supplies do not exceed the assessed benefits in terms of avoided dental caries.

Table 7: Costs and benefits of water fluoridation

	Current coverage 2.1m receiving fluoride	Extended coverage: extra 1.1m receiving fluoride	Total 3.2m receiving fluoride
	PV $m	PV $m	PV $m
Sapere estimates			
PV costs	-177	-144	-321
PV benefits	1,578	789	2,367
Net benefits	1,401	645	2,046

This appendix reconciles the costs and benefits of extending water fluoridation with the costs and benefits of the tooth-brushing and education programme assessed in this report. To do so a number of adjustments are needed for comparability.

Different discount rate

In its study, Sapere used a 3.5 percent real discount rate. For the tooth brushing study, a real discount rate of 7 percent was used in line with the Treasury's recommendations for cost-benefit analysis in the public sector (the public sector discount rate). Adjusting the Sapere estimates to a 7 percent real discount rate reduces the 20-year PV costs of fluoridation by $26 million and the PV benefits of avoided dental treatment costs by $413 million, resulting in an overall reduction in the PV of the net benefits of $387 million (to $1,014 million). This is shown in Table 8.

Table 8: Costs and benefits of Sapere fluoridation estimates adjusted to standard discount rate

	Current coverage 2.1m receiving fluoride	**Extended coverage: extra 1.1m receiving fluoride**	**Total 3.2m receiving fluoride**
	PV $m	PV $m	PV $m
Sapere estimate of net benefits	1,401	645	2,046
Effect of standard public sector discount rate			
On PV costs	26	21	47
On PV benefits	-413	-206	-619
On net benefits	-387	-185	-572
Adjusted net benefit estimate	**1,014**	**460**	**1,474**

Sapere estimates the PV benefits of extending fluoridation to currently unserved communities (over 500 population) to be $789 million. The associated present value costs were estimated to be $144 million, for a net benefit of $645 million. Using a 7 percent discount rate reduces the PV costs of extending fluoridation by $21 million and the benefits of avoided dental treatment costs by $206 million. The overall reduction in net benefits is $185 million (to $460 million).

In summary, the impact of using the standard discount rate on Sapere's cost-benefit estimates are as follows:

- the net benefit from water fluoridation of $1,401 million reduces by $387 million to $1,014 million;
- the net benefit from extending water fluoridation reduces by $185 million to $460 million; and
- the overall net benefits of water fluoridation reduce by $619 million to $1,474 million.

Benefit group

This tooth-brushing and education study focusses on the benefit group of under-18 year olds. The Sapere study has as its focus the whole population. Thus, there is a material difference in the benefit group between the two studies.

Under-18 year olds were selected for the tooth-brushing study because their dental-treatment costs are assisted by DHBs at a cost to the Health budget and because we have good quality comparable data for this age group is available from the overseas studies of tooth brushing. Since 2006 (at least) the Ministry of Health has re-orientated child and adolescent oral health services with those ages from birth to age 18 years being a priority group[33].

The under-18-year old age cohort makes up less than one-quarter of the population on average over the 20-year study period. Treatment costs for under-18-year olds are lower than for adults. We have calculated the distribution by age grouping of Sapere's estimates of present value benefits from extending fluoridation (to communities over 500 population). We estimate the proportion of the benefits accruing to children and adolescents aged under 18 years is only around 10.5 percent. That is, almost 90 percent of the benefits of avoided dental treatment costs in the Sapere study accrues to adults.

If the intent of government health policy is to give priority to the dental health of under-18-year olds, then there is a considerable spill-over beyond that group implied by extending fluoridation to communities with populations over 500 at a cost of $144 million (at 3.5 percent discount rate) and $123 million (at a 7 percent discount rate).

The situation is compounded by the available technical evidence of water fluoridation having an effect on preventing dental caries in adults. The Cochrane Review[34] [35]of available studies of the effects of water fluoridation, for example, found evidence for reductions in dmft and DMFT in children and in the percentage of caries-free children. However, the authors noted that 71 percent of those studies were carried out before 1975 and the widespread introduction of fluoride toothpaste. The authors also state: "There are no studies that met the review's inclusion criteria, from which to determine the effectiveness of water fluoridation for preventing caries in adults" (page 32).

Two Australian studies (Griffin 2007 and Slade 2013) that evaluate the effectiveness of water fluoridation for caries prevention are referred to in Cochrane even though they did not meet the inclusion criteria (page 31). Cochrane includes a comment that "Griffin and colleagues acknowledge that the paucity of studies and the quality of included studies limits their review".

The upshot of this is there may be no reliable evidentiary basis for a claim that adults benefit from water fluoridation. Therefore, the attributed benefits of fluoridation to that segment of the population should be treated with caution.

It is legitimate, in our view, to attribute a life-long benefit of fluoridation from avoided treatment of permanent teeth in adolescence. This arises because adolescents who have avoided treatments to their permanent teeth also avoid repairs and replacements to those teeth. Once a tooth has a filling, the filling needs to be maintained for as long as the tooth remains. Our estimates of the lifelong

[33] Ministry of Health (2006), Good Oral Health for All, for Life: The Strategic Vision for Oral Health in New Zealand. Wellington: Ministry of Health.

[34] Water fluoridation for the prevention of dental caries (Review), Iheozor-Ejiofo Z et al, The Cochrane Collaboration, The Cochrane Library 2015.

[35] Cochrane Reviews are the leading resource for systematic reviews of primary research in human health care and health policy, and are internationally recognised as the highest standard in evidence-based health care resources. They investigate the effects of interventions for prevention, treatment, and rehabilitation. Cochrane Reviews are peer reviewed and updated regularly to incorporate new research. The governing body of the Cochrane Collaboration Steering Group (CCSG), a UK registered charity.

benefits of avoiding treatment in adolescence are scaled using the differences in effect between our Nexø case and Sapere's 50 percent bigger effect of water fluoridation.

Table 9: Costs and benefits of extending fluoridation excluding effects among adults

	Current coverage 2.1m receiving fluoride	Extended coverage: extra 1.1m receiving fluoride	Total 3.2m receiving fluoride
	PV $m	PV $m	PV $m
Sapere estimate of net benefits (at 7 percent)	1,014	460	1,474
Effect of preventative effect of water fluoridation on adults			
On PV costs	0	0	0
On PV benefits	-908	-412	-1,319
PV lifetime benefit of avoided adolescent caries	13	6	19
On net benefits	-895	-405	-1,300
Adjusted net benefit estimate	**119**	**55**	**174**

If the Sapere estimates of the effects of fluoridation are adjusted to focus only on the benefits and cost to those under 18, the present value benefits need to be adjusted downwards by $895 million to $119 million in respect of the current coverage of water fluoridation. The net benefits of extending water fluoridation coverage need to be reduced by $405 million to $55 million (see Table 9).

Looking at the costs and benefits of current fluoridation activities, if the Sapere estimates are adjusted to focus only on the benefits and costs to those under 18, the net benefits reduce from $1,474 million to $174 million (at a 7 percent discount rate).

Effects of fluoridation

Sapere estimates a 40 percent to 44 percent increase in sound tooth surfaces from fluoridation, which translates to an average 30 percent increase in sound teeth associated with fluoridation. Increases in sound teeth from tooth brushing are estimated to be in the range of 17 percent to 23 percent (or roughly 20 percent on average). So, comparing the two interventions, it is implied by the Sapere estimates that fluoridation is on average 50 percent more effective in preventing caries than tooth brushing.

The Cochrane Review, found that water fluoridation is effective at reducing levels of tooth decay among children in the range described by Sapere. However, Cochrane states "These results are based predominantly on old studies and may not be applicable today". Of the studies that met the reviewers' inclusion criteria, 71 percent were conducted prior to 1975 and the widespread introduction of fluoride toothpastes.

We know that levels of tooth decay in children and young adults in New Zealand declined after the 1970s in both fluoridated and un-fluoridated areas, reaching a plateau in the 1990s. The relevant question is whether the levels of effect attributable to water fluoridation from studies carried out mostly before 1975 are applicable now. This issue is related to the matter raised in this report at pages 24 and 25 about practical limits to the effect of tooth brushing.

It seems more plausible that the change occurring from extending community water fluoridation can be predicted from the dental health status of children in fluoridated areas[36]:

- for five-year olds, there is an 8 percent improvement in the number that are caries free and a 20 percent improvement in sound teeth; and
- for children in year 12, there is a 9 percent improvement in the number that are caries free and a 23 percent improvement in sound teeth.

Tooth brushing and education provides a verifiable intervention with known effect on dental caries. Approximately two-thirds of children and adolescents who ordinarily would not brush their teeth in accordance with the Ministry of Health's guideline would, under the programme outlined in this report, experience at least one brushing during school or pre-school attendance. In contrast, as the York University review of 3,200 research papers on fluoridation and its effects on dental health showed, the studies that met the minimum quality threshold suggested there was a possibly an increase in the number of children without dental caries in areas with fluoridated water, but the studies generally could not exclude other explanations for the variance. In contrast, with tooth brushing, the causal mechanism at work when fluoride is added to drinking water is at best unclear and not undisputed in the scientific community.

Cost-benefit analysis forces parties to disclose, and open to scrutiny, thecausal mechanisms by which they think policy interventions operate. But even in simple examples, cost-benefit calculations can become muddy. To identify effective interventions and validly compare alternatives, the ability to reliably attribute causality is critical.

Differences due to fluoridation effectiveness in children and adolescents under 18 years reduce Sapere's estimate of the net benefits of current fluoridation by $90 million to $924 million, and reduces the net benefits of extending water fluoridation by $59 million to $401 million (see Table 10).

Table 10: Effects of water fluoridation adjustments

	Current coverage 2.1m receiving fluoride	Extended coverage: extra 1.1m receiving fluoride	Total 3.2m receiving fluoride
	PV $m	PV $m	PV $m
Sapere estimate of net benefits (at 7 percent)	1,014	460	1,474
Effect of observed water fluoridation effectiveness			
On PV costs	0	0	0
On PV benefits	-90	-59	-149
On net benefits	-90	-59	-149
Adjusted net benefit estimate	**924**	**401**	**1,324**

[36] See MoH (2014), Age 5 and Year 8 oral health data from the Community Oral Health Service.

Reconciliation summary

Table 11 reconciles the water fluoridation report on the same basis for the tooth-brushing and education study.

Table 11: Water fluoridation reconciliation summary

	Current coverage 2.1m receiving fluoride	Extended coverage: extra 1.1m receiving fluoride	Total 3.2m receiving fluoride
	PV $m	PV $m	PV $m
Sapere estimates			
PV costs	-177	-144	-321
PV benefits	1,578	789	2,367
Net benefits	1,401	645	2,046
Effect of standard public sector discount rate[1]			
On PV costs	26	21	47
On PV benefits	-413	-206	-619
On net benefits	-387	-185	-572
Effect of preventative effect of water fluoridation on adults[2]			
On PV costs	0	0	0
On PV benefits	-908	-412	-1,319
PV lifetime benefit of avoided adolescent caries[3a, 3b]	13	6	19
On net benefits	-895	-405	-1,300
Effect of observed water fluoridation effectiveness[4]			
On PV costs	0	0	0
On PV benefits	-90	-59	-149
On net benefits	-90	-59	-149
Reconciled costs and benefits			
PV costs	-151	-123	-274
PV benefits	180	118	299
Net benefits (B - C)	**29**	**-5**	**24**
Benefit-cost ratio (B/C)	*1.2x*	*1.0x*	*1.1x*

Notes:

1. Using 7 percent real discount instead of 3.5 percent real.
2. Based on Cochrane Review 2015.

3a. Scaling TDB estimate of lifelong benefits of prevention (20%) to Sapere's water fluoridation effectiveness (30%).

	TDB whole pop. estimate	Oral health improvement: TDB	Oral health improvement: Sapere	Scaled whole pop. estimate
	PV $m	%	%	PV $m
PV lifetime benefit of avoided adolescent caries	18	20%	30%	27

3b. Scaling TDB whole population lifetime benefits to populations served by water fluoridation

	Served pop	Benefit attributed
	No.	PV $m
No. receiving fluoride	2.1	13
No. in communities <500	1.1	6
Not on community water	1.3	8

Total population	4.5	27
Benefit to population receiving fluoride	3.2	19

4. Based on oral health of children in fluoridated areas compared to un-fluoridated area (see MoH 2015). Fluoridation status refers to the water supply of the school which the student attended, rather than the fluoridation status of the area in which they resided.

In summary, if the adjustments noted above are made to the Sapere study:

- the net benefit from water fluoridation of $1,401 million reduces by $1,372 million to $29 million (benefit-cost ratio of 1.2x);
- the net benefit from extending water fluoridation reduces by $650 million to -$5 million (benefit-cost ratio of <1.0x); and
- the overall net benefits of water fluoridation reduce by $2,022 million to $24 million (benefit-cost ratio of 1.1x).

These adjusted estimates are on a comparable basis to the estimates present in section 7.2 of the start-up scenario for tooth brushing and education.

Various decision rules may be used for comparing costs and benefits. The correct criterion for adjusting benefits and costs to a unique value is the net present value (NPV) or "net benefits" criterion. The correct rule is to adopt any project with a positive NPV, reject any project with a negative NPV and to rank projects by their NPVs.

Decision rules in cost-benefit analysis tell us that when the NPV is less than zero the proposal is inferior in economic efficiency term to doing nothing. Put differently, proceeding with a negative NPV proposal destroys resources that could alternatively be used to improve the material wellbeing of society.

When the net benefits of several proposals are ranked, adopting the one with the highest NPV is consistent with maximising economic efficiency and benefit.

Discounted and annualised amounts

In the Sapere report, as is conventional for cost-benefit analyses, monetary amounts are reported discounted to a present value amount (over a 20-year period at a 3.5 percent discount rate). In this tooth-brushing report we present results as an annualised amount for compatibility with the way budgets are established. There is a simple mathematical relationship between the two approaches. Present value benefits and costs can be converted to an annualised basis and vice-versa using multipliers as follows:

Table 12: Multipliers for converting discounted and annualised monetary amounts

Discount rate	Annualised equivalent	Discount factor
3.5%	7.0%	14.2
7.0%	9.4%	10.6

That is, to annualise a PV amount discounted at 3.5 percent over 20 years, multiply by 7 percent (or divide by 14.2).

In Table 13 below we present the discounted amounts shown in Tables 7 and 8 above with the annualised equivalents.

Table 13: Discounted and annualised equivalence of Sapere results

	Benefits		Costs		Net	
	Discounted	Annualised	Discounted	Annualised	Discounted	Annualised
	PV $m	$m p.a.	PV $m	$m p.a.	PV $m	$m p.a.
Current fluoridation coverage						
PV @ 3.5%	$1,578	$111	-$177	-$12	$1,401	$99
PV @ 7.0%	$1,165	$110	-$151	-$14	$1,014	$96
Extended fluoridation						
PV @ 3.5%	$789	$56	-$144	-$10	$645	$45
PV @ 7.0%	$583	$55	-$123	-$12	$460	$43
Total						
PV @ 3.5%	$2,367	$167	-$321	-$23	$2,046	$144
PV @ 7.0%	$1,748	$165	-$274	-$26	$1,474	$139

Start-up scenario

In section 7.2 we present a start-up scenario for the tooth-brushing programme. This scenario is based on the premise that costs and benefits of any prevention programme may not occur in parallel and the benefits will evolve over time. In the tooth-brushing start-up scenario, costs build up over three years from inception before any material benefits emerge, and it is fourteen years from inception before benefits reach steady state (see Figure 11). The monetary effect of this benefit "ramp" is material compared to the alternative scenario that steady-state benefits are reached immediately after costs are incurred. This is because on-average for the first fourteen years the benefits are roughly one-half of the steady state, and steady-state benefits are realised in the remaining six of twenty years.

The reduction in present value benefits of tooth brushing due to the ramp is $398 million (over 20 years at 7 percent discount rate) compared to immediate realisation of steady-state benefits, i.e., from $706 million to $398 million.

The net present value of the tooth-brushing programme is assessed as $277 million over twenty years, but had we not deferred the steady state, it would be assessed as $585 million.

Conclusions

The Sapere study sets out with the same goal as the study of tooth-brushing and education to measure the economic costs and benefits attributable to a health intervention. Sapere measured the net economic benefits of community water fluoridation over 20 years (at a 3.5 percent real discount rate) as follows:

- a net saving from water fluoridation of $1,401 million, made up of a present value cost of fluoridation of $177 million and offsetting benefits of $1,578 million from reduced dental decay treatment costs; and
- extending water fluoridation to communities with over 500 residents costs an extra $144 million with offsetting benefits of an extra $789 million, and a NPV of net benefits of $645

million over 20 years (the extension would cover an additional 1.1 million individuals, 3.2 million individuals in total with 1.3 million without access to fluoridated water supplies).

To compare these estimates to those presented in the tooth-brushing and education study some adjustments are considered:

- in the tooth-brushing study a higher discount rate was used in line with the Treasury's recommendations for cost-benefit analysis in the public sector;
- there may be no evidentiary basis to justify the claim in the Sapere report that adults in adulthood get benefits from water fluoridation. Therefore the additional benefits attributed to fluoridation for the adult segment of the population should be treated with caution; and
- using the observed levels of tooth decay in children in fluoridated and un-fluoridated areas, instead of the levels of effect attributable to water fluoridation from studies carried out mostly before 1975.

If these adjustments are made, the cumulative effect on the estimates in the Sapere report is as follows:

- the net benefit from water fluoridation of $1,401 million reduces by $1,372 million to $29 million (benefit-cost ratio of 1.2x);
- the net benefit from extending water fluoridation reduces by $650 million to -$5 million (benefit-cost ratio of <1.0x); and
- the overall net benefits of water fluoridation reduce by $2,022 million to $24 million (benefit-cost ratio of 1.1x).

These adjusted estimates are on a comparable basis to the estimates present in section 7.2 of the start-up scenario for tooth brushing and education.

Finally, and no less importantly, is the size of the effect attributed to fluoridation. In contrast to tooth brushing, where there is reliable means of attributing causality to the effect on oral health, possible other explanations for observations of better oral health (among children) receiving fluoridated water have not been eliminated in the scientific studies. Identifying effective policy interventions rests critically on the ability to reliably attribute causality.

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