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Sunlight Exposure: Communicating the Benefits and Risks of Ultraviolet Light to the General Population: Cost-effectiveness model Technical report

Final Report

ROBERT HODGSON, Consultant
ISOBEL CARPENTER, Research Assistant
MICHELLE JENKS, Consultant
SARAH DICKINSON, Research Assistant
MATTHEW TAYLOR. Director

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THE UNIVERSITY of York

INVESTORS IN PEOPLE

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1. BACKGROUND

Solar radiation or sunlight principally consists of ultraviolet radiation (UV): ultraviolet A (UVA), ultraviolet B (UVB) and ultraviolet C (UVC), visible light and infrared.[1] Exposure to UV radiation and, therefore, sunlight, carries both positive and negative consequences for human health.

The National Institute for Health and Care Excellence (NICE) Centre for Public Health (CPH) commissioned the development of a de novo economic model to assess the cost-effectiveness of interventions that seek to present and disseminate complex health risk information relating to safe sun exposure.

2. METHODS

As part of the programme of work commissioned by NICE to support the development of guidance on communicating the benefits and risks of ultraviolet light (sunlight) to the general public, a number of systematic reviews have been conducted. These included a review of the evidence of effectiveness of interventions that seek to present and disseminate complex health risk information relating to safe sun exposure.[2]

The review identified a large number of studies and identified a number of interventions that have been shown to be effective in altering sun behaviour practices and/or reducing the incidence of sunburn. None of the studies identified in the effectiveness review, however, focused on the delivery of a complex message communicating both the risks and benefits of sun exposure.

Based on the evidence found, the economic modelling considered five types of interventions:

Information programme for school children ('Living with the Sun'): The 'Living with the Sun' (LWS) programme is series of ten practical workshops activities delivered within school to primary aged children (for the purposes of the model it was assumed the children were aged 7).

Photo-aging: The intervention consisted of participants being presented information about photo-aging and effective practices for minimising photo-aging via a 10 minute video and slide show. Participants then had UV facial photographs taken. Participants were told that any dark, freckled, or pitted areas in the UV photograph, showed underlying skin damage that would get worse if they continued their current sun exposure levels without additional sun protection. This intervention was delivered to graduates within the trial and it was assumed that young people age between the ages of 18 and 24 were the target population for the purposes of the model.

Tailored messaging: The intervention consisted of three sets of educational newsletters about skin cancer and sun protection being sent to the parents of school aged children (for the purposes of the model it was assumed the children were aged 7). The second newsletter addressed personalised risk perception using tailored information about each child's specific risk factors (hair, eye, and skin colour; freckling; tendency to burn/tan), based on information at enrolment or skin examinations. Newsletters for children (included age-appropriate information and activities) were sent with parental newsletters but did not require parent involvement. Within the trial these letters were posted for purposes of the model, it was however, assumed that the children hand delivered the letters to parents.

Text messages: The intervention consisted of daily text message reminders sent via mobile phone. The text message had two components: a "hook" text detailing daily local weather information and a "prompt" text reminding users to apply sunscreen. For the purpose of the model, it was assumed that these would only be sent in the summer months of May to August. The target population was 18 to 50-year-old adults.

Mass media (SunSmart campaign): The SunSmart campaign is a skin cancer prevention programme which involved public education and advocacy. It consisted of a national media campaign to raise awareness of the risks of skin cancer. A number of policy changes were also introduced including manufacturing standards for sunglasses, and policies regarding the use of sun protection in schools and in the workplace. Within the model the focus was primarily on the mass media element of the SunSmart campaign. It was assumed the whole population was the target of this intervention.

The comparator used in the model was to do nothing.

A model was built to estimate the incremental cost-effectiveness ratio (ICER) of each of the interventions. The model included the following conditions associated with exposure to sunlight:

- Malignant melanoma (MM);
- Basal Cell Carcinoma (BCC);
- Squamous Cell Carcinoma (SCC);
- Sunburn.

It is known that sun exposure is associated with cataracts and vitamin D deficiency. However, lack of appropriate data meant that it was not possible to include the health effect within the model.

The model structure was based on a simple decision tree in which the incidence of each of the conditions associated with sun exposure was calculated both with and without the intervention. From this the total QALYs and costs associated with these incidence rates was calculated and an ICER estimated.

The effectiveness studies included in the model all report a number of different outcomes describing both changes in behaviour, such as increased use of sunscreen or wearing a hat, as well as direct measures of sun exposure, including the number of sunburns reported.

These surrogate outcomes were linked to the different health outcomes in different ways. The incidence of both MM and BCC is linked to the pattern of sun exposure and were linked to lifetime number of sunburn using epidemiological data. Squamous cell carcinoma differs from the other skin cancer types in that it is thought that the main risk factor is total lifetime sun exposure.[3] The impact of interventions on SCC was, therefore, modelled by linking increases in the use of sun protection practices to reductions in total lifetime sun exposure and this was then linked to the incidence of SCC.

3. RESULTS

The results show a considerable spread in the cost-effectiveness estimate of the different interventions. Three of the interventions, ‘Living with the Sun’, photo-aging and text messages, on the basis of the baseline results, would not be considered cost-effective with respective ICERs of £312,744 £316,968 and £65,945 per QALY. In all three cases the estimated ICER significantly exceeds £20,000. Two of the interventions, tailored messages and mass media, are however cost-effective based on the baseline estimates. The tailored message intervention has an estimated ICER of £16,859, while the mass media intervention is dominant. These results are largely robust to a range of input values. The disparity in cost-effectiveness estimates can be very clearly put down to a large difference in the cost of implementing the interventions and in their effectiveness.

The results of this economic evaluation should, however, be interpreted with a degree of caution. Estimating the cost-effectiveness of interventions aimed at reducing sun exposure is complex and poses a significant methodological challenge. The model is particularly subject to a high degree of structural uncertainty. This is due to the fact the trials investigating the modelled interventions report behavioural outcomes rather than health outcomes. This means that within the model a series of steps are followed linking the outcomes reported in the studies with the health outcomes used in the model. This process of linking study outcomes with health outcomes is based on limited data and makes a number of simplifying assumptions which introduce uncertainty into the model.

A further substantial assumption made in the model relates to the persistence of improved behaviour. It was therefore necessary to make a number of assumptions based on evidence from the behavioural psychology literature as to the likely duration of the effect of each of the interventions on behaviour. In most cases this, however, had minimal effect on the cost-effectiveness estimates obtained unless the impact of the intervention lasted in excess of 10 years or more. In the case of the text messages intervention, however, a fairly small increase in the duration of effect (3 years) would be enough for the intervention to be cost-effective.

Abbreviations

BCC	Basal Cell Carcinoma
DALY	Disability-Adjusted Life Year
DLQI	Dermatological Life Quality Index
ICER	Incremental Cost-Effectiveness Ratio
MM	Malignant Melanoma
NMSC	Non-malignant skin cancer
OR	Odds Ratio
PH32	Public Health Guidance 32
ONS	Office for National Statistics
QALY	Quality-Adjusted Life Year
QoL	Quality of Life
PSA	Probabilistic Sensitivity Analysis
RCT	Randomised Control Trial
RR	Relative Risk
SCC	Squamous Cell Carcinoma
SED	Standard Erythema Dose
SPF	Sun Protection Factor
TA	Teaching Assistant
UV	Ultraviolet
UVA	Ultraviolet A
UVB	Ultraviolet B
UVC	Ultraviolet C

Section 1: Introduction

The National Institute for Health and Care Excellence Centre for Public Health (NICE CPH) has contracted York Health Economics Consortium (YHEC) and the University of Leeds Nutritional Epidemiology Group (NEG) to produce three evidence reviews, a documentary analysis and an economic model of interventions that present and disseminate the health risks and benefits of ultraviolet radiation (UV) to the general public. This is the report of the economic model.

1.1 BACKGROUND

Solar radiation or sunlight principally consists of ultraviolet radiation (UV): ultraviolet A (UVA), ultraviolet B (UVB) and ultraviolet C (UVC), visible light and infrared.[1] Exposure to UV radiation and, therefore, sunlight, carries both positive and negative consequences for human health.

Too much sun exposure is associated with an increase in the risk of developing a range of health conditions. The main risk from UV exposure is skin cancer.[4] The prevalence and mortality associated with skin cancer have increased significantly over the past decade despite improvements in treatment. In 2011 there were over 2200 deaths from skin cancer in the UK.[5] Sun exposure is also responsible for erythema (sunburn) and is associated with a number of eye conditions, including cataracts.[4]

Exposure to too little sunlight can also lead to health problems. Ultraviolet B radiation is crucial in the synthesis of vitamin D, which is produced in the skin through a photosynthetic reaction.[6] Vitamin D is an essential nutrient that is needed to help maintain calcium and phosphate levels in the body and also to develop healthy bones and promote skeletal growth. Vitamin D deficiency can result in bones not forming properly and the development of rickets in children, which is characterised by growth retardation and skeletal deformities. In both children and adults, vitamin D deficiency can also result in bone pain, such as osteomalacia.[7] Furthermore, there is some evidence that vitamin D may have an important role to play in human health, beyond its involvement in bone health. Poor vitamin D status has been linked with a range of chronic diseases such as cancers and cardiovascular disease (CVD) as well as markers of cardio metabolic health including obesity and type 2 diabetes mellitus, although the evidence is generally insufficient to attribute causality.[8]

A number of previous analyses have been carried out assessing the cost-effectiveness of interventions aimed at preventing the primary condition associated with sun exposure: skin cancer. These include a cost-effectiveness analysis developed as part of NICE Public Health Guidance 32 (PH32), which sets out the need to communicate the risks related to UV exposure from the perspective of skin cancer risk.[9] The guidelines make recommendations for a national mass media campaign alongside local information provision, and set out who should be involved and how. The guidelines promote an integrated message targeted at high risk population groups that acknowledges and challenges commonly held perceptions around UV exposure. They also acknowledge the need for a balanced message that incorporates an understanding of the health benefits of UV exposure. NICE will also publish guidelines to inform the implementation of existing guidance on the prevention of vitamin D deficiency in November 2014.

To complement these guidelines, NICE CPH is developing further guidance on UV exposure focusing on communicating the risks and benefits to the general population. This model will inform the development of that guidance.

1.2 AIM OF THE ECONOMIC MODEL

The aim of the economic model is to assess the cost-effectiveness of interventions that seek to present and disseminate complex health risk information relating to safe sun exposure.

1.3 OVERVIEW OF METHODS

It was decided that a decision-analytic model would be developed in order to estimate the expected costs and benefits of various interventions seeking to modify exposure to sunlight. The costs and consequences of various interventions could then be directly compared in order to assess which are most effective and cost-effective. This model and the process of development are described in full in Section 3.

In order to assess the cost-effectiveness of a particular intervention, a standard unit of benefit is required in order to compare across different health areas. For example, if a certain number of cases in one disease area are cured and a certain number of events in another are averted, a common unit is needed to decide which of these outcomes is more desirable. Health economics uses the quality-adjusted life year (QALY) for this purpose. The QALY incorporates the life years gained from a treatment strategy, adjusted for the quality of life (QoL) that the person experiences during those years. Quality of life is determined using measures of utility, which describe health-related quality of life on a scale of 0 to 1, with 1 being full health and 0 being dead. For example, if a person lives for 10 years with a utility of 0.5 they will experience 5 QALYs. If they live for 4 years with a utility of 0.75 they will experience 3 QALYs. The impact of diseases on QoL can be elicited in a number ways including elicitation of experts; directly by seeking to assess patients' preference for particular health states; and, indirectly using generic utility instruments which ask patients to rate their heath across a number of dimensions of human health.

Cost-effectiveness analysis is based on the comparison of one intervention with another, such as standard care or no intervention. In order to do this it is the *incremental* QALYs and *incremental* costs that are considered. Many new interventions are more costly and also provide more health benefits. In order to decide whether the extra health benefits are worth the extra costs of the intervention, the incremental cost-effectiveness ratio (ICER) is calculated. The ICER subtracts the cost of the current strategy from the cost of the new strategy, divided by the benefits of the current strategy subtracted from the benefits of the new strategy in order to determine the incremental cost per unit of benefit. The formula for calculating the ICER is shown below.

The higher the ICER the higher the cost per QALY gained. NICE generally considers interventions with an ICER less than £20,000 per QALY gained to be cost-effective. Above this threshold, judgements around the acceptability of the intervention as an efficient use of NHS resources are made according to the degree of certainty around the ICER, how accurately changes in quality of life have been captured and how innovative the intervention in question is.[10]

1.4 REPORT STRUCTURE

The remainder of this report is organised as follows:

- Section 2 provides an overview of the identification and selection of the interventions included in the model;
- Section 3 describes the structure of the economic model;
- Section 4 describes the results of the economic model;
- Section 5 discusses the limitations of the work and advises upon future research recommendations.

Section 2: Evidence of Effectiveness

As part of the programme of work commissioned by NICE to support the development of guidance on communicating the benefits and risks of ultraviolet light (sunlight) to the general public, a number of systematic reviews have been conducted. These included a review of the evidence of effectiveness of interventions that seek to present and disseminate complex health risk information relating to safe sun exposure.[2]

The review identified a large number of studies and identified a number of interventions that have been shown to be effective in altering sun behaviour practices and/or reducing the incidence of sunburn.[2] None of the studies identified in the effectiveness review, however, focused on the delivery of a complex message communicating both the risks and benefits of sun exposure.[2] Furthermore, only a single study focused upon delivering an intervention aiming to encourage greater sun exposure with the aim of minimising vitamin D deficiency and associated conditions. However, this intervention was not found to be effective.[2]

The lack of evidence into the effectiveness of interventions aimed at delivering a complex message communicating both the risks and benefits of sun exposure means it is not possible within the economic model to assess the cost-effectiveness of any such intervention. As a consequence conditions associated with vitamin D deficiency are not included in the model. This is because it is not possible to quantify the impact of any of the interventions on the incidence of vitamin D deficiency. Furthermore, the inclusion of vitamin D related conditions would have added considerable complexity to the model as the nature of the relationship between sun exposure and vitamin D levels is complex and dependent upon both the frequency and duration of any exposure. The model presented below, therefore, focuses on assessing the cost-effectiveness of interventions identified within the systematic review,[2] which solely aim to reduce the incidence of conditions associated with over exposure to the sun. The next section, however, aims to quantify the health burden associated with rickets and osteomalacia. These are the two principal conditions associated with vitamin D deficiency; this is so to allow some idea of the potential health gains possible by preventing cases of vitamin D deficiency.

The remainder of Section 2 justifies the selection of the interventions modelled within the cost-effectiveness analysis (Section 2.2) and provides details of the interventions selected, including details on the effectiveness of these interventions and costs associated with their delivery (Section 2.3).

2.1 HEALTH BURDEN OF VITAMIN D DEFICIENCY RELATED CONDITIONS

Rickets is a disease that affects bone development in children[11]. It causes the bones to become soft and weak, which can lead to bone deformities and a greater risk of bone fractures. Rickets is most commonly caused by a deficiency in vitamin D and calcium. The number of children affected by rickets is small, with incidence ranging from 3.16 per 100,000 to 120 per 100,000 [12-14]. Rickets incidence usually occurs before the age of 5. In 2013 it was estimated that there were 4,090,165 children aged 0-5 across England[15]. At an incidence rate of 7.5 per 100,000[13] this would give an approximate incidence of 307 children aged 0-5 diagnosed with rickets each year. In most cases, rickets is treated by increasing intake of vitamin D and calcium, either by diet, supplements or injections[16]. It is understood that rickets rarely leads to permanent disability in the UK.

Rickets in adults is known as osteomalacia[17]. Osteomalacia is treated in the same way as rickets. Both rickets and osteomalacia are more common in those with darker skin[17, 18], and osteomalacia is also more common in the over 65's age group[18]. No incidence data is, however, available for osteomalacia in the UK.

No QALY data is available for either rickets or osteomalacia describing the health loss associated with these two conditions. Estimates of the disease burden resulting from rickets and osteomalacia have, however, been estimated using disability-adjusted life years (DALYs)[19], which are an alternative way of parameterising the disease burden from particular diseases. DALYs differ in a number of important ways to QALYs and are often elicited from expert opinion rather than from patients. Importantly NICE do not accept DALYs as an appropriate measure of disease burden. It is however, possible to utilise the values used in estimating DALYs to estimate the QALY loss from a disease. This was done by subtracting the disability weights used in the DALY calculations from one.[20] Table 2.1 presents the QALY loss associated with rickets and osteomalacia.

Table 2.1: QALY loss rickets and osteomalacia

	Rickets onset under 5 years of age	Rickets onset 5 to 15 years of age	Osteomalacia
QALY loss	0.3	0.2	0.1

Based on the QALY losses described in Table 2.1, a disease duration of 6 months and the range of incidence rates above, the total QALYs lost from rickets can be estimated. These are presented in Table 2.2 over the page. Under all scenarios the numbers of QALYs lost is small, though it should be noted that this assumes that rickets are treated quickly and no permanent disability occurs.

Table 2.2: Total QALYs lost to rickets

	Goldacre (2014) Incidence rate 3.16 per 100,000	Callaghan (2006) incidence 7.5 per 100,000	Moy (2012) incidence 120 per 100,000
Total QALYs lost[a]	17.24	40.9	654.7

[a] Assumes 80% of cases are in under 5's

2.2 SELECTION OF INTERVENTIONS

The economic evaluation was undertaken for a selected number of studies identified in the evidence review. The process for selecting studies to be modelled included two steps. The first step involved excluding studies that were not suitable for modelling. Studies were included if they met all of the following criteria:

- Outcomes in terms of sun protection or sun exposure behaviour (as opposed to knowledge and attitudes) were reported;
- Evidence was of at least moderate quality as assessed by the review team[2] (a summary of the quality rating of each of the relevant studies is included in Appendix C);
- At least one statistically significant outcome was reported.

Applying these criteria led to the exclusion of a large proportion of the interventions identified in the systematic review.[2] Based on the evidence found, the economic modelling considers five types of interventions:

- Information programme for school children ('Living with the Sun');
- Photo-aging;
- Tailored messaging;
- Text messages;
- Mass media.

The second step consisted of selecting the best available evidence within each type of intervention. In order to do so, the studies were coded according to the following criteria:

- Country of study;
- Internal validity;
- Change in the number of sunburns reported as an outcome;
- Follow-up period.

Reporting of change in the number of sunburns was included as a criterion for selecting studies as this is a key outcome for the model. This is because sunburn both directly results in QALY losses and can be linked to a number of other diseases associated with exposure to UV radiation (sunlight). No other disease outcomes were reported in the trials and hence these were not considered as criteria for selecting studies.

Table 2.3 summarises the scores given against these criteria, resulting in a range of scores between 0 and 5.

Table 2.3: Criteria for selecting studies to include in the economic modelling

Criteria	**Score: 0 to 5**
Country	USA or Australia = 0 Northern Europe = 1
Internal validity (as assessed by the review team)	Poor = 0 Moderate = 1 Good = 2
Sunburn reported	No = 0 Yes = 1
Follow-up period	Less than 1 year = 0 1 year or more = 1

The interventions that received the highest scores within each intervention criteria were included in the economic analysis. These are summarised in Table 2.4 (studies marked in bold are those selected to be modelled). In the case of photo-aging the scores for all of the identified studies were very low, though the study by Mahler *et al*. (2013)[21] stood out due to its extended follow-up period. Only one trial was identified for the education programme for children, however, this scored 5/5 on the above criteria. Two trials, Armstrong (2009) [22] and Gold (2011)[23], evaluated the effectiveness of text message reminders. Both of these scored poorly on the criteria above, scoring just 1/5 each. It was decided to base the model on the Armstrong study as the impact of the intervention was observed to have a statistically significant effect in the use of sun protection practices in this study. Both of the studies evaluating the mass media campaign were observational studies and therefore quality was not considered as a factor. The studies identified for inclusion in the economic analysis were, therefore, Mahler (2013)[21] for photo-aging, Crane (2012)[24] for tailored messages interventions, Sancho-Garnier (2012)[25] for the educational programme ‘Living with the Sun’, Armstrong (2009)[22] for the text messages intervention and Dobbinson (2008) [26] for the mass media intervention.

Table 2.4: Studies selected for economic modelling

Intervention type	Author	Country	Internal validity	Sunburn reported	Follow-up period	Score: 0 to 5
Photo-aging	Schuz (2013)[27]	Australia	Poor	No	Less than 1 year	0
Photo-aging	Moser (2012)[28]	US	Poor	No	Less than 1 year	0
Photo-aging	Siegel (2010)[29]	US	Poor	No	Less than 1 year	0
Photo-aging	**Mahler (2013)[21]**	**US**	**Poor**	**No**	**1 year or more**	**1**
Tailored interventions	Glanz (2013)[30]	US	Good	Yes	Less than 1 year	3
Tailored messages	Manne (2010)[31]	US	Good	No	1 year or more	3
Tailored messages	**Crane (2012)[24]**	**US**	**Moderate**	**Yes**	**1 year or more**	**3**
Tailored messages	Glanz (2010)[32]	US	Moderate	Yes	Less than 1 year	2
Tailored messages	Rat (2014)[33]	France	Moderate	Yes	Less than 1 year	3
Tailored messages	Falk (2011)[34]	Sweden	Poor	Yes	1 year or more	3
Tailored messages	Roberts (2009)[35]	US	Moderate	Yes	Less than 1 year	2
Tailored messages	Reynolds (2008)[36]	US	Poor	Yes	Less than 1 year	1
'Living with the Sun'	**Sancho-Garnier (2012)[25]**	**France**	**Good**	**Yes**	**1 year or more**	**5**
Text messages	**Armstrong (2009)[22]**	**US**	**Moderate**	**No**	**Less than 1 year**	**1**
Text messages	Gold (2011)[23]	Australia	Poor	No[a]	1 year or more	1
Mass media campaign	**Dobbinson (2008)[26]**	**Australia**	**NA[b]**	**No**	**1 year or more**	**1**
Mass media campaign	Dixon (2008)[37]	Australia	NA[b]	Yes	1 year or more	2

[a]Data on frequency of sunburn were collected, but not reported in the trial report.
[b] These were observational studies.

2.3 EFFECTIVENESS AND COST OF IMPLEMENTING INTERVENTIONS

This section presents the effect and cost of the interventions included in the economic analysis and describes the methods employed to calculate them.

One of the significant limitations of the evidence base regarding the effectiveness of interventions is that the duration of follow-up for all studies was relatively short, with a maximum follow up of three years. The duration of the effect of any intervention beyond this period is therefore unknown. The duration of effect of any intervention is likely to have a significant impact on the cost-effectiveness and so a search of the behavioural psychology literature was carried out with the aim of better understanding the potential for different types of intervention to influence behaviour in the medium to long term. The results of this search were mixed. There were a number of studies suggesting that media campaigns tend to only generate 'behavioural changes' for only a short time following broadcast and tend not to lead to long term changes in behaviour.[38, 39] To establish permanent changes in behaviour a change in the social norms would be required. To achieve this kind of a change the literature suggested that an extended period of engagement would be necessary, with literature referring to changes in smoking social norms taking 50 years and condom use more than 20 years.[40] A number of the interventions considered are aimed at school children and so the literature was examined for evidence that childhood learned behaviour was carried on into adulthood. A number of studies were identified that demonstrated that behavioural traits observed childhood can be used to predict adult behaviour.[41, 42] However, this literature primarily focuses on negative behaviours such as delinquency and violent crime. Furthermore, it is not always clear that the behaviour predictors are learned. It therefore seems inappropriate to extrapolate from these studies to the present context. Within the model it was assumed for the 'Living with the Sun' and photo-aging that the initial effect occurs in the first year of implementation and decays subsequently in linear fashion over a period of three years. For the tailored messages intervention we assumed the intervention effect lasted for the three years based on the three year follow-up reported in the trial. For the mass media and text message intervention it was assumed that the initial effect lasts only a single year. The validity of these assumptions will be explored in the sensitivity analysis.

The cost of the interventions to the public sector was estimated as the incremental cost per person. Incremental cost is defined as the cost of the intervention less the cost for the comparator or counterfactual, as defined in the effect studies. In most studies, however, individuals in the control group received no intervention. Therefore, the incremental cost is given by the cost of the interventions. Costs were estimated by valuing the resources used to delivering the intervention, which were derived from the effect studies. Data on unit costs was drawn from a variety of sources and are detailed below with respect to the specific interventions.

2.3.1 Photo-aging

Intervention: The intervention consisted of participants being presented information about photo-aging and effective practices for minimising photo-aging via a 10 minute video and slide show. The video depicted photo-aging (including photographs of extreme cases of wrinkles and age spots, describing how sun exposure leads to photo-aging and then discussed effective practices for minimising photo-aging). Participants then had UV facial photographs taken. Participants were told that any dark, freckled, or pitted areas in the UV photograph, but not in the natural-light photograph, showed underlying skin damage that would get worse if they continued their current sun exposure levels without additional sun protection.

Calculating effectiveness: The model breaks down protection practices into the use of four common sun protection practices which are commonly part of sun protection messages:

- Use of sunscreen;
- Use of clothing;
- Use of shade;
- Use of hats.

The Mahler *et al.* (2013)[21] study reported a number of potentially relevant outcomes describing sun exposure behaviour. These included number of hours spent sunbathing per week, tanning salon use and use of sun protection practices, during both incidental and intentional sun exposure. For the purpose of the model the use of sun protection practices, during both incidental and intentional sun exposure, were used. The average of these was taken so as to calculate the average impact of the intervention on using sun protection. As the Mahler study did not distinguish between different types of protection it was assumed that the impact of the intervention was the same for all four protection practices. The study reported separately for two locations California and Iowa. The results for Iowa were used as this is a more temperate climate than California and more similar to the climate in the UK.

The Mahler study reported their results as z scores. The baseline mean and standard deviation were used to calculate the proportion of individuals using protection post-intervention. Relative risk was then calculated by dividing the risk of using protection in the intervention group (UV photograph, photo-aging video) by the risk of using protection in the control group (no photograph, no photo-aging video). It was assumed that not everyone would attend the photo-aging intervention, so was therefore assumed that participation would be 30%. The relative risk was adjusted assuming that only 30% of any target population would agree to receive the message.

The effectiveness values used in the model are presented in Table 2.5.

Table 2.5: Effectiveness of photo-aging

Relative risk sunscreen	Relative risk shade	Relative risk clothing	Relative risk hat
1.105	1.105	1.105	1.105

Calculating costs of implementation: Mahler *et al., (*2013)[21] carried out a RCT to determine the effect of both the provision of photo-aging information and a UV photograph on sun protection intentions and behaviours.[21] Photo-aging information consisted of viewing a 10 minute video. As in a NHS setting this video could be viewed online, it was assumed there was no cost for this part of the intervention. The UV photo imaging was assumed to be taken during a 20 minute appointment with a hospital radiographer.[43] Using a UV face scanner the radiographer would take a UV image of the patient's face. UV face scanners can be purchased online for around £160. It was assumed the device had a life span of one year, or 6,264 uses, based upon 24 uses per day (three appointments per hour for an eight hours day) on Monday to Friday only (261 days per year). Table 2.6 displays the costs incurred per patient of UV imaging.

To engage people in the attending the photo-aging session it was also assumed that there would need to be a media campaign to encourage enrolment. This was assumed to consist of a short television campaign. The costs of implementing a television media campaign consist of two components, the cost of production of the advert itself and the purchase of air time with broadcasters. The former is a fixed cost and does not vary with the number of times the advert is shown. The productions cost of developing a television advert can vary substantially from a few thousand pounds to more than a £100,000 particularly if celebrity endorsements are used.[44] For the purposes of the model, a moderate figure of £60,000 was selected to develop the television advert. The cost of buying air time with broadcasters similarly varies substantially with the channel and time of broadcast. For the purposes of the model, it was assumed that the advert would be broadcast on the terrestrial channels ITV and Channel 4, being shown an equal number of times on each channel. Average prices were obtained for broadcasting on ITV and Channel 4 in England only (adverts can be broadcast regionally) from an advertising agency "TV advertising".[45] The price of a 30 second advert on ITV was £10,056. The price of a 30 second advert on Channel 4 was £4,188. It was assumed that the media campaign would run for 4 weeks a year and would consist of 4 adverts per day on each channel.

Table 2.6: UV imaging costs

Intervention component	Costs
UV face scanner	£160
Cost of camera per patient	£0.03
Hospital radiographer (PSSRU: £34 per hour)	£11.33
Total cost per patient	**£11.36**
Cost of ITV advert	£10,056
Cost of Channel 4 advert	£4,188
Broadcast costs (£7,122* 56*4)	**£1,595,328.00**
Production costs	**£60,000**
Fixed costs	**£1,659,516**
Cost per head[a]	£12.48

[a] Assumes population is 18 to 24 year olds and 30% participation.

2.3.2 'Living with the Sun'

Intervention: The 'Living with the Sun' (LWS) programme is practical classroom work and includes activities designed to increase children's scientific knowledge of the Sun, its characteristics and activities in relation to life on the Earth. It consists of ten workshops covering four topics:

- The effect of sun exposure on the body;
- The different skin types and their sensitivity to sunlight;
- The determinants of variations in the UV intensity;
- Sun protection strategies.

Calculating effectiveness: The Sancho-Garnier (2012)[25] reports a number of outcomes describing individual use of sun protection practices including the use of the following:

- Sunscreen;
- T-shirt;
- Shade;
- Hats;
- Sunglasses.

Data were used from the first four of these in the model calculating relative risks for each of the above sun practices. Data on sunglass use was not used because it is only likely to have very minimal impact on the total sun exposure experienced individual and therefore does not impact on the likelihood of experiencing sunburn or skin cancer. To calculate the relative risks for each of the four outcomes the mean difference in the use of each sun protection practice was calculated. This was then added to the baseline risk of using that practice, which was calculated as the average use across both the control group and intervention group pre-intervention. The risk of using the protection in the intervention group was then divided by the baseline risk to calculate a relative risk.

In addition to the change in the sun behavioural outcomes, Sancho-Garnier *et al.*, (2012)[25] also reported the difference in the number of sunburns. A relative risk was also calculated for this outcome. The effectiveness values used in the model are presented in Table 2.7.

Table 2.7: Effectiveness of 'Living with the Sun'

Relative risk sunburn	Relative risk sunscreen	Relative risk shade	Relative risk clothing	Relative risk hat
0.96	1.05	1.04	1.38	1.04

Calculating costs of implementation: The health education programme 'Living with the Sun' was evaluated by Sancho-Garnier *et al.*, (2012)[25]. The programme involves delivery of a free access education programme by a primary school teacher during 10 workshops. Prior to delivery of the programme teachers are trained. The costs shown in Table 2.8 of receiving the education programme per UK child were calculated using information provided by Sancho-Garnier *et al.* (2012)[25] on the intervention, published data and assumptions[25]. Although in the RCT the education programme is delivered by a single teacher per class, in the UK primary school teachers are accompanied by a teaching assistant (TA).[46] For the purpose of the model, it was assumed that the TA would not participate in the delivery of the lesson.

A full-time classroom teacher has an average salary of £36,400 per year (Department for Education, 2014).[46] The National Union of Teachers (NUT) states that a teacher should work a maximum of 1265 hours per year (NUT, 2012).[47] This information can be used to calculate an hourly salary of a teacher of £27.35. Sancho-Garnier *et al*. (2012)[25] did not report the length per workshop nor the time taken to train teachers[25]. It has been assumed that teachers and TAs were trained for 4 hours prior to delivering the programme. Each workshop is assumed to take 45 minutes based upon the midpoint of a Key Stage 2 lesson (QCA, 2002).[48] Primary school classes have an average of 20.4 students (per classroom teacher, not including TAs) (Department for Education, 2014).[46]

Table 2.8: Cost of 'Living with the Sun' education programme

Intervention component	**Costs**
Cost of training teacher (4 hours of teachers time)	£109.41
Cost of delivery by teacher (10*45 minutes of teachers time)	£205.14
Total cost per class	£314.55
Total cost per child (Based on 20.4 students per class)	**£15.42**

2.3.3 Tailored messages

Intervention: The intervention consisted of three sets of educational newsletters about skin cancer and sun protection, based on Precaution Adoption Process Model, and related sun protection resources (e.g. swim shirt, hat and sunscreen). Newsletters were mailed to parents and children. The first parental newsletter of each annual series provided general information about skin cancer and its causes. The second addressed personalised risk perception using tailored information about each child's specific risk factors (hair, eye, and skin colour; freckling; tendency to burn/tan), based on information at enrolment or skin examinations. Further newsletters addressed sun protection strategies for reducing children's risk and ways to overcome barriers (e.g. through testimonials conveying positive social norms and interactive features). Newsletters for children (included age-appropriate information and activities) were sent with parental newsletters but did not require parent involvement.

Calculating effectiveness: A number of relevant outcomes were reported in the Crane (2012)[24] study including the use of sunscreen, protective clothing, hats and shade, as well as the reduction in the number of sunburns experienced. These were reported over a three year period. The Crane (2012)[24] reports the odds of using each of the types of protection/being sunburnt for both the intervention and control group. These were used to calculate risks of using each protection type and then a relative risk was calculated. In the case of the number of sunburn the Crane (2012)[24] study reports both odds of getting severe and non-severe sunburn for the purpose of the model, an average of these two was taken. The effectiveness values used in the model are presented in Table 2.9.

Table 2.9: Effectiveness tailored messages

Year	Relative risk Sunburn	Relative risk Sunscreen	Relative risk Shade	Relative risk Clothing	Relative risk hat
Year 1	0.81	1	1.00	1.07	1.004
Year 2	0.76	1.007	1.00	1.09	1.019
Year 3	0.89	1.028	1.03	1.1	1.12

Calculating costs of implementation: Crane et al. (2012)[24] undertook a RCT to evaluate the effect of a mailed intervention to promote sun protection of children[24]. This involved both parents and children being sent educational newsletters relating to sun exposure over a four year period. In the first year parents were sent three newsletters and children were sent sun product resources including swim shirts, sun hats, sunscreen and a backpack. In the second year parents were sent four educational newsletters. In the third year children were sent one newsletter and parents four newsletters and in the final year children received two newsletters and their parents three.[24] The study reported that newsletters were one to four sides long. When calculating the cost of the intervention it was conservatively assumed each newsletter was four sides long. A cost of £0.05 per side was assumed. It assumed that the parent's newsletter is delivered by the child and as such that there are no delivery costs for these newsletter. This contrasts with the trial where the letters were posted. Costs of the intervention incurred after the first year (Year 0) were discounted at 1.5% per year in line with the methods for the development of NICE Public Health guidance.[10] To allow for a tailored message to be delivered costs of administering a short survey consisting of 2 sides of A4. The processing of the survey and administering the process of selecting the correct newsletter for each child was assumed to be carried out by a school administrator. The average salary of a school administrator is estimated to be £18,000 a year.[49] Assuming a working 37.5 hours a week for 44 weeks a year, this works out as £0.18 per minute. It was assumed that the processing of each survey would take 3 minutes per child and that ensuring each child/parent got the right newsletter would take a further 1 minute per newsletter. The cost of the intervention per child each year is shown in Table 2.10.

Table 2.10: Cost of tailored messages

Intervention component	Costs[a,b]
School administrator salary per year	£18,000[49]
School administrator salary per minute	£0.18
Year 0:	
Administration of survey	£0.55
Administration of tailoring (1*newsletters)	£0.18
Cost of Survey (1* 2 sided survey)	£0.10
Newsletters (3*4 sided newsletter)	£0.60
Total (Year 0)	**£1.43**
Year 1:	
Administration of tailoring (1*newsletters)	£0.18
Newsletters (4*4 sided newsletter)	£0.80
Total (Year 1)	£0.98
Discounted total (Year 1)	**£0.97**
Year 2:	
Administration of tailoring (1*newsletters)	£0.18
Newsletters (5*4 sided newsletter)	£1.00
Total (Year 2)	£1.18
Discounted total (Year 2)	**£1.15**
Year 3:	
Administration of tailoring (1*newsletters)	£0.18
Newsletters (5*4 sided newsletter)	£1.00
Total (Year 3)	£1.18
Discounted total (Year 3)	**£1.15**
Intervention total	**£4.77**
Discounted intervention total per child	**£4.67**

[a] NICE Public Health Guidance[10] [b] Totaljobs[49]

2.3.4 Text messages

Intervention: The intervention consisted of daily text message reminders sent via mobile phone. The text message had 2 components: a "hook" text detailing daily local weather information and a "prompt" text reminding users to apply sunscreen. For the purpose of the model, it was assumed that these would only be sent in the summer months of May to August.

Calculating effectiveness: The study by Armstrong *et al.* (2009)[22] only reported one relevant outcome the use of sunscreen which was measured objectively with the use of electronic monitors attached to the sunscreen tube. The study by Armstrong reports the proportion of individuals using sunscreen on average over the course of the study. These were used to calculate a relative risk of using sunscreen in the intervention group relative to the control group. The use of text messaging services, however, requires consent by individuals to receive the messages, using these estimates of effectiveness would therefore overestimate the impact of the intervention as it assumes everyone would opt into receiving the messages. Armstrong *et al.* (2009)[22] reported of the participants in the intervention arm, 69% would use the text message service if was available. It was assumed that mobile phone ownership is near universal for the target population; OFCOM put the figure at 92% for the population as a whole and noted a down trend in ownership with age.[50] The relative risk was therefore adjusted assuming that only 69% of any target population would agree to receive the message. The effectiveness values used in the model are presented in Table 2.11.

Table 2.11: Effectiveness text messages

	Relative risk sunscreen	Relative risk shade	Relative risk clothing	Relative risk hat
Unadjusted	1.33	1.33	1.33	1.33
Adjusted	1.23	1.23	1.23	1.23

Calculating costs of implementation: The intervention implemented in the Armstrong *et al.* (2009)[22] study consisted of two daily text messages, which is assumed for the purposes of the model, and are delivered to those who participate through the months May to August. This is 123 days and therefore 246 text messages are sent per person enrolled. The cost of a text message based on bulk text message prices is £0.018 per message.[51] It was assumed this would require some management to write the message indicating the weather for that day. This was included as fixed cost i.e. one that doesn't change with number of people receiving the message. This task was assumed to be carried out by meteorologist who would take one hour per day for 123 days a year. It was assumed that a meteorologist has a salary of £35,000[52] per year and a working week of 38.5 hours. A meteorologist therefore has an hourly rate of £17.48 per hour. To engage people in the text message programme it was also assumed that there would need to be a media campaign to encourage enrolment. This was assumed to consist of a short television campaign of four weeks duration using costs as described for the photo-aging intervention.

Table 2.12: Cost of text messages

Intervention component	Costs
Cost per message	£0.018
Total costs of messages (246*£0.018)	£4.43
Cost writing message by meteorologist (246*17.48)	**£4300.08**
Cost of ITV advert	£10,056
Cost of Channel 4 advert	£4,188
Broadcast costs (£7,122* 56*4)	**£1,595,328**
Production costs	**£60,000**
Fixed costs	**£1,659,628**
Costs per head[a]	**£4.53**

[a] Assumes population is 18 to 50 year olds and 69% participation.

2.3.5 Mass media (SunSmart programme)

Intervention: The SunSmart campaign is a skin cancer prevention programme which involved public education and advocacy. It consisted of a national media campaign to raise awareness of the risks of skin cancer. A number of policy changes have also been introduced including manufacturing standards for sunglasses, and policies regards the use of sun protection in schools and in the workplace.

Calculating effectiveness: The study by Dobbinson (2008)[26] reported odds ratios using a number of forms of sun protection as well as the odds of sun burning (during peak hours of 11am to 3pm) relative to baseline. The odds ratios were adjusted for a number of covariates using a logistic regression. These odds ratios were converted to risk ratio assuming a baseline risk of the behaviour as used in the model (8.75% for protection practices and 15% chance of burning). These baseline risks are almost certainly not reflective of the baseline risks in the Dobbinson (2008)[26] study, but these were not reported. The estimated relative risks are likely to be optimistic as the baseline risk of using protection and experiencing sunburn is likely to be higher in Australia and this should be taken into account when interpreting cost-effectiveness estimates. Dobbinson (2008)[26] did not report an outcome relating to the use of shade as a form of protection, but instead reported time outdoors and the odds ratio for this outcome was used instead. For clothing the odds ratio for the use of ¾ or long sleeved tops was used.

Table 2.13: Effectiveness mass media

Relative risk sunburn	Relative risk sunscreen	Relative risk shade	Relative risk clothing	Relative risk hat
0.81	1.03	1.00	1.07	1.01

Calculating costs of implementation: SunSmart was a multifaceted campaign, but it's principal feature was media principally consisting of a television campaign. For the purposes of the model, costs of implementing a televised media were therefore focused on. This was assumed to consist of an extended television campaign of 12 weeks using costs as described for the photo-aging intervention. Costs for the media intervention are summarised in Table 2.14 below.

Table 2.14: Cost of mass media

Intervention component	Costs
Cost of ITV advert	£10,056
Cost of Channel 4 advert	£4,188
Broadcast costs	**£4,785,984**
Production costs	**£60,000**
Total costs	**£4,845,984**
Costs per head[a]	**£0.09**

[a] Assumes population is whole population.

Section 3: Model Structure

3.1 SCOPE OF MODEL

As previously stated the aim of the economic model is to assess the cost-effectiveness of interventions that seek to present and disseminate complex health risk information relating to safe sun exposure. However, as explained in Section 2.1 it was not possible to include health conditions associated with vitamin D deficiency due to lack of appropriate effectiveness data. The model, therefore, solely focuses on the risks of exposure to sunlight. Exposure to the sun is associated with a number of health conditions including skin cancers, sunburn and cataracts.[4]

It was aim of this model to capture the impact of changes in sun exposure on all three of these conditions. After examining the literature closely it was found, however, that while there was a body of evidence supporting a causal link between cataracts formation and sunlight exposure,[53-56] the nature of this relationship is still not fully understood. Importantly, for the purposes of the model there is minimal epidemiological evidence describing the nature of any dose response relationship. This information is key to being able to model the impact of interventions on the likelihood of experiencing cataracts and therefore unfortunately means that cataracts cannot be included as a health outcome in the economic model.

The omission of cataracts from the model has a potentially substantial impact on the cost-effectiveness estimates obtained because cataracts have a high incidence rate amongst older people. It is estimated that there are over 300,000[57] procedures are carried out annually to correct for cataracts in the UK at an estimated cost of over £200 million per annum.[43] The cost-effectiveness ratios calculated are, therefore, likely to underestimate the true benefits of implementing the interventions.

The model therefore includes the following conditions:

- Malignant Melanoma (MM);
- Basal Cell Carcinoma (BCC);
- Squamous Cell Carcinoma (SCC);
- Sunburn.

3.2 JUSTIFICATION OF MODEL STRUCTURE

As previously discussed a number of previous analyses have been carried out assessing the cost-effectiveness of interventions aimed at preventing the primary disease associated with sun exposure: skin cancer. These cost-effectiveness analyses identified as part of the systematic review of cost-effectiveness have taken a number of approaches. The majority have opted to use a decision tree, while one uses a Markov structure and another a hybrid approach.

The choice of model type and model structure is central to determining the accuracy of the cost-effectiveness estimates obtained from the model. There are two alternative model types that could be used; a decision tree or a Markov model.

Decision trees assign a probability of particular outcomes such as the likelihood of an individual getting skin cancer and calculate pay-offs (costs and QALYs) for each alternative state of the world i.e. with and without cancer. Expected costs and benefits are then calculated by summing the probability of each outcome with value of the costs and benefits.

Markov models follow a cohort of individuals through a number of discrete mutually-exclusive health states which are evaluated at regular intervals (e.g. a month or a year) to determine the number of individuals in each state. Each of these health states is associated with both costs and QALYs from which total benefit and costs can be calculated. Transition matrices define the probabilities of moving between the different health states. Usually these probabilities are the same throughout the lifetime of the model, but Markov models can be built to incorporate time variant transition matrices. Interventions act by altering the transition matrix and altering the probability of moving between health states e.g. lowering the probability of moving from healthy to having skin cancer.

A Markov structure can be used in two alternative ways for the purposes of modelling the impact of sunlight exposure.

Under the first alternative the Markov model has one or more health states for each of the conditions associated with sun exposure. This form of Markov model would potentially allow for a more accurate portrayal of the consequences (costs and QALYs) of each of the included conditions. Interventions therefore act by reducing the likelihood of moving to one of the disease states. The advantages of this type of Markov model are, however, likely to be relatively small in the context of the current model as most of the conditions associated with over exposure to the sun are of relatively short duration. The exception to this is malignant melanoma. Even for malignant melanoma, however, it is not clear that adopting this approach would be particularly beneficial as the interventions aim to prevent skin cancer rather than reduce morbidity or mortality associated with malignant melanoma.

The second possible Markov structure is the one adopted in previous skin cancer guidance[58] where a Markov model is used to model the use of sun protection practices. This form of Markov model allows for a more sophisticated portrayal of the use of protection practices. Interventions act on the model by altering the probability of using protection directly and these are then mapped on to disease outcomes. The primary advantage of this form of Markov model is that it is a dynamic model modelling the impact of the interventions and therefore potentially more accurately reflects differences in protection practices in the population and the impact interventions are likely to have on those practices. Furthermore, this form of Markov model can arguably better represent any potential decay in the effectiveness of intervention.

There are two principal disadvantages of this form of Markov model. The first is the complexity of this form for model means that the impact of assumptions made in the model on resulting cost-effectiveness estimates is less clear. The model of the health effects of sunlight exposure will require extensive assumptions to be made about how changes in sun practices impact on lifetime sun exposure and on the likelihood of experiencing associated diseases. These assumptions are likely to have a significant impact on the cost-effectiveness estimates predicted by the model. Understanding the impact of these assumptions is therefore important to making judgements regarding the reliability of the cost-effectiveness estimates produced by the model. This will be substantially more difficult if the more complicated model structure required in a Markov model is adopted.

The second issue is that this model places significant emphasis on the impact of interventions on the use of sun protection practices. These are then mapped on to the probability of using protection which is then mapped on to sun exposure outcomes such as total lifetime sun exposure and sun burns before being mapped on to the other disease outcomes (malignant melanoma and non-malignant skin cancers). There is therefore a long chain of causality between the impact of the interventions and the disease outcomes. This introduces a significant amount of structural uncertainty in the model that it is all but impossible to parameterise and therefore cannot be accounted for in the model. Furthermore, this approach ignores data reported in a number of the modelled interventions on reduction in sunburns which can be much more directly linked with a number of the disease outcomes of the model (as well as being an outcome of the model itself).

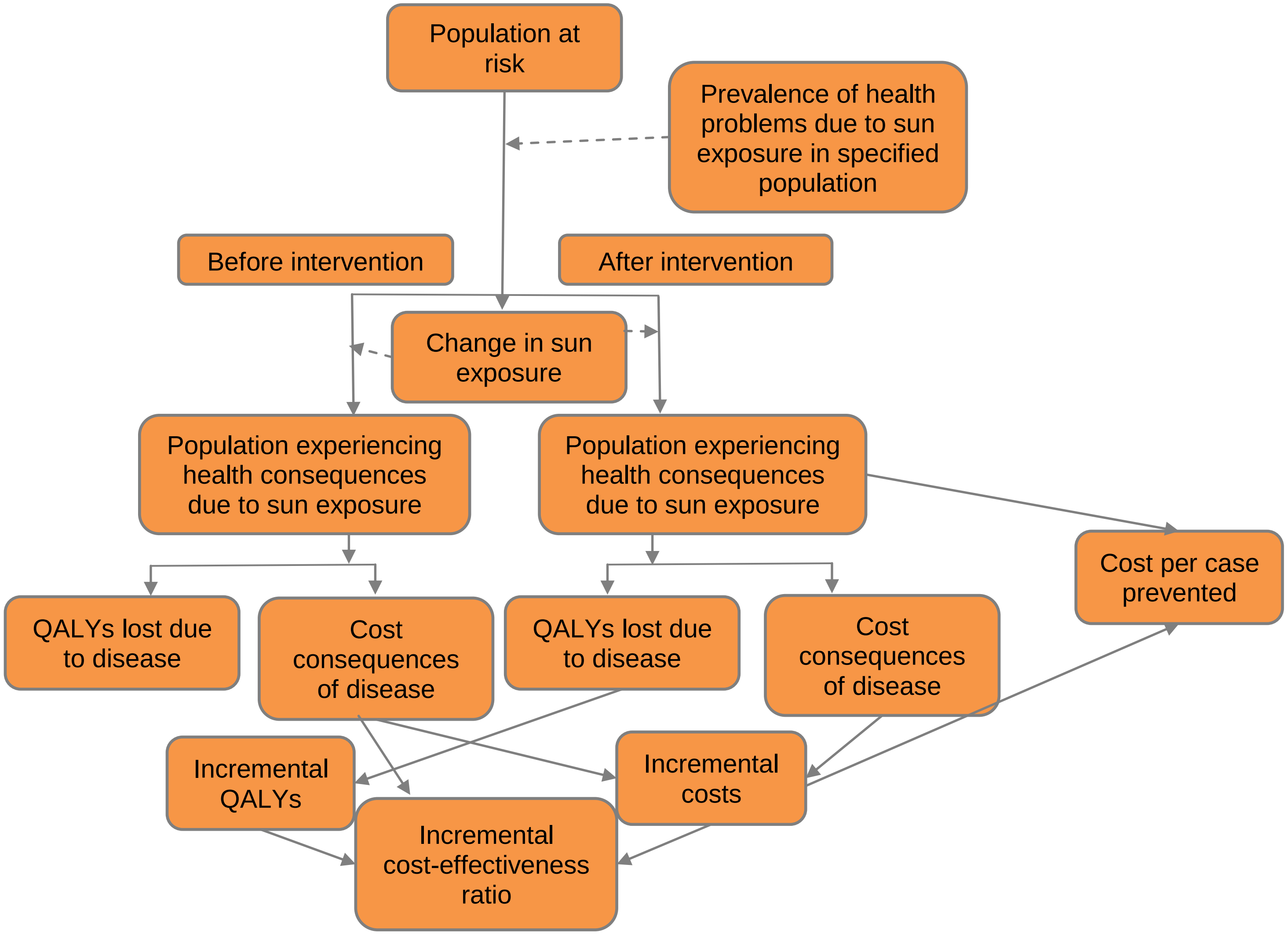
On consideration of these advantages and disadvantages it was therefore decided to use a decision tree approach for the current model.

3.3 OVERVIEW OF MODEL STRUCTURE

Figure 3.1 depicts the proposed basic model structure. This model structure is generic to all the conditions considered as possible health consequences of exposure to the sun. To link the impact of interventions on sun exposure practices and ultimately health consequences and associated costs, a step-by-step approach will be used. Each step in this process is described below.

The model uses a time horizon of 80 years and discount rates of 1.5% applied to both costs and benefits. For the interventions ‘Living with the Sun’ and tailored messages, the population were children with a starting age of seven. For the intervention photo-aging, the population was young adults aged 18 to 24 with an average age of 21. For the mass media campaign the population was the whole population. For the text message intervention, the population was adults aged 18 to 50, with an average age of 34. A summary of all inputs used in the model and the key assumptions made are included in Appendixes A and B respectively.

Figure 3.1: Model structure



Step 1: Specify each population 'at risk'

The first step in the modelling process was to identify the population at risk and the size of each of these groups. The model currently uses three populations, these are as follows:

- Children aged 7 years of which is the population for the 'Living with the Sun' programme and the tailored message =;
- Young adults aged 18 to 24 with mean age of 21 which is the population in the photo-aging intervention;
- Adults aged 18 to 50 with a mean age of 34 which is the population for the text message intervention;
- Whole population, this is the population for the mass media intervention.

The size of all three of these populations was identified using data from the ONS.[59]

Step 2: Identify baseline disease risk

The second step was to identify the baseline risk (incidence rate) for each of the conditions associated with sun exposure for the target population both now and at all subsequent time points. This was primarily done using incidence data from epidemiological studies which are described in Table 3.1, Table 3.2, and Table 3.3. The figures relating to the incidence of sunburn are nearly 20 years old and therefore likely to be out of date, however, the reported values were used rather than speculating about trends in the incidence of sunburns. Slightly, more recent data from a study available in Gould et al (2003)[60], however suggest a similar incidence rate of sun burn with overall rate of 18.5% in individuals aged 16 and over. This compares to 16% from the Melia and Bulman (1995)[61] study. Data for the incidence of sunburn was not available from Melia and Bulman (1995).[61] Expert opinion provided by Professor Lesley Rhodes, however, suggested that the incidence of sunburn is likely to be lower in children than adults and therefore we assumed a relatively low incidence of sunburn in children under 13. The incidence of sunburn is explored in the sensitivity analysis.

The estimated incidence of BCC is likely to be conservative one as studies suggested that 30-50% of BCC are treated in primary care or the private sector may never reach the registries.[51] Higher incidence rates have the effect of increasing cost-effective and so estimates of cost-effectiveness the estimates generated by model can therefore be considered conservative.

The incidence of SCC was not identified from epidemiological sources and instead was calculated using a model linking lifetime sun exposure with the incidence of SCC. Further details of this linking process are described in Section 3.5.

Table 3.1: Incidence rates for sunburn

Age	Incidence rate[a]
Aged 0 to 2	10% [b]
Aged 3 to 12	15%
Aged 13 to 15	28%[b]
Aged 16 to 24	28%
Aged 25 to 34	23%
Aged 35 to 44	16%
Aged 45 to 54	16%
Aged 55 and over	6%

[a] Melia and Bulman (1995)[61]
[b]Assumed value

Table 3.2: Incidence rates for malignant melanoma

Age	Incidence rate per 100,000[a]
0-4	0.04
5-9	0.06
10-14	0.18
15-19	1.00
20-24	3.54
25-29	5.96
30-34	10.23
35-39	14.31
40-44	16.41
45-49	20.96
50-54	22.1
55-59	28.99
60-64	35.46
65-69	50.51
70-74	53.53
75-79	63.56
80-84	66.08
85-89	74.6
90+	74.72

[a] ONS Cancer registry statistics and ONS Population statistics[5, 59]

Table 3.3: Incidence rates for Basal Cell Carcinoma

Age	Incidence rate per 100,000[a]
0-4	0.05
5-9	0.10
10-14	0.14
15-19	0.51
20-24	1.10
25-29	4.22
30-34	8.69
35-39	15.37
40-44	29.02
45-49	46.89
50-54	68.13
55-59	101.31
60-64	154.51
65-69	280.16
70-74	381.38
75-79	528.68
80-84	667.77
85-89	791.92
90+	853.91

[a] ONS Cancer registry statistics and ONS Population statistics[5, 59]

Step 3: Determine the incidence of disease in each group

Following the identification of the incidence rates for each of the included health effects, the next step is to apply these incidence rates and the population size along with a mortality rate to account for ongoing mortality in the population. The mortality rate applied was based on life tables produced by the Government Actuaries department.[62] This allows the calculation of the incidence of each condition in the target population both now and at subsequent time periods. For example, 28% of 25 year olds are sunburnt in a year and there are 470,000 25 year olds in the population, so the incidence of sunburn would be 131,600 cases per year. Note the incidence rate is population average and individuals will have a range of incidence rates including zero sunburns and rates above 100% where individuals experience multiple sunburns in a year.

Step 4: Linking interventions to sun exposure and health outcomes

The next step was to link the outcomes reported for each for the interventions to health outcomes assessed in the model. The effectiveness studies included in the model all report a number of different outcomes describing both changes in behaviour, such as increased use of sunscreen or wearing a hat ,as well as direct measures of sun exposure, including the number of sunburns reported in both the control and treatment arm of the trial. Table 3.4 summarises the outcomes used in the model.

Table 3.4: Outcomes included in model for each intervention

Intervention	Sunburn	Use shade	Use clothing	Use sunscreen	Use hat
Photo-aging		✓	✓	✓	✓
'Living with the Sun'	✓	✓	✓	✓	✓
Tailored messages	✓	✓	✓	✓	✓
Text messages		✓	✓	✓	✓
Mass media	✓	✓	✓	✓	✓

For the interventions 'Living with the Sun', tailored messages and mass media campaign the number of sunburns were reported and from this it was possible to calculate a relative risk that could be directly applied to the incidence rate of sunburn. The impact of these interventions on sunburn could, therefore, be assessed directly. However, none of the studies assessing the effectiveness of photo-aging or text messages reported changes in the number of sunburns. The impact of this intervention on the number of sunburns was, therefore, assessed by linking increases in the use of sun protection practices to the likelihood of experiencing sunburn. This was also done for the other interventions to validate the method and allow for a consistent approach in measuring the impact of interventions on sunburn. The method of linking safe sun practices is described in detail in Section 3.3.

Evidence suggests that the incidence of both MM and BCC is linked to the pattern of sun exposure as well as, possibly, the total amount of sun exposure.[3] In particular, MM and BCC are associated with high levels of intermittent exposure.[3] Sunburn is generally thought to be a relatively good proxy for high levels of intermittent sun exposure[63] and, therefore, sunburn is an important risk factor for both MM and BCC.

The incidence of sunburn was, therefore, linked to the incidence of both MM and BCC, based on epidemiological evidence. The method used to link sunburn incidence with both MM and BCC is described in detail in Section 3.3. Interventions, therefore, act to reduce the incidence of MM and BCC by reducing the incidence of sunburn.

Squamous cell carcinoma differs from the other skin cancer types in that it is thought that the main risk factor is total lifetime sun exposure.[3] The impact of interventions on SCC was, therefore, modelled by linking increases in the use of sun protection practices to reductions in total lifetime sun exposure and this was then linked to the incidence of SCC. This process of linking sun protection practices with the incidence of SCC is described in detail in Section 3.5.

Having linked the interventions with changes in the incidence rate of the relevant conditions, it is then possible to calculate the incidence of each of the conditions in the population by applying these incidence rates to the total population size. For example, if an intervention reduces the incidence of sunburn by 10% then the incidence of sunburn for 25 year olds would now be 25.2%. Applying this to the population size of 470,000, the incidence of sunburn amongst 25 year olds would, therefore, be 118,440 per year.

Step 5: Determining the QALYs lost

In Step 5 the health consequences of the conditions considered in the model are determined. For each condition the QALY loss from each case was identified. Table 3.5 summarises the method for calculation and corresponding values. The QALY loss associated with non-malignant skin cancer (NMSC) - i.e. BCC and SCC - is 0.028, equivalent to 10 days in full health. No data distinguishing BCC from SCC was found. The QALY loss associated with MM is 6.09. The latter comprises of two elements:

- QALYs lost due to morbidity associated with non-fatal cases of MM;
- QALYs lost due to morbidity and premature mortality associated with fatal cases of MM.

Focused searching was undertaken to identify published literature reporting utility or QALY loss associated with sunburn. No studies reporting this were identified. Lucas *et al*. (2008)[64] reported disability-adjusted life years (DALYs) occurring due to sunburn in their burden of disease study. It was not possible to convert the data in this study to QALYs for use in the economic model. Therefore, quality of life (QoL) following sunburn was taken from Guitera *et al*. (2004)[65] who measured the QoL of patients suffering sunburn going to their pharmacy for their first treatment using the Dermatological Life Quality Index (DLQI). DLQI is a disease-specific questionnaire used widely in dermatology. DLQI scores were provided for patients with three or fewer sunburned areas (DLQI score of 3.3) and for patients with four or more sunburned areas (DLQI score of 6.8). Guitera *et al*. (2004)[65] reported the mean number of sunburned areas to be 2.3 and as patients within this study were already likely to have more severe than usual sunburn, requiring a visit to the pharmacy, the DLQI score of 3.3 (fewer sunburned areas) was used within the economic model.

The DLQI score was converted into a utility score using the following equation (Parsi *et al*., 2011[66]):

EQ-5D utility score = 0.956 - [0.0248 x (DLQI score)]

This provided a utility score of 0.874061 for people with sunburn for the duration of their sunburn. Sunburn was judged to last two days, in line with the prevalence data taken from Melia and Bulman (1995)[61]. Given that the DLQI score only considered skin related quality of life, baseline utility for days without sunburn was assumed to be one. This data was used to calculate the QALY loss associated with sunburn:

*QALY in the year of sunburn = (0.874061/365)*2 days + (1/365)*(365 - 2 days)*
= 0.99931

QALY loss in the year of sunburn = 1 − 0.99931 = 0.00069

Table 3.5: QALY loss for each condition

Condition	Value	Source
NSMC (Includes both BCC and SCC)	0.028	Freedberg *et al*. (1999)[67]
Non-fatal malignant melanoma	0.466	Freedberg *et al*. (1999)[67]
Fatal malignant melanoma	23.6	Freedberg *et al*. (1999)[67]
Average of fatal and non-fatal malignant melanoma	6.03	Freedberg *et al*. (1999)[67]
Sunburn	0.00069	Guitera *et al*. (2004)[65] and, Melia and Bulman (1995)[61]

The QALY losses for each disease were applied to the incidence of each of the health outcomes in the population assuming no intervention was implemented and for each of the interventions. For example, if a case of MM results in a loss of 6.03 QALYS and there are 100 cases of MM then 603 QALYS would be lost. QALYs lost in subsequent years were discounted using a discount rate of 1.5% such that QALYs lost further in the future are valued less now.

Step 6: Determining costs

In Step 6 the total costs were calculated. These consist of the costs implementing the intervention within the target population and the costs associated with treating each of the conditions.

Total costs of implementing each of the interventions were determined by multiplying the cost per head by the size of the target population.

Estimates of the health care costs associated with each of the skin cancers were calculated from data on treatment costs provided by Morris *et al.* (2009).[68] The authors estimated the cost of MM and NMSC to the National Health Service (NHS), using data on health services use and unit costs from published sources in the UK. Cost estimates were reported on 2002 prices. The resulting costs per case inflated to 2014 prices are £1,480 for NMSC and £2,807 for MM. It was assumed that there are no health care costs associated with sunburn and that this condition is self-managed. It is however, accepted that in cases of severe sunburn, this may result in health costs. It is, however, unlikely that this a substantial proportion of cases of sunburn. Resulting costs are therefore likely to be minimal. Table 3.6 summarises the method for calculation and corresponding values.

Table 3.6: Health care costs to the NHS associated with included conditions

Condition	Calculation	Value in (2014) £'s	Source
NSMC (Includes both BCC and SCC)	Total cost to the NHS (£57,878,000) divided by number of registrations (50,394) inflated to 2014 prices	£1,480.15	Morris *et al*. (2009)[68] and HM Treasury (2010)[69]
Malignant melanoma	Total cost to the NHS (£13,208,000) divided by number of registrations (6,062) inflated to 2014 prices	£2,807.63	Morris *et al*. (2009)[68] and HM Treasury (2010)[69]
Sunburn	N/A	£0	Assumption

These costs were then multiplied by the incidence of each of the conditions in the no intervention and intervention groups to calculate total costs of treatment for each group. As with QALYs, costs incurred in the future were discounted at a rate of 1.5% such that costs occurring further in the future are valued less.

Total costs for the no intervention and intervention groups were calculated by adding the costs of implementing the interventions to the treatment costs.

Step 7: Calculating the ICER

The final step in the model is to calculate the incremental costs and benefits and the ICER. As described in Section 1.3 this is done by subtracting the total costs assuming no intervention is implemented from the total costs of having to implement the intervention to calculate incremental costs. Similarly incremental QALYs gained are calculated by subtracting the total QALYs lost if the intervention is implemented from the total QALYS lost assuming the intervention is not implemented. Note this is the reverse of normal as these are lost QALYs that are prevented. These are then combined using the formula below to calculate an ICER.

3.4 LINKING SUN PROTECTION WITH SUNBURN INCIDENCE

While two of the interventions, ‘Living with the Sun’ and tailored messages, reported a reduction in the number of sunburns, none of the studies evaluating the effectiveness of photo-aging or text messages reported sunburn as an outcome, including the modelled studies Mahler (2013)[21] and Armstrong (2009)[22]. To model the impact of photo-aging and text messages on the incidence of sunburn it was therefore necessary to link the behavioural outcomes reported in the Mahler (2013)[21] and Armstrong (2009)[22] study with the incidence of sunburn. This was done using data from an epidemiological data reported on the prevalence of sunburn and sun protection practices in a Danish population.[70] This study investigated the likelihood of experiencing sunburn in the last 12 months when using each of the four protection practices; hat use, shade use, sunscreen use and clothing use. The results of this study are worthy of particular note to the committee as they suggest that hat use has no or minimal impact on the incidence of sunburn and perhaps more surprisingly that sunburn was more common amongst those who use sunscreen. This maybe because the use of sunscreen means people tend to spend longer in the Sun believing they have alleviated any risk and therefore burn. The model therefore assumed that the content of any messages focused on increasing the use of clothing and shade as methods of protection.

This study was used to calculate the likelihood of being sunburnt when using either clothing, shade or, clothing and shade as a method of protection. The risk ratio was then applied for each of these behaviours calculated from the results of either the Mahler (2013)[21] or Armstrong (2009)[22] study to calculate the likelihood of being sunburnt when the intervention was implemented.

In addition to using this indirect method of calculating the impact of the intervention on sunburn for photo-aging, it was also applied to the other two interventions ‘Living with the Sun’ and tailored messages. This was done as a validity check on the method as the values could then be compared to the estimates reported in the trial. Table 3.7 reports the effect using the trial data and the one indirect estimate calculated using the method described above. It shows our method to be a reasonable estimate of the reported impact on sunburn for the ‘Living with the Sun’ intervention, but a fairly poor one for tailored messages and a mass media campaign.

Table 3.7: Relative risk of sunburn using alternative methods of calculation

Intervention	RR of sunburn reported in study	RR of sunburn calculated from use of protection practices
Photo-aging	N/A	0.95
‘Living with the Sun’	0.96	0.95
Tailored messages	0.81	0.95
Text messages	N/A	0.89
Mass media	0.70	0.89

For the baseline results the relative risk reported in the study was used where possible.

3.5 LINKING SUNBURN TO INCIDENCE OF MALIGNANT MELANOMA AND BASAL CELL CARCINOMA

As described in Section 3.2, MM and BCC are associated with high levels of intermittent sun exposure. Within the model intermittent sun exposure is approximated by lifetime number of sunburns. This section describes how the lifetime number of sunburns was linked with the incidence of MM and BCC.

Based on a meta-analysis of epidemiological studies, Dennis *et al*. (2008)[71] calculated the odds ratio (OR) of an increase of 5 sunburns during a life to be 1.26. Assuming a linear relationship between sunburn and MM (it was recognised that in all likelihood, the relationship is in fact non-linear, but epidemiological evidence linking sunburn and MM is limited and therefore it is possible to make this simplifying assumption) and using the incidence rate of MM, it is possible to calculate the additional risk of one extra sunburn .This is done by first calculating the odds of getting MM where:

Odds of developing MM are = incidence rate/(1 - incidence rate)

=0.0002/(1-0.0002) = 0.0200877

This is then multiplied by the odds ratio 1.26 to calculate the odds of getting MM with an additional 5 sunburns.

Odds of developing MM with an additional 5 sunburns = 1.26 x 0.0200877= 0.000253

This can then be converted back to an incidence rate for a population with 5 more sunburns on average.

Incidence rate associated with 5 more sunburns = 0.000253/(1 + 0.000253) = 0.00025

Subtracting the original incidence rate from the incidence rate with 5 more sunburns then allows us to calculate the added extra risk of 5 or more sunburns. Dividing this by 5 then allows us to obtain the added extra risk of MM from an additional sunburn.

0.000253-0.0002 = .000052

Additional risk associated with an extra sunburn = 0.00052/5 = 0.000010

Using the change in the number of sunburns measured either directly from the intervention studies or calculated indirectly, as described in Section 3.3; the risk of additional sunburn can be used to calculate the incidence of MM assuming the intervention is implemented.

A similar procedure was also used to model the influence of sunburn on BCC. The odds ratio applied was based on an analysis by Armstrong and Kricker (2001)[63] that reports that suggested each additional sunburn increased the odds of developing BCC by 1.40.

3.6 LINKING SUN PROTECTION WITH INCIDENCE OF SQUAMOUS CELL CARCINOMA

As described in Section 3.2, the risk of SCC is associated with total lifetime exposure. To model the impact of interventions it is, therefore, necessary to model the impact each of the interventions have on lifetime sun exposure.

As no data exists on lifetime sun exposure a behavioural model was developed following the approach taken in skin cancer guidance model PH32 (Matrix 2010).[58] This was used to predict lifetime sun exposure. The behavioural model simulates individuals' behaviour in terms of sun protection and calculates lifetime sun exposure. Lifetime sun exposure is measured in terms of standard erythema dose (SED) as the cumulative sum of annual SED over the 80 year period.

3.6.1 Modelling lifetime sun exposure

In order to estimate sun exposure, it was assumed that the calendar year is divided into 3 periods: a low-SED period (October to March); a high-SED period (April to September); and a holiday period (3 weeks in July). The average number of SED per hour of unprotected exposure during each of these periods was obtained from Diffey (2008)[72] and represents climate conditions of Northern Europe (50° N 0° W) and Florida (28° N 82° W) for the 3 week holiday period. It was assumed that individuals take holiday abroad 60% of the time and stayed in the UK the remaining 40% of time. These assumptions are based on the inputs used in the public health guidance model for skin cancer.[58] While the plausibility of these values may be a matter of some debate, the use of alternative values is unlikely to have a significant impact on resulting estimates of cost-effectiveness.

Data on time spent outdoors was taken from the Matrix study[58] which collected data through a web-based survey hosted by Cancer Research UK in 2007. Table 3.8 presents the average hours spent outdoors per day and the SED per hour of unprotected exposure during each of these periods.

Table 3.8: Average hours spent outdoors per day and SED per hour of unprotected exposure

Period	Hours outdoors per day	SED per hour of unprotected exposure	Source
Non-risk period (Oct - Mar)	0.64	0.10	Diffey (2008)[72]
Risk period (Apr - Sept)	0.93	0.45	
Holiday period in England(July)	5.00	0.67	
Holiday period in sunnier climate (July)	5.00	1.48	

The SED per hour of protected sun exposure can be estimated as a percentage of the SED per hour of unprotected sun exposure, where the percentage depends on four variables:

- Protection offered by the different types of protection (i.e. the sun protection factor, SPF);
- Body areas protected by each type of protection;
- Percentage of body covered by each type of protection;
- Frequency of protection.

Table 3.9 presents the SPF afforded by different types of protection. These represent effective, as opposed to nominal, SPFs.

Table 3.9: SPF afforded by each protection type

Protection type	Effective SPF	Source
Sunscreen	5	Matrix (2010)[58]
Shade	10	
Clothing	20	
Hat	10	

Table 3.10 presents the body areas and percentages of body covered by each type of protection. These are based on the values in the Matrix model. The body areas selected, were however arbitrary, though it is unlikely that changes to these assumptions, would make a significant difference in the overall level of sun exposure experienced by individuals.

Table 3.10: Body areas and percentage of body covered by each type of protection

Type of protection	Head	Chest and back	Arms	Legs	Source
	9%	36%	18%	37%	Hettiaratchy and Papini (2004)[73]
Sunscreen	✓	✓	✓	✓	Assumption
Shade	✓	✓	✓	✓	
Light clothing		✓		✓	
Full clothing		✓	✓	✓	
Hat	✓				

Based on Tables 3.9 and Tables 3.10, the protection provided by each of the four types of protection was calculated by multiplying the levels of SPF afforded by each type of protection, by the percentage of the body protected. Table 3.11 presents a summary of the levels of sun absorption for each type of protection.

Table 3.11: Percentage of sun exposure absorbed by skin for different combinations of sun protection

Type of protection	% Sun absorbed by skin
Sunscreen + Shade + Protective clothing + Hat	0.6%
Sunscreen only	20.0%
Shade only	10.0%
Light clothing only	30.7%
Full clothing	13.5%
Hat only	91.7%

It was assumed for the purposes of the model that individuals in the winter months (October to March) individuals always wear full clothing and, therefore, receive 13.5% of the total SEDs during these months. Based on the Matrix model of skin cancer it can be assumed that during the summer months and the holiday period individuals use protection 35% of the time. With absorption rate equal to the average of using each of the four methods of protection or alternatively that they use each methods of protection 8.75 % of the time and no protection 65% of the time.

Annual exposure is, therefore, estimated as follows:

$$SED_W \times AF \times H_W$$

$$+$$

$$SED_S \times (1-P_S - P_D - P_H - P_C) \times H_S + H_S \times SED_S*((P_S \times A_s) + (P_D \times A_D) + (P_H \times A_H) + (P_C \times A_C))$$

$$+$$

$$SED_H \times (1-P_S - P_D - P_H - P_C) \times H_H + H_H \times SED_H \times ((P_S \times A_s) + (P_D \times A_D) + (P_H * A_H) + (P_C \times A_C))$$

Where:

SED_W is Standard erythema dose in winter
SED_S is Standard erythema dose in summer
SED_H is Standard erythema dose on holiday
H_W Hours spent outdoor in winter
H_S Hours spent outdoor in summer
H_H Hours spent outdoor on holiday
P_S is the probability of using sunscreen
P_D is the probability of using shade
P_H is the probability of using a hat
P_C is the probability of using clothing
A_F is the % absorption using fully clothed
A_S is the % absorption using sunscreen
A_D is the % absorption using shade
A_H is the % absorption using a hat
A_C is the % absorption using clothing

Lifetime sun exposure is then calculated by aggregating annual exposure across the 80 year period for which the model was run.

3.6.2 The effect of the interventions on individuals' lifetime sun exposure

To model the impact of interventions the relative risk of adopting a particular type of protection was applied to the baseline probability of adopting that protection equal to 8.75% for all of the four types of protection and using the above to calculate annual exposure.

3.6.3 Total sun exposure and incidence of squamous cell carcinoma

Using the annual sun exposure predicted by equation above the age specific incidence rate is estimated using a sun dose-risk relationship derived from a multivariate analysis of epidemiological data in which age and sun exposure were identified as the two most important factors in determining risk.[3, 74]. The relationship can be expressed as follows:

Where:
α is the age exponent
β is the dose exponent
γ is the genetic susceptibility factor
SED_t is the annual SED at age *t*

SED_t was estimated using the method described above. Table 3.12 presents the values for α, β and γ. Population data used corresponds to England.[59]

Table 3.12: Parameters required to calculate the sun dose-risk relationship for SCC

Parameter	Value	Source
Age exponent	5.1	Diffey (1992)[74]
Dose exponent	2.3	
Genetic susceptibility factor	1.65E-12	

Using this equation the age specific incidence rates of SCC was calculated in the baseline and in the intervention scenarios. Applying these to the population in England calculating the difference between baseline and intervention scenarios provides an estimate of the number of cases of SCC averted due to the intervention.

In order to validate the model the age-standardised incidence rate for SCC was calculated and compared with the actual reported incidence rate. The age-standardised incidence rate can be calculated as follows:

Where:

R_t = age *t* specific incidence rate
N_t = population in England at age *t*

Our model estimates there are 18717 cases of SCC in the England per year. Incidence data from the ONS cancer registry[5] statistics reports there to 79000 Non-malignant skin cancers of which approximately 25% or 19750 cases per year are SCC. Our model is therefore a relatively accurate predictor of the incidence of SCC.

Section 4: Results: Cost-effectiveness Analysis

Tables 4.1, 4.2, 4.3, 4.4 and 4.5 respectively present the baseline cost-effectiveness estimates for the interventions, 'Living with the Sun', photo-aging, tailored messages mass media and text messages.

The results show a considerable spread in the cost-effectiveness estimates of the different interventions. Three of the interventions, 'Living with the Sun', photo-aging and text messages on the basis of the baseline results would not be consider cost-effective with respective ICERs of £312,744, £316,968 and £65,945 per QALY. In all three cases the estimated ICER significantly exceeds the £20,000. Two of the interventions tailored messages and mass media are, however cost-effective based on the baseline estimates. The tailored message intervention has an estimated ICER of £16,859, while the mass media intervention is dominant. This means that the intervention is both more effective than the comparator and costs less than the comparator. This may seem a little odd given that the comparator is do nothing and therefore by definition a costless intervention, however, the reason that the intervention costs less is because it avoids expenditure on treatment and these cost saving outweigh the cost of implementing the intervention.

The difference in the cost-effectiveness estimates obtained for the different interventions can be very clearly put down to two factors:

- Differences in the cost of implementing each of the interventions;
- Differences in the effectiveness of the interventions.

The mass media intervention, for example, is very cheap to implement in cost per head terms relative to the other inventions and so doesn't actually have to be that effective at this cost per head to be a cost-effective intervention. The mass media intervention, however is in fact estimated to be the most effective intervention and hence is estimated to be highly cost effective. In contrast the 'Living with the Sun'; photo-aging and text messages are all relatively expensive to implement and are much less effective, resulting in high estimates of cost-effectiveness.

The difference in the cost-effectiveness of the 'Living with the Sun' educational programme and the tailored messages intervention are worthy of discussion as both of these interventions are aimed a primary aged children (7 year olds) and have relatively similar effectiveness with regard to the use of sun protection practices. The model, however, generates quite radically different estimates of cost-effectiveness. This is for two reasons:

- The cost per head of implementing the two interventions is quite different, the tailored messages intervention is only £4.67 compared with £15.42 per head for the 'Living with the Sun' intervention.
- The tailored messages intervention is considerably more effective in terms of reducing the incidence of sunburn (RR of 0.81 compared 0.96). This is very important as in the model reduction in the incidenc of sunburn generate QALYS directly from reductions in the incidence of sunburn itself, but also reductions in MM and BCC. Therefore considerably more QALYs are gained by implementing the tailored interventions than the 'Living with the Sun' intervention in the model.

In terms of breaking down where the benefits and cost savings resulting from implementing the interventions come from there are clear trends. For all five of the intervention the bulk of the QALYs are gained from preventing cases of MM. This is perhaps surprising as the incidence of MM is relatively low when compared with all the other conditions. The QALY gains from preventing sunburns and NMSC per case are, however, very small per case relative to preventing a case of MM. In terms of costs saved the largest difference in costs are for BCC and to a less extent SCC. This is relatively intuitive given the cost of treatment are relatively high and both BCC and SCC have far higher incidence rates than MM.

Table 4.1: Baseline results for 'Living with the Sun'

	Living with the Sun	**Do nothing**	**Incremental**
Intervention costs	£9,885,222	£0.00	£9,885,222
Cost of Sunburn	£0.00	£0.00	£0.00
Cost of MM	£13,864,884	£13,875,587	-£10,703
Cost of BCC	£36,758,889	£36,787,055	-£28,166
Cost of SCC	£11,819,693	£11,873,821	-£54,127
Total costs	**£72,328,688**	**£62,536,463**	**£9,792,226**
QALYs lost due Sunburn	3,401	3,408	6.5
QALYs lost due MM	30,121	30,144	23.3
QALYs lost due BCC	695	696	0.5
QALYs lost due SCC	224	225	1.0
Total QALYs Lost	**34,441**	**34,473**	**31.3**

Incremental cost-effectiveness ratio	**£312,744**
Net benefit	**-£9,166,012**

Table 4.2: Baseline results for photo-aging

	Photo aging	Do nothing	Incremental
Intervention costs	£18,458,407	£0.00	£18,458,407
Cost of Sunburn	£0.00	£0.00	£0.00
Cost of MM	£39,130,785	£39,151,937	-£21,152
Cost of BCC	£105,110,251	£105,166,648	-£56,397
Cost of SCC	£33,907,367	£33,929,819	-£22,452
Total costs	**£196,606,811**	**£178,248,404**	**£18,358,406**
QALYs lost due Sunburn	6,163	6,174	10.5
QALYs lost due MM	85,011	85,057	46.0
QALYs lost due BCC	1,988	1,989	1.1
QALYs lost due SCC	641	642	0.4
Total QALYs Lost	**93,804**	**93,862**	**57.9**

Incremental cost-effectiveness ratio	**£316,968**
Net benefit	**-£17,200,029**

Table 4.3: Baseline results for tailored messaging

	Tailored message	Do nothing	Incremental
Intervention costs	£2,993,774	£0.00	£2,993,774
Cost of Sunburn	£0.00	£0.00	£0.00
Cost of MM	£13,817,791	£13,875,587	-£57,795
Cost of BCC	£36,634,958	£36,787,055	-£152,097
Cost of SCC	£11,854,579	£11,873,821	-£19,242
Total costs	**£65,301,102**	**£62,536,463**	**£2,764,639**
QALYs lost due Sunburn	3,373	3,408	35.2
QALYs lost due MM	30,019	30,144	125.6
QALYs lost due BCC	693	696	2.9
QALYs lost due SCC	224	225	0.4
Total QALYs Lost	**34,309**	**34,473**	**164.0**

Incremental cost-effectiveness ratio	**£16,859**
Net benefit	**£515,134**

Table 4.4: Baseline results for mass media campaign

	Media campaign	Do nothing	Incremental
Intervention costs	£4,845,984	£0.00	£4,845,984
Cost of Sunburn	£0.00	£0.00	£0.00
Cost of MM	£1,618,245,182	£1,619,730,741	-£1,485,559
Cost of BCC	£4,988,497,200	£4,993,042,864	-£4,545,664
Cost of SCC	£1,616,215,699	£1,618,563,658	-£2,347,960
Total costs	**£8,227,804,065**	**£8,231,337,263**	**-£3,533,198**
QALYs lost due Sunburn	172,731	173,381	649.1
QALYs lost due MM	3,515,594	3,518,821	3227.3
QALYs lost due BCC	94,367	94,453	86.0
QALYs lost due SCC	30,574	30,618	44.4
Total QALYs Lost	**3,813,267**	**3,817,273**	**4006.9**

Incremental cost-effectiveness ratio	**Dominant**
Net benefit	**£83,670,578**

Table 4.5: Baseline results for text messages

	Text messages	Do nothing	Incremental
Intervention costs	£75,446,122	£0.00	£75,446,122
Cost of Sunburn	£0.00	£0.00	£0.00
Cost of MM	£493,475,456	£493,887,419	-£411,963
Cost of BCC	£1,428,352,751	£1,429,536,365	-£1,183,614
Cost of SCC	£462,038,539	£462,589,502	-£550,963
Total costs	**£2,459,312,869**	**£2,386,013,285**	**£73,299,583**
QALYs lost due Sunburn	78,125	78,309	183.7
QALYs lost due MM	1,072,062	1,072,957	895.0
QALYs lost due BCC	27,020	27,043	22.4
QALYs lost due SCC	8,740	8,751	10.4
Total QALYs Lost	**1,185,948**	**1,187,059**	**1111.5**

Incremental cost-effectiveness ratio	**£65,945**
Net benefit	**-£51,069,070**

4.1 ONE-WAY SENSITIVITY ANALYSIS

The following section presents a number of one-way sensitivity analyses in which key inputs of the model are varied to see they impact on cost-effectiveness. The one-way sensitivity analysis is presented using the metric net-benefit as a measure of cost-effectiveness rather than the ICER as this is always numeric value, where an ICER isn't. This is the case, for example, when an intervention is dominant i.e. both cheaper and more effective. Net benefit expresses the benefit of an intervention in terms of money value. It is calculated assuming that a QALY is worth a certain amount of money to society. The incremental costs are then deducted from this value to calculate the net monetary benefit to society, see formula below. It is assumed that each QALY was worth £20,000 to society. This is on the basis that the value society is willing to pay for QALY is around £20,000.

The results of the one-way sensitivity analysis demonstrate a number of general trends, which are worthy of note. Firstly, increases in the costs of treating all the conditions increases the cost-effectiveness estimates obtained. The biggest impact is seen in for the costs of treating sunburn. This is because it makes preventing incidence of these conditions more worthwhile (in monetary terms). Secondly, increases in the incidence of each of the conditions model also increase the cost-effectiveness of the interventions. This simply reflects the fact there are more QALY losses and costs to be prevented. As one would expect, it was observed that increases in effectiveness results in increases in higher estimates of cost-effectiveness. It is, however, notable that the RR of sunburn is far more influential than changes in the use of protection on the cost-effectiveness estimates for the interventions, mass media, 'Living with the Sun' and tailored messages. These result should, however, be interpreted carefully as changes in the use of protection are likely results in fewer sunburns and this relationship is not accounted for in these analyses.

4.1.1 'Living with the Sun'

Figures 4.1 to 4.14 depict the one-way sensitivity analysis for the 'Living with the Sun' intervention. In only one of the one-way sensitivity analyses is the 'Living with the Sun' intervention cost-effective. This is in the analysis looking at how additional years of full effectiveness impact on cost-effectiveness (Figure 4.12). However, it is necessary for the effect last for nearly 10 years for it to be cost-effective and this seems highly unlikely unless a permanent change in behaviour is generated by the intervention.

Figure 4.1: Cost of sunburn

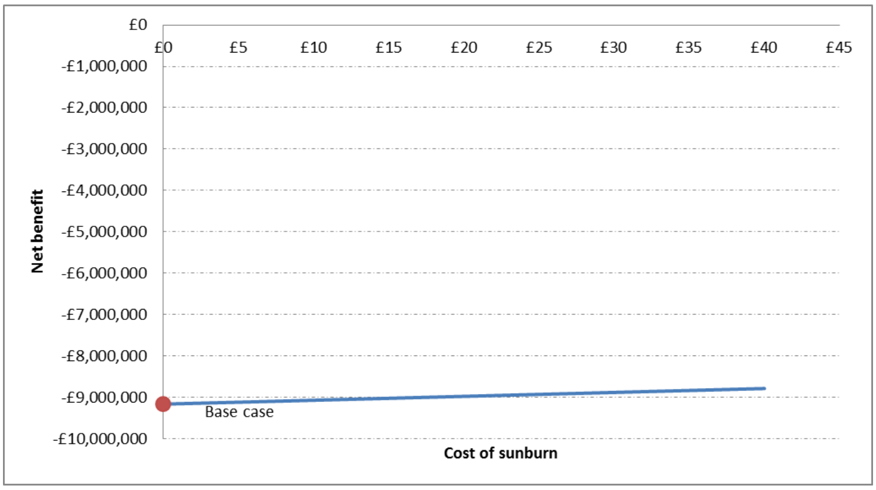


Figure 4.2: Cost of malignant melanoma

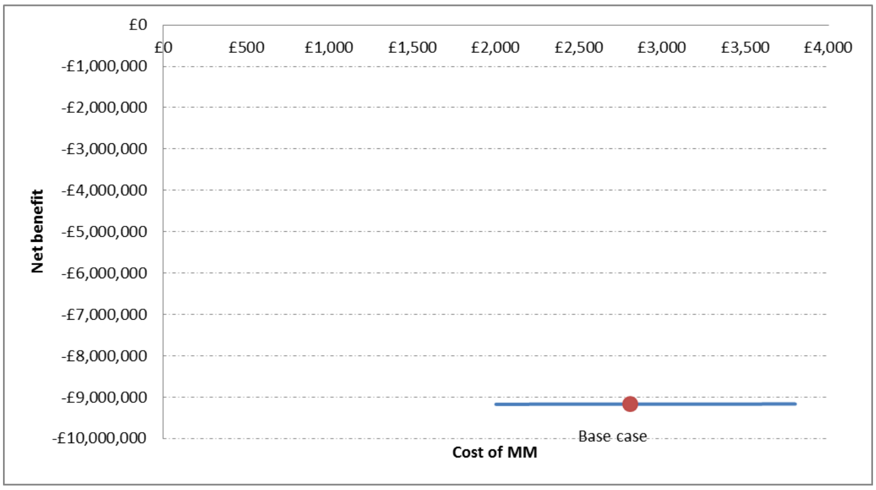


Figure 4.3: Cost of basal cell carcinoma

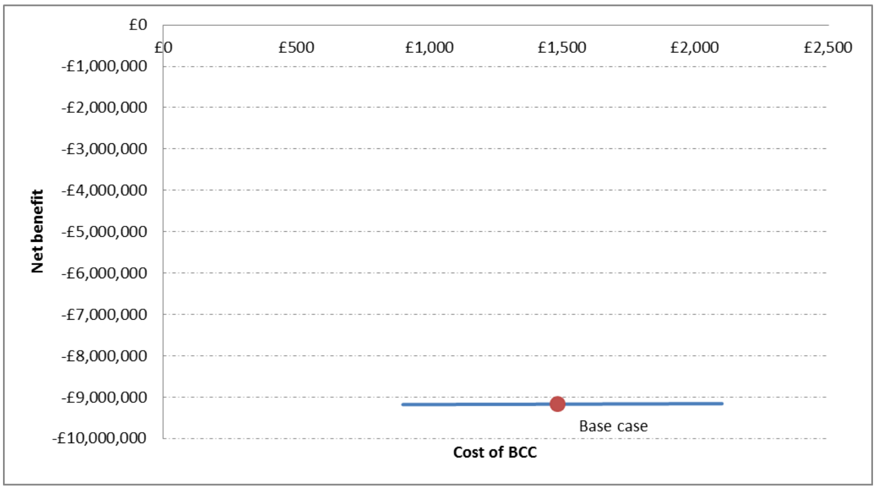


Figure 4.4: Squamous cell carcinoma

Figure 4.5: Cost of intervention

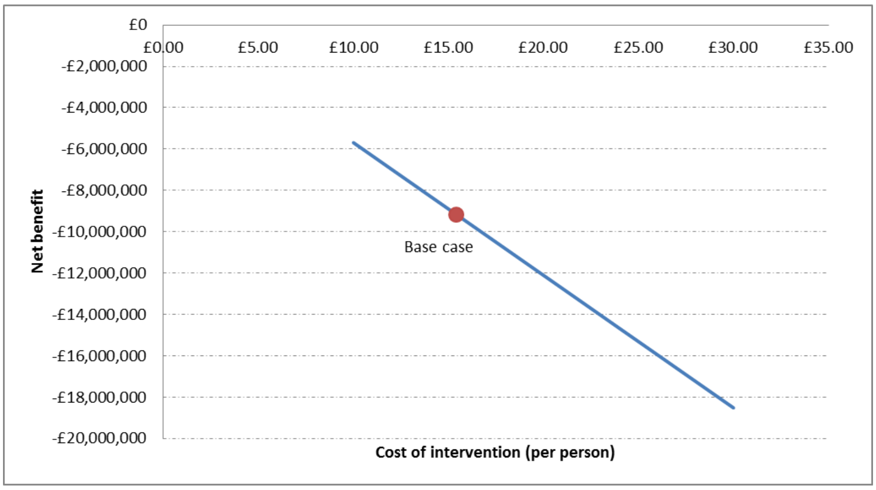


Figure 4.6: Relative risk of sunburn with intervention

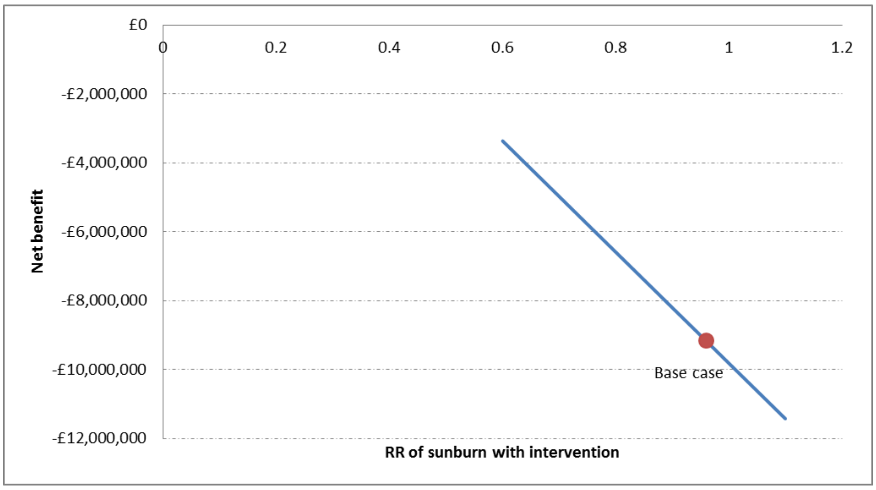


Figure 4.7: Risk ratio of using protection practice

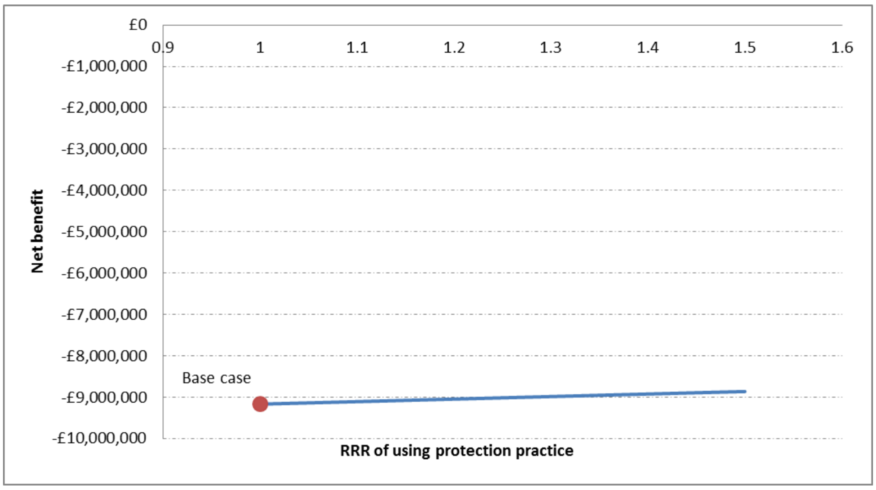


Figure 4.8 Risk ratio of sunburn incidence

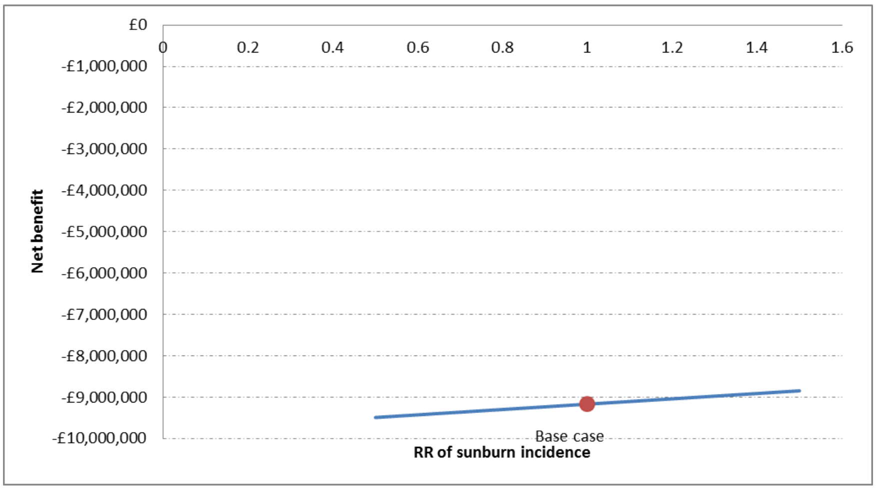


Figure 4.9: Risk ratio of malignant melanoma

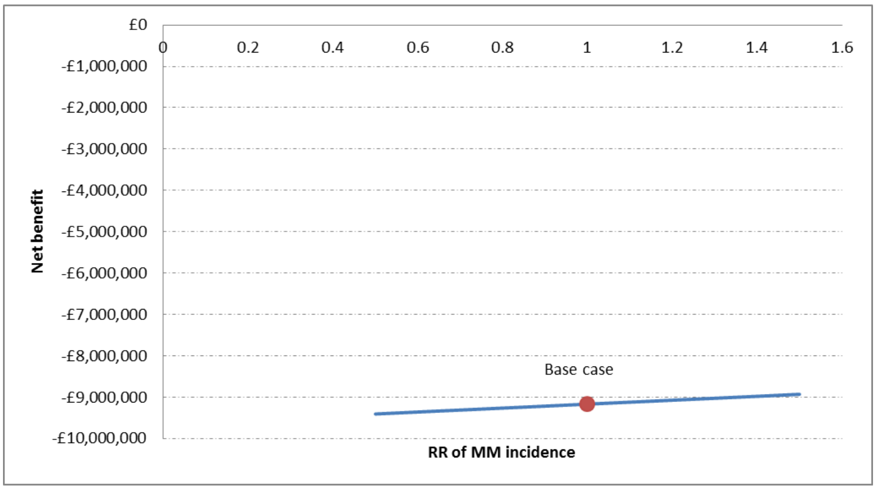


Figure 4.10: Risk ratio of basal cell carcinoma

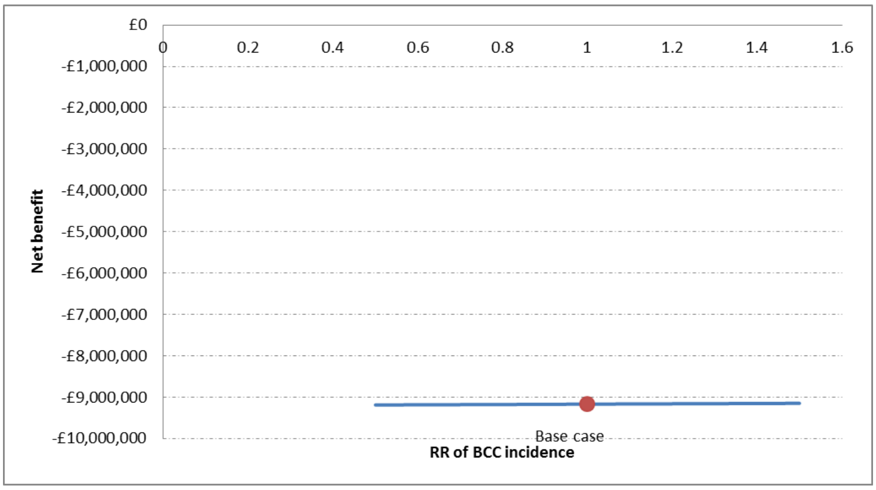


Figure 4.11: Risk ratio of standard erythema dose per year

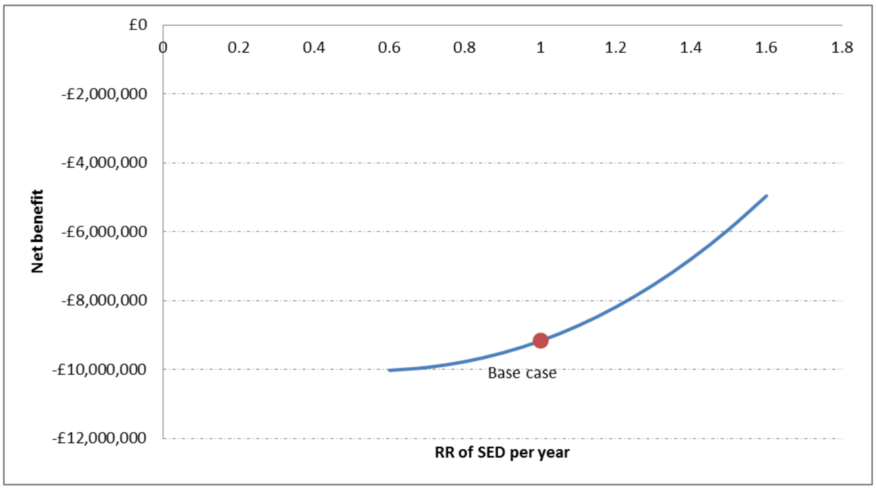


Figure 4.12: Additional years of full effectiveness

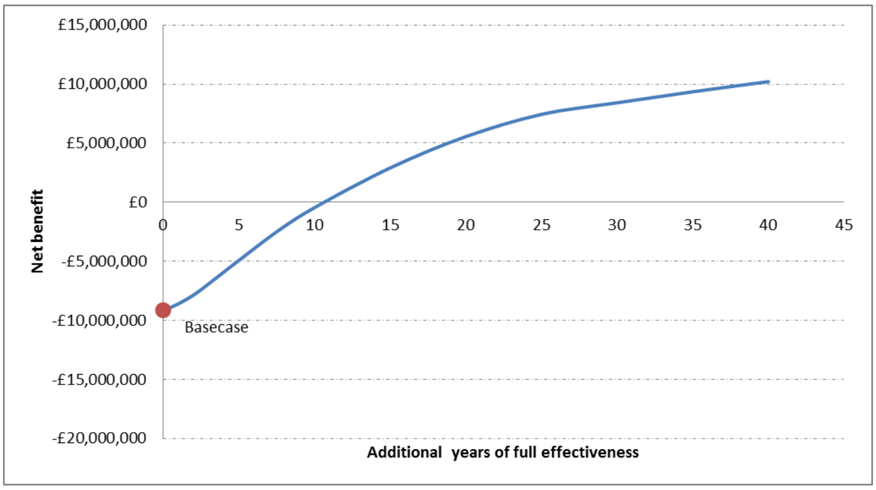


Figure 4.13 Discount rate costs

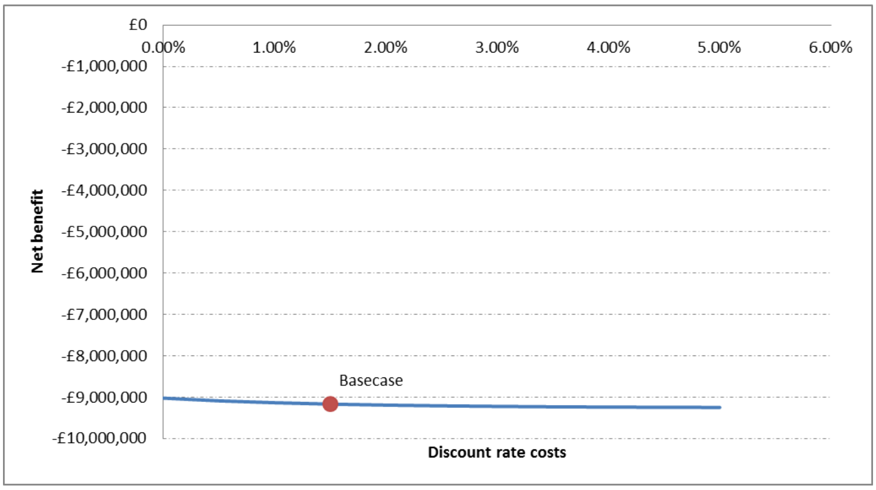
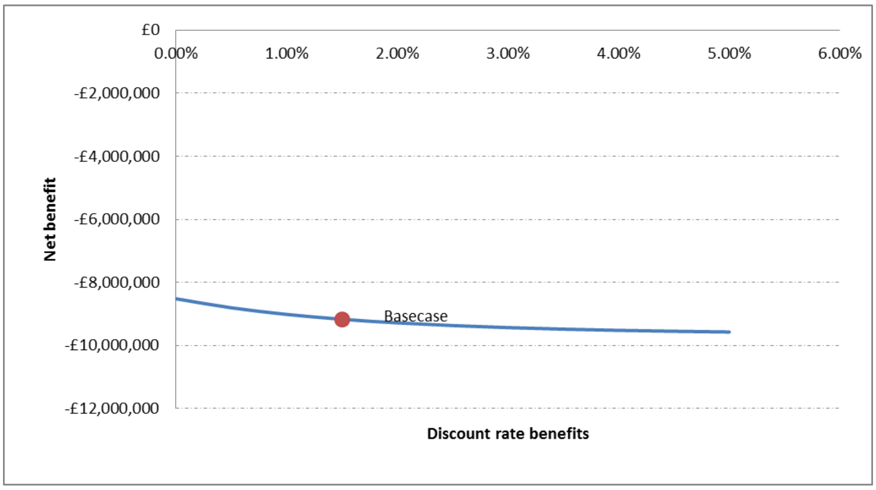


Figure 4.14 Discount rate benefits



4.1.2 Photo-aging

Figures 4.15 to 4.28 depict the one-way sensitivity analysis for the photo-aging intervention. The one-way sensitivity analyses present below show that the photo-aging intervention is rarely cost-effective. In only one analysis is the intervention potentially cost-effective, this is the analysis looking at the RR of sunburn with the intervention. The analysis shows that the cost-effectiveness estimate obtained is particularly sensitivity to this parameter. This is due to the high incidence of sunburn in the target population, meaning there are is greater potential for the intervention to reduce the lifetime number of sunburns.

Figure 4.15: Cost of sunburn

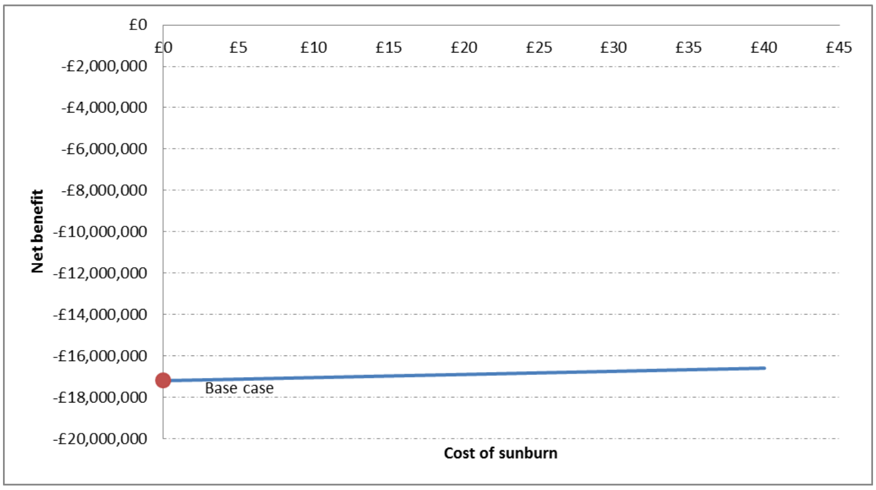


Figure 4.16: Cost of malignant melanoma

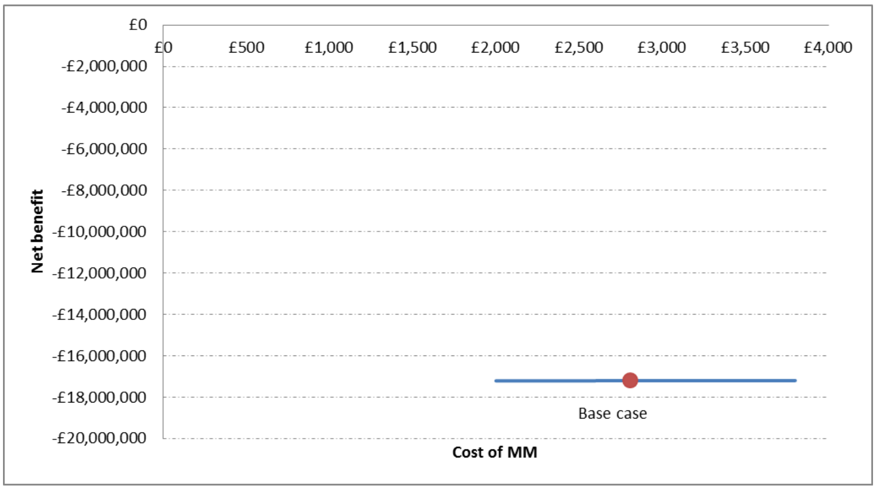


Figure 4.17: Cost of basal cell carcinoma

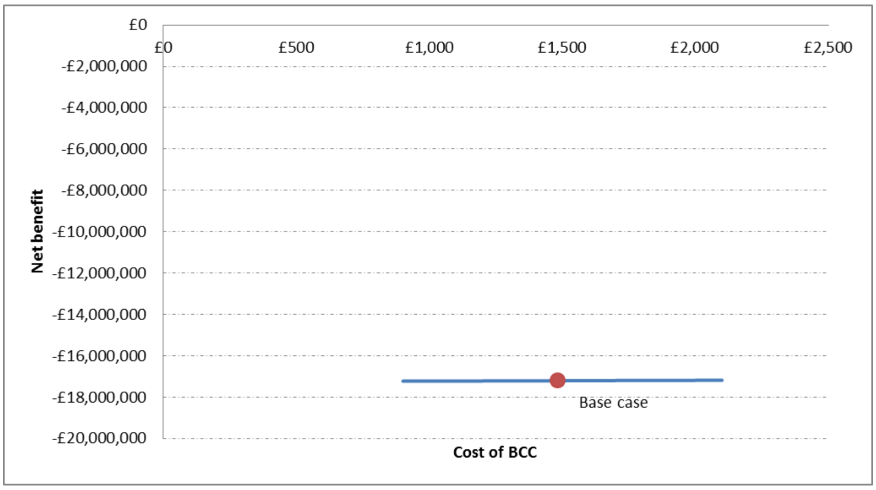


Figure 4.18: Cost of Squamous cell carcinoma

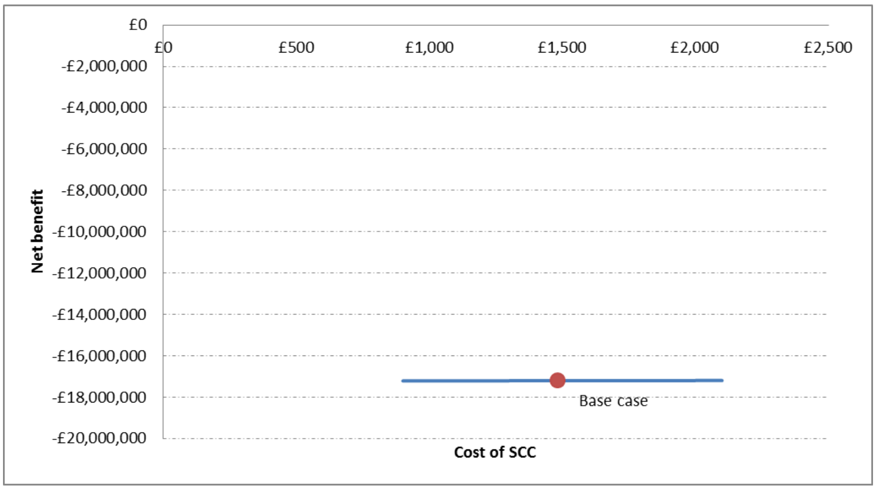


Figure 4.19: Cost of Intervention

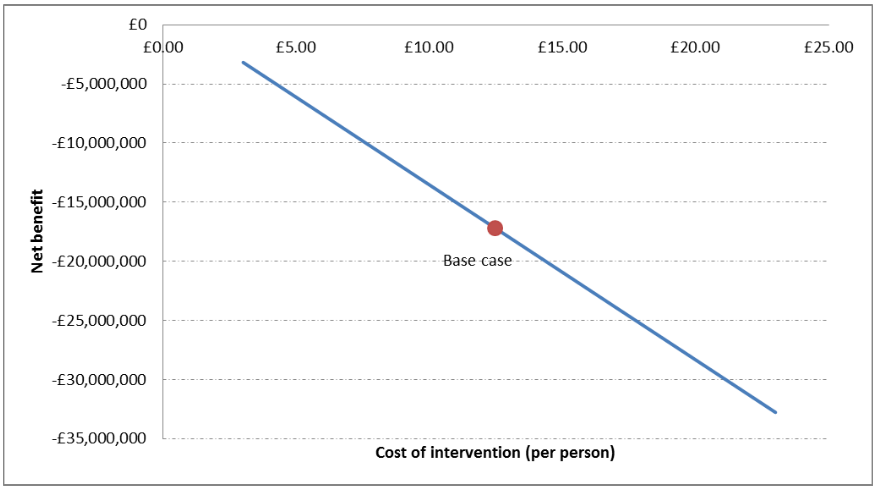


Figure 4.20: Relative risk of sunburn with intervention

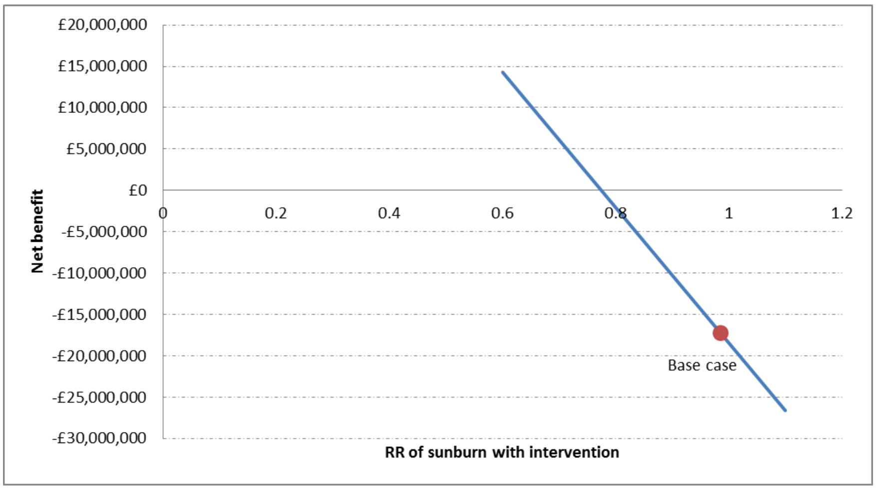


Figure 4.21: Ratio of Relative risk of using protection practice

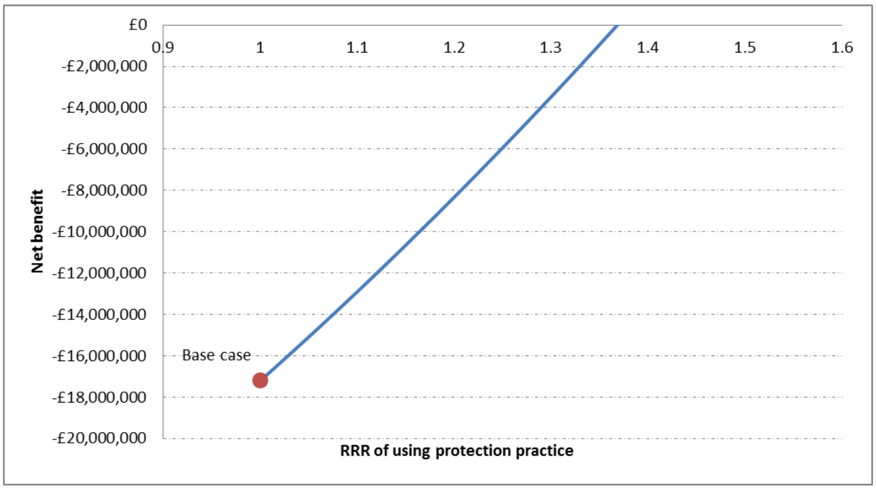


Figure 4.22: Risk ratio of sunburn incidence

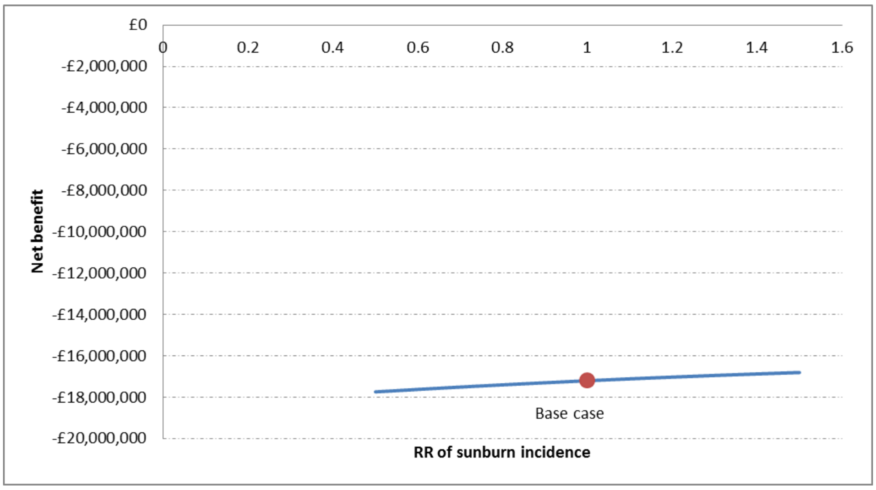


Figure 4.23: Risk ratio of malignant melanoma incidence

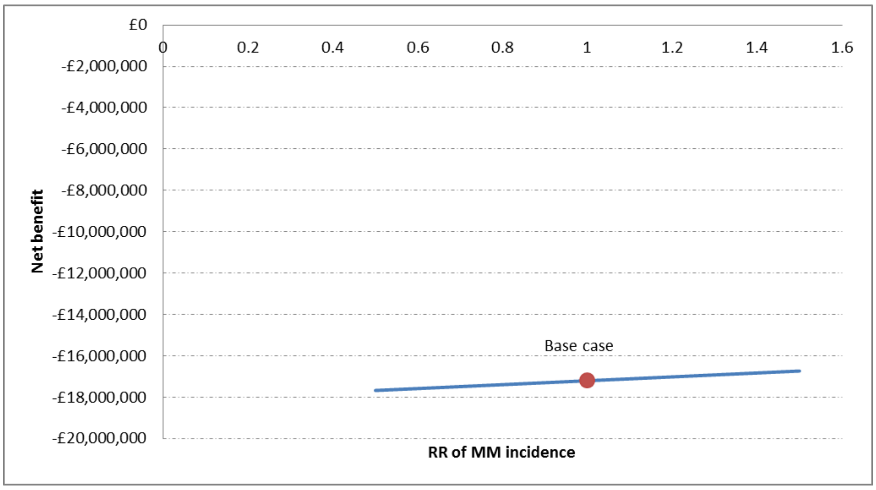


Figure 4.24: Risk ratio of basal cell carcinoma incidence

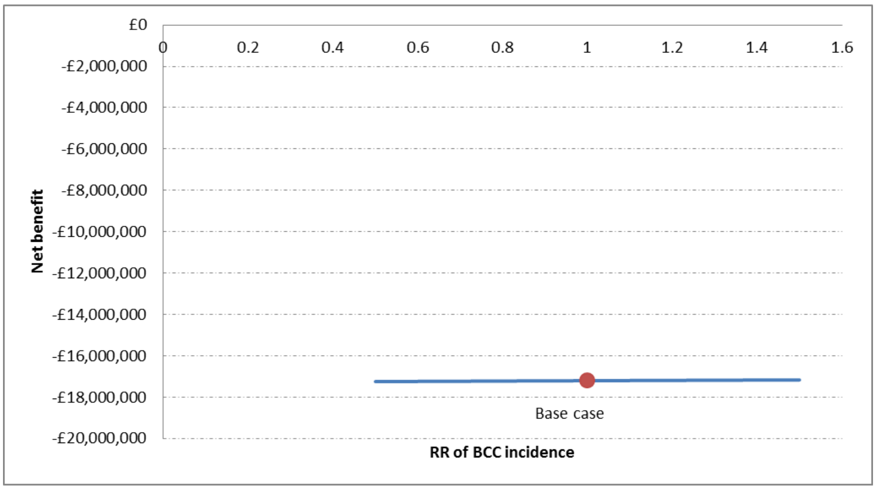


Figure 4.25: Risk ratio of standard erythema dose

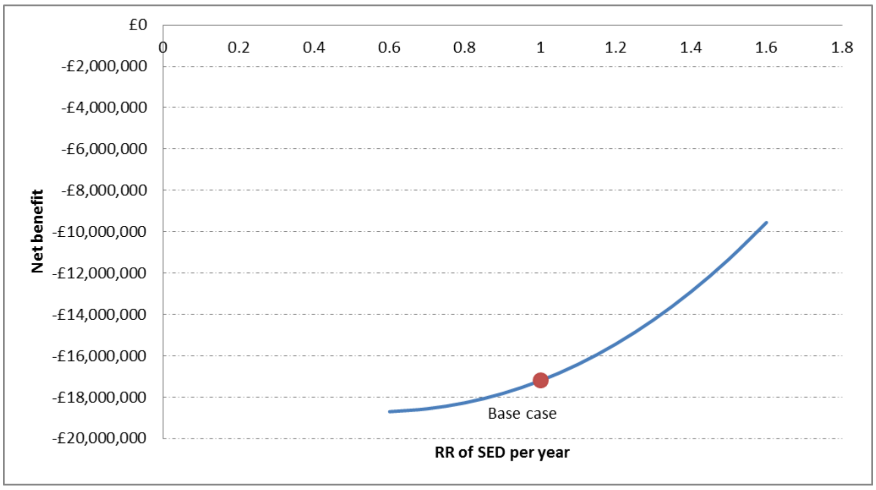


Figure 4.26: Additional years of full effectiveness

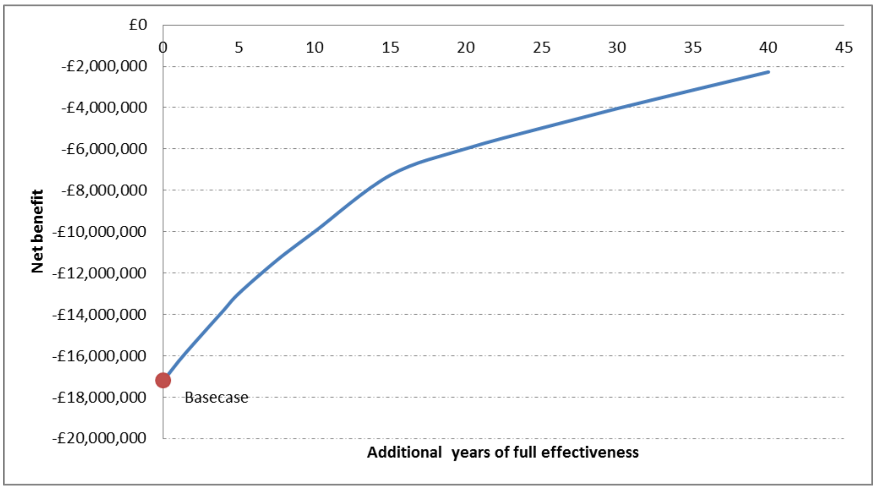


Figure 4.27: Discount rate costs

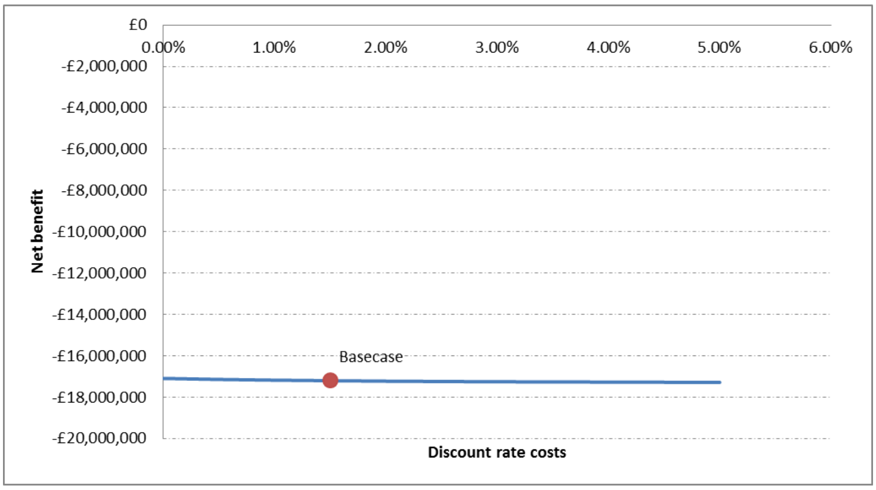
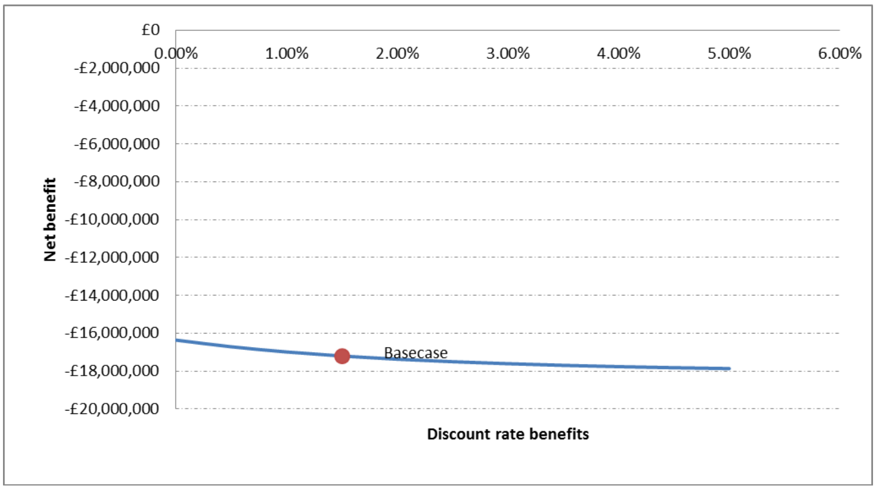


Figure 4.28: Discount rate benefits



4.1.3 Tailored messages

Figures 4.29 to 4.42 depict the one-way sensitivity analysis for the tailored messages intervention. The cost-effectiveness of the tailored messages intervention is largely robust to a range of inputs. It is, however, sensitivity to changes in the cost of delivering the intervention the degree of effectiveness and the incidence of the included conditions. The former is particularly worthy of attention as only relatively small increase in the per-head costs are required for the tailored messages intervention to no longer be considered cost-effective.

Figure 4.29: Cost of sunburn

Figure 4.30: Cost of malignant melanoma

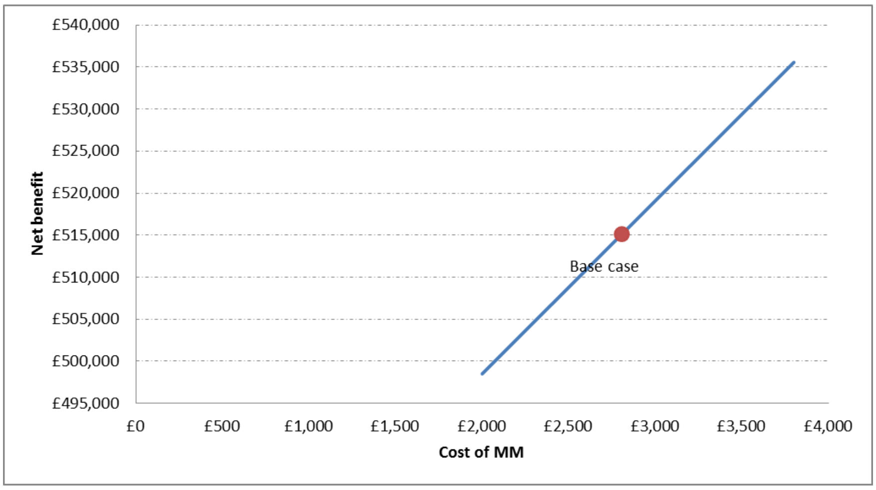


Figure 4.31: Cost of basal cell carcinoma

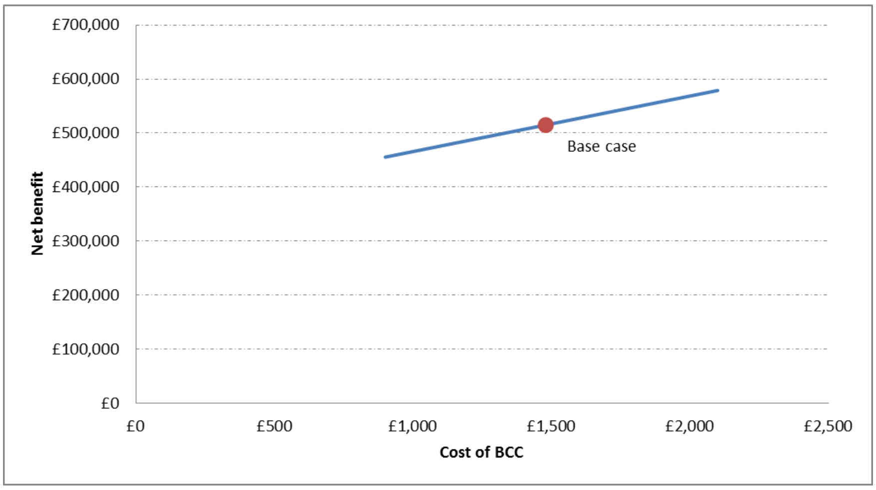


Figure 4.32: Cost of Squamous cell carcinoma

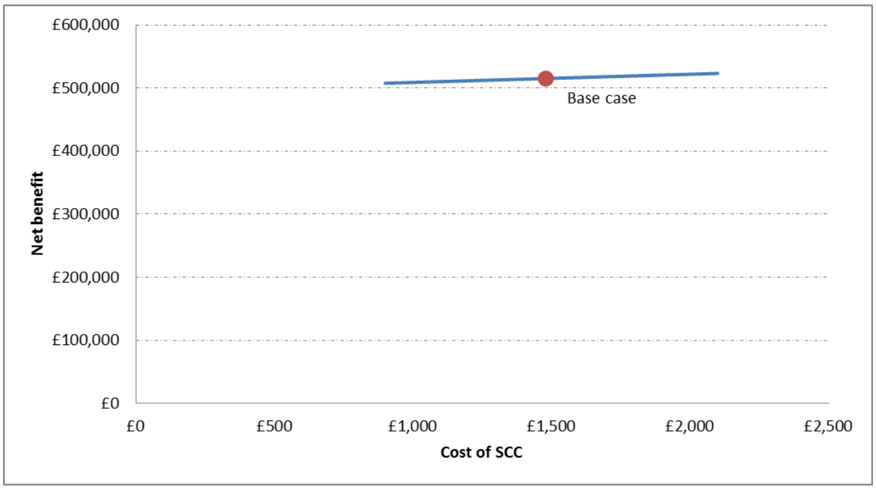


Figure 4.33: Cost of Intervention

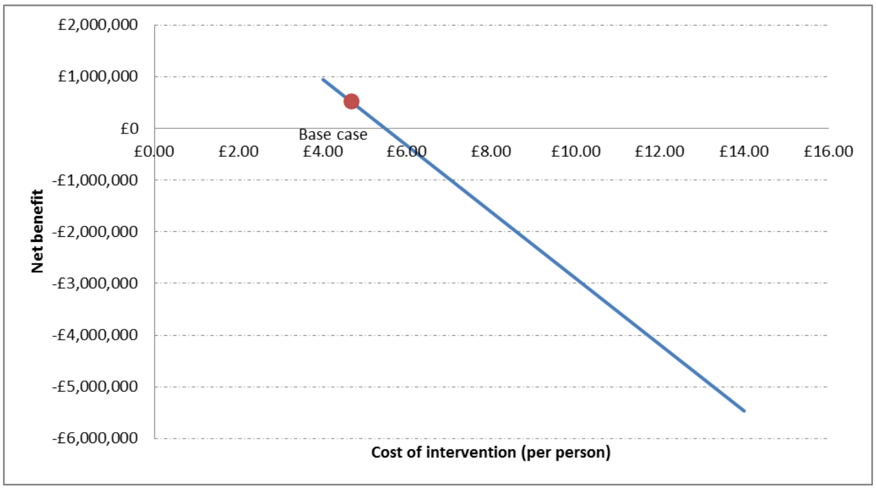


Figure 4.34: Relative risk of sunburn with intervention

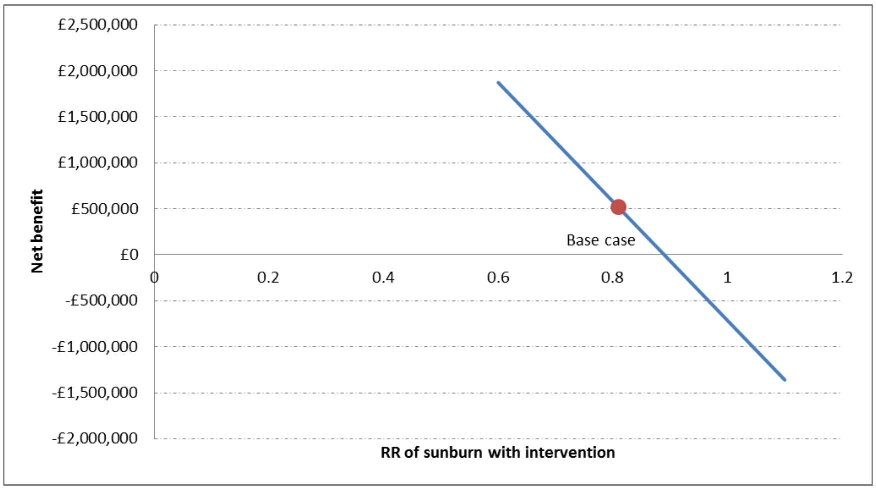


Figure 4.35: Ratio of Relative risk of using protection practice

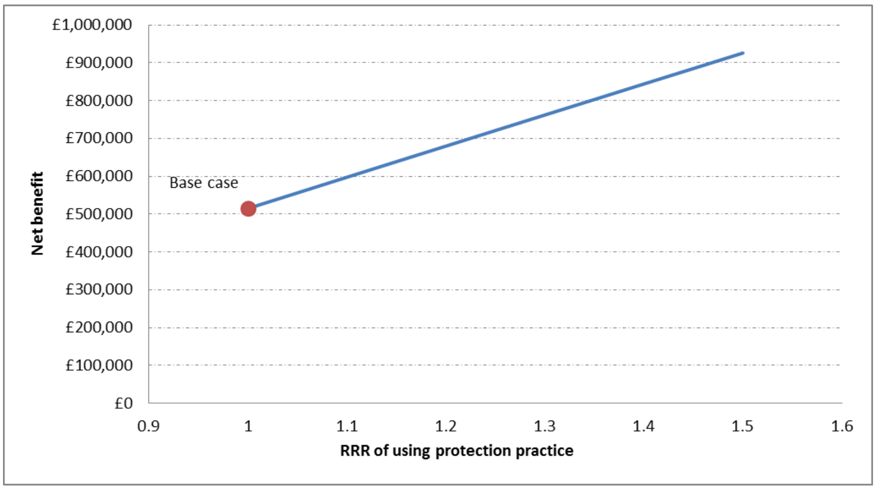


Figure 4.36: Risk ratio of sunburn incidence

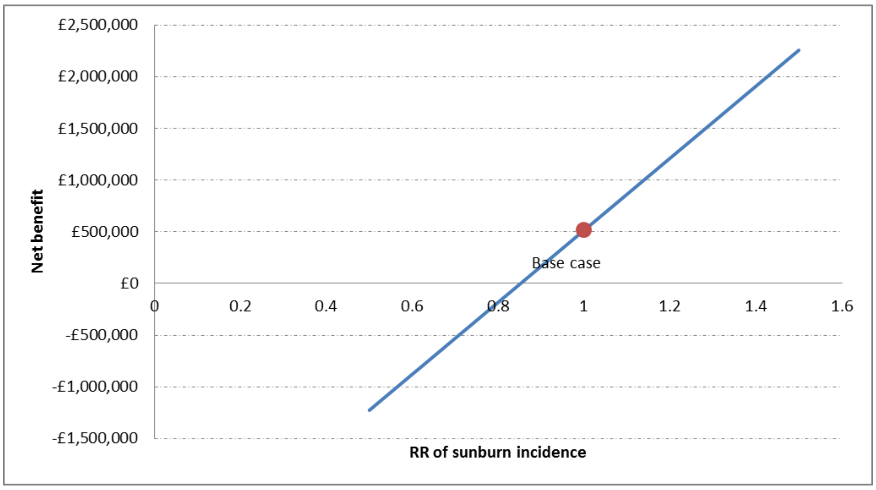


Figure 4.37: Risk ratio of malignant melanoma incidence

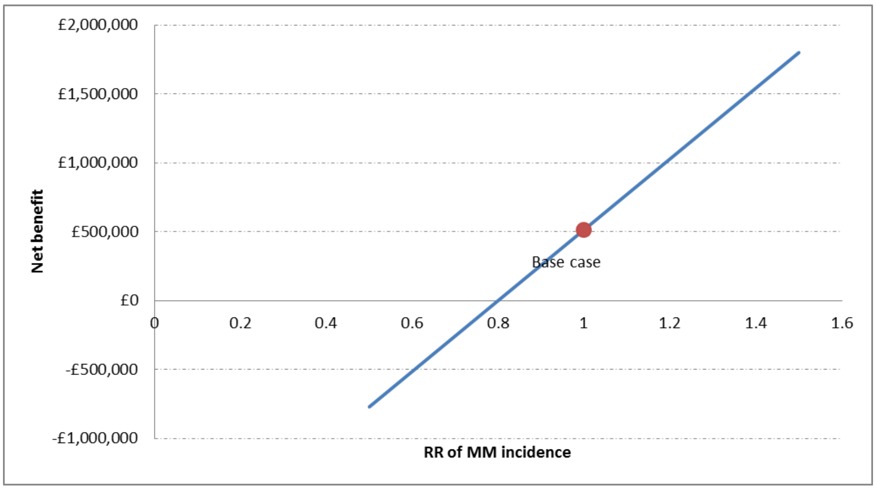


Figure 4.38: Risk ratio of basal cell carcinoma incidence

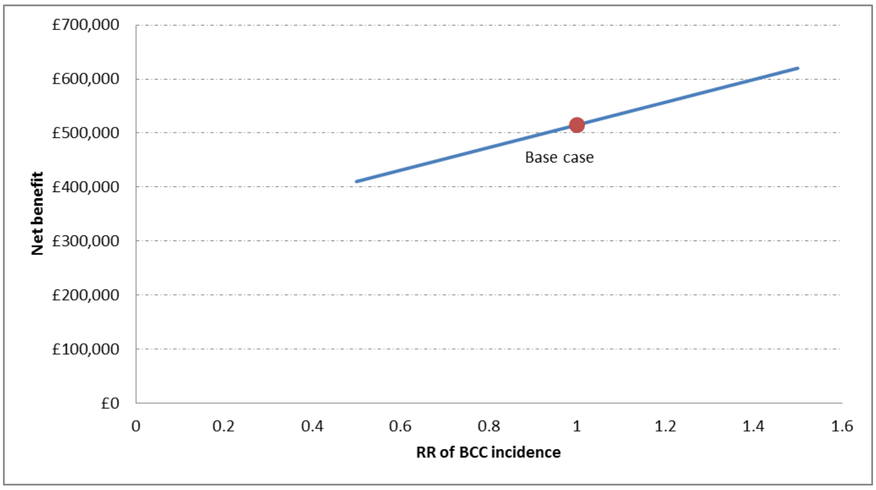


Figure 4.39: Risk ratio of standard erythema dose

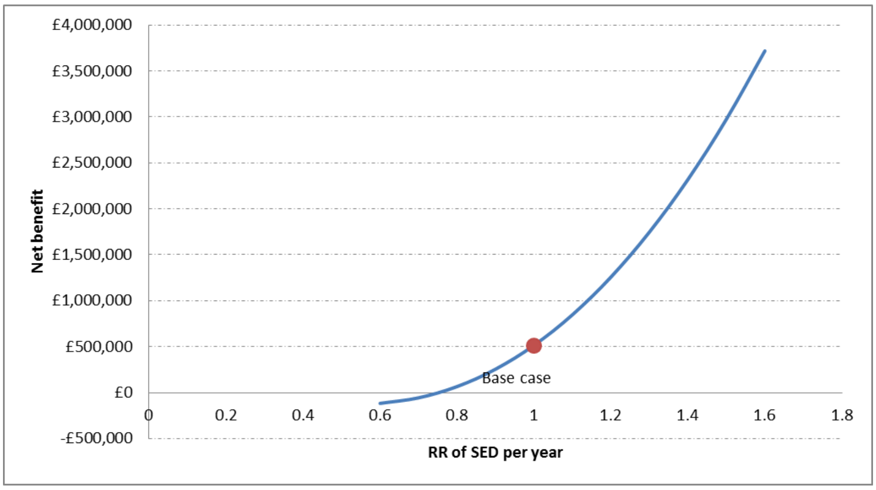


Figure 4.40: Additional years of full effectiveness

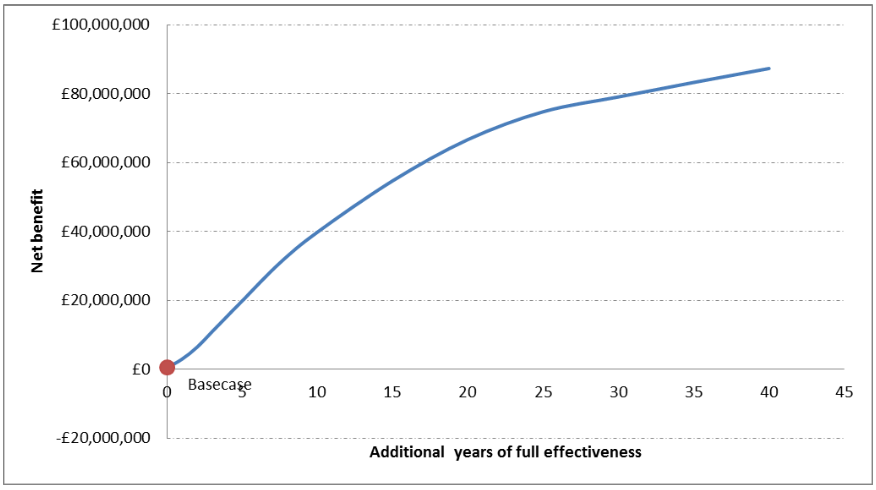


Figure 4.41: Discount rate costs

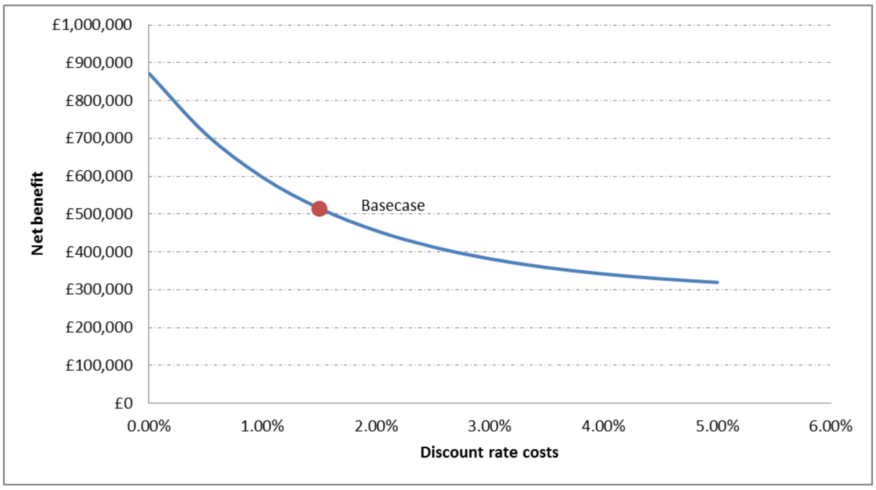
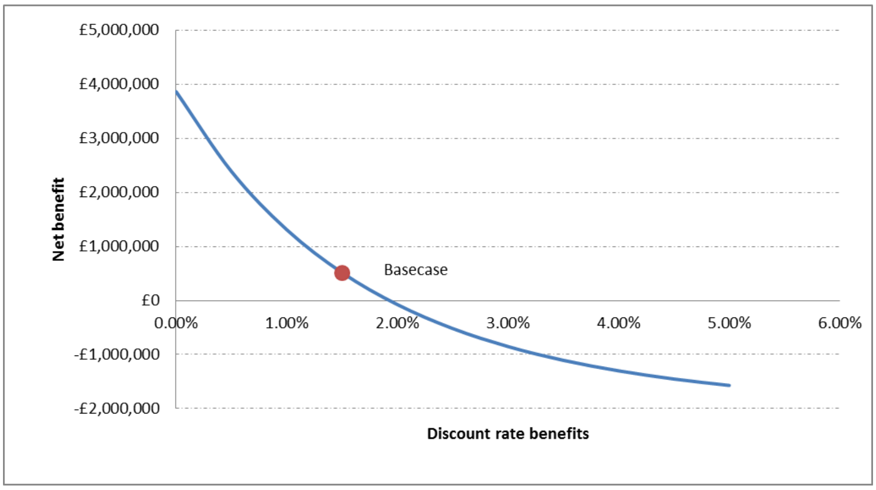


Figure 4.42: Discount rate benefits



4.1.4 Mass media

Figures 4.43 to 4.56 depict the one-way sensitivity analysis for the mass media intervention. Similar to the tailored messages intention the mass media intervention remains cost effective over a range of input values. Of particular importance with this intervention is that it would be cost effective over a wide range of effectiveness estimates. This because the data from this intervention was taken from an observational study is therefore likely to be less reliable than that obtained from a trial.

Figure 4.43: Cost of sunburn

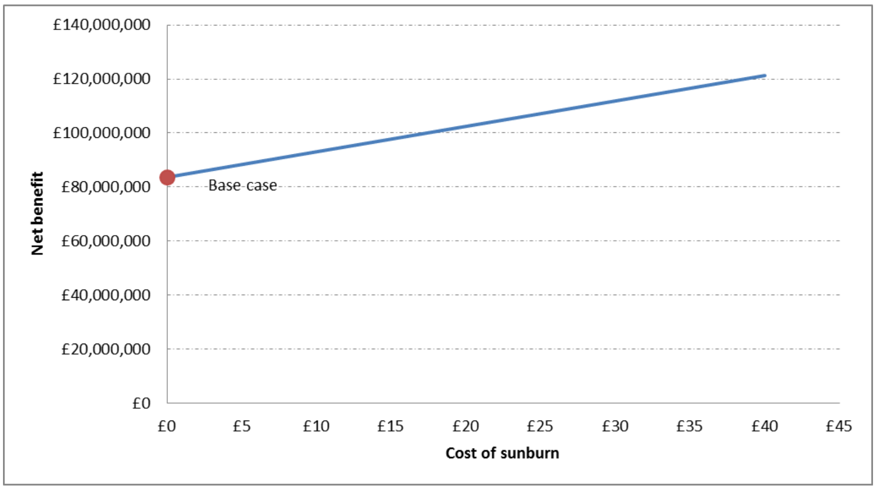


Figure 4.44: Cost of malignant melanoma

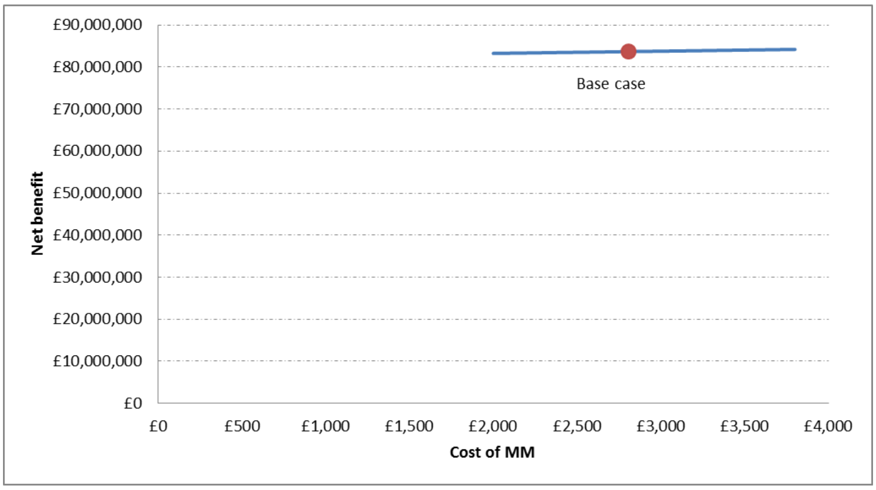


Figure 4.45: Cost of basal cell carcinoma

Figure 4.46: Cost of squamous cell carcinoma

Figure 4.47: Cost of intervention

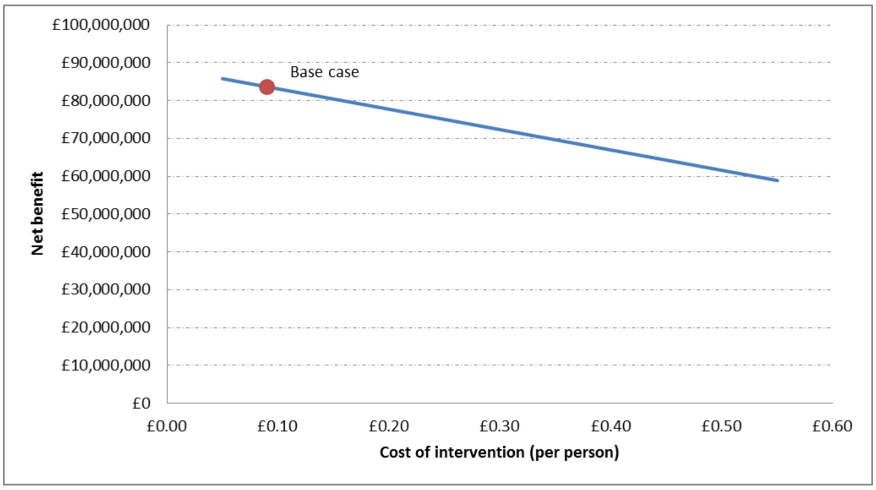


Figure 4.48: Relative risk of sunburn with intervention

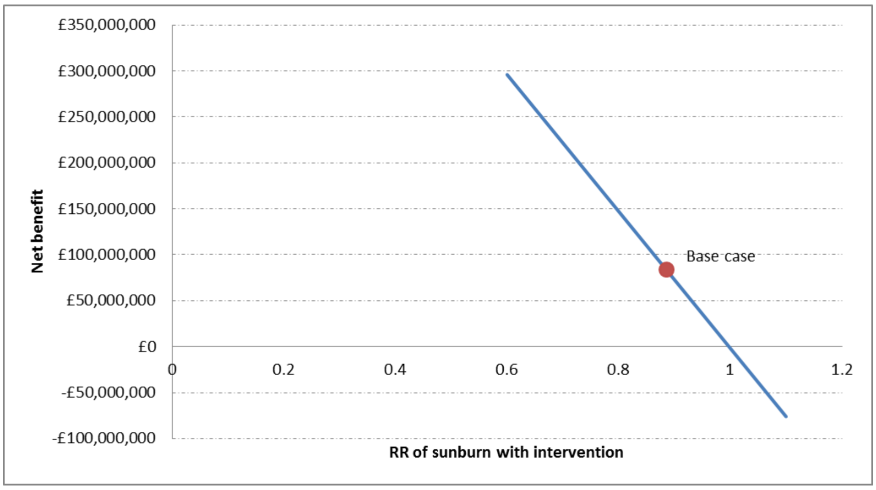


Figure 4.49: Ratio of relative risk of using protection practice

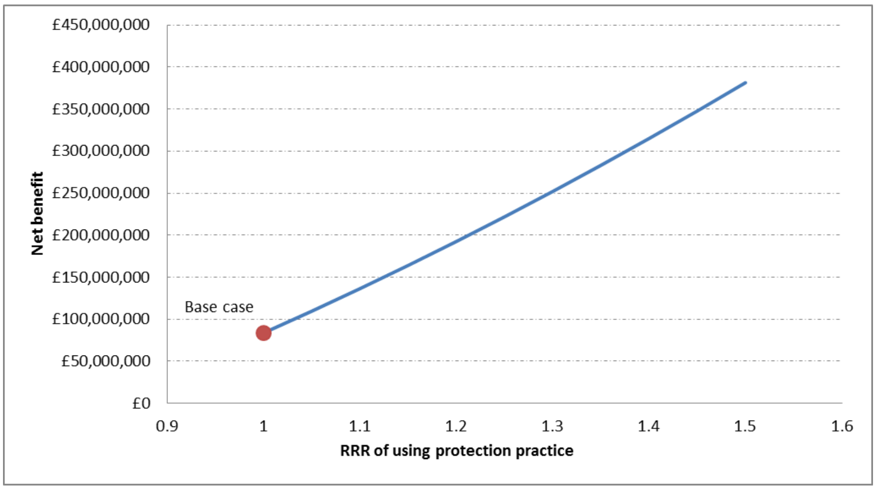


Figure 4.50: Risk ratio of sunburn incidence

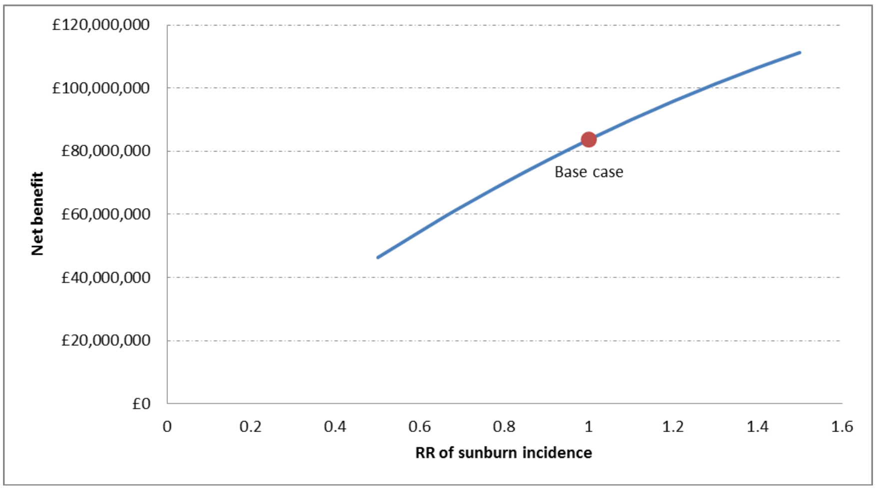


Figure 4.51: Risk ratio of malignant melanoma incidence

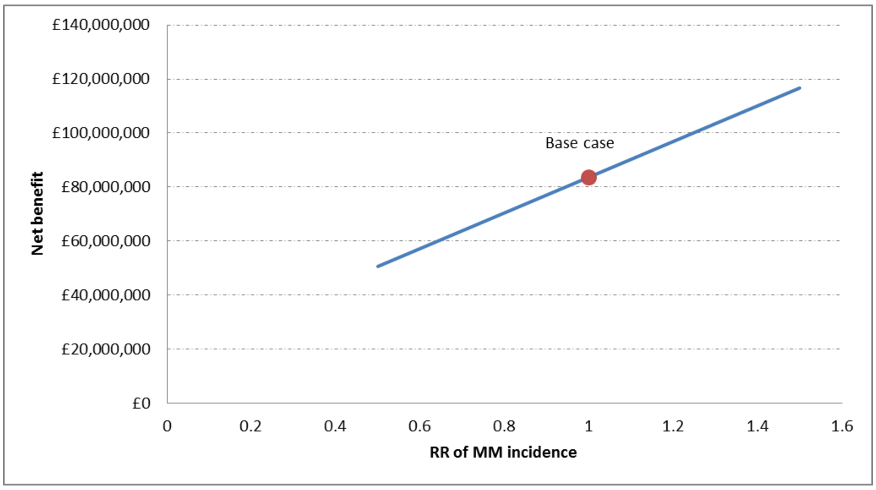


Figure 4.52: Risk ratio of basal cell carcinoma incidence

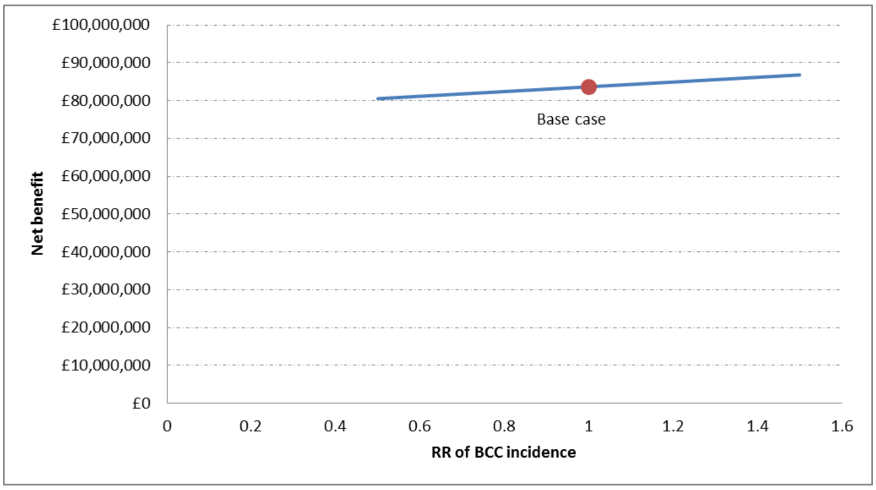


Figure 4.53: Risk ratio of standard erythema dose

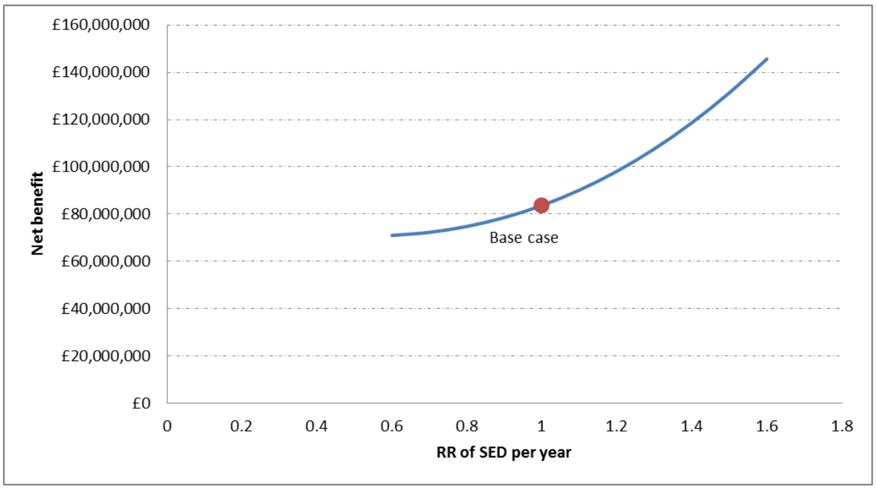


Figure 4.54: Additional years of full effectiveness

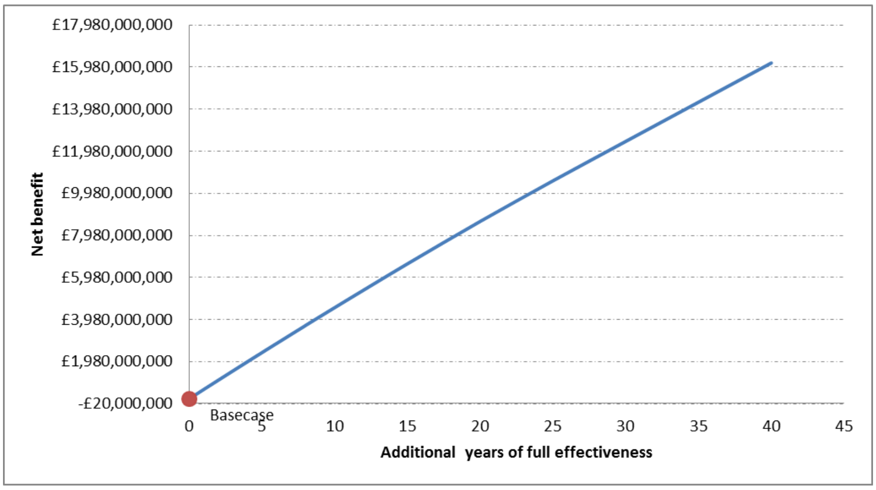


Figure 4.55: Discount rate costs

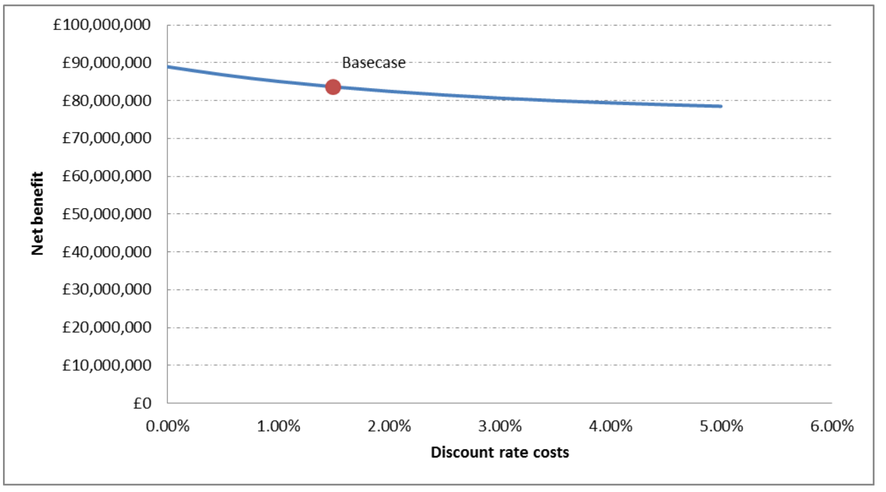
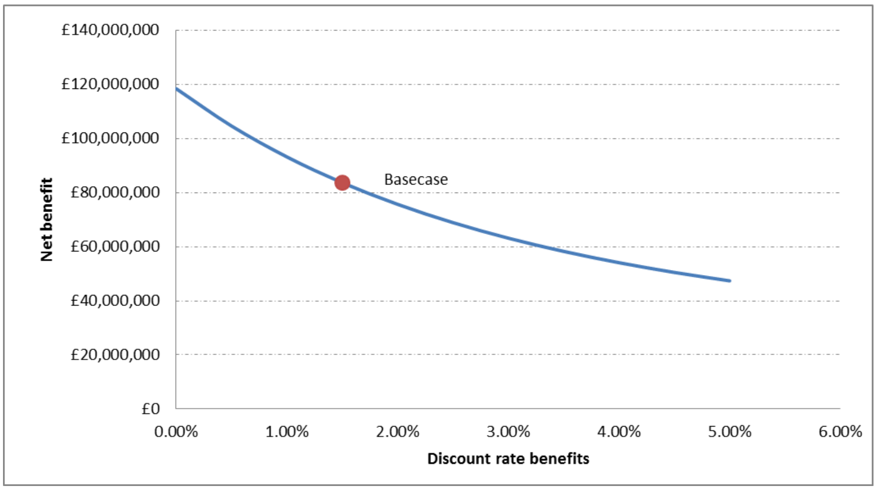


Figure 4.56: Discount rate benefits



4.1.5 Text messages

Figures 4.57 to 4.68 depict the one-way sensitivity analysis for the text messages intervention. The text message intervention is cost-ineffective across a wide range of input values, but maybe cost-effective if it was more effective or the duration full effectiveness lasted was longer.

Figure 4.57: Cost of sunburn

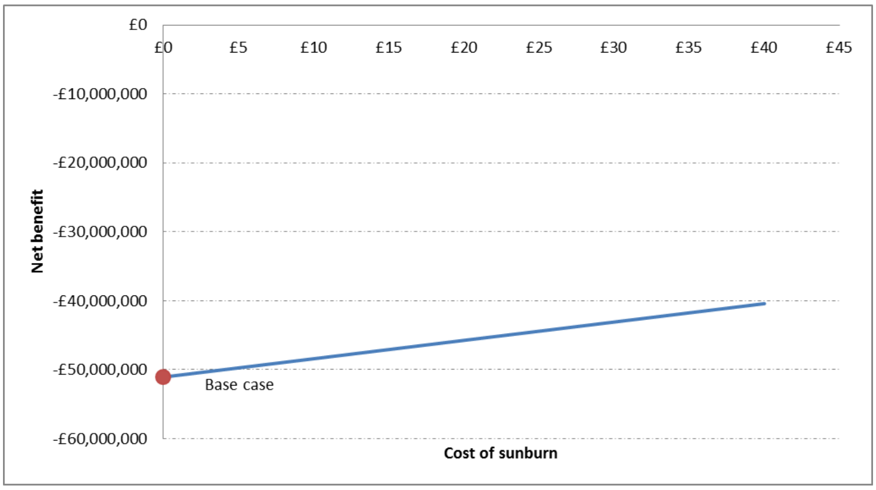


Figure 4.58: Cost of malignant melanoma

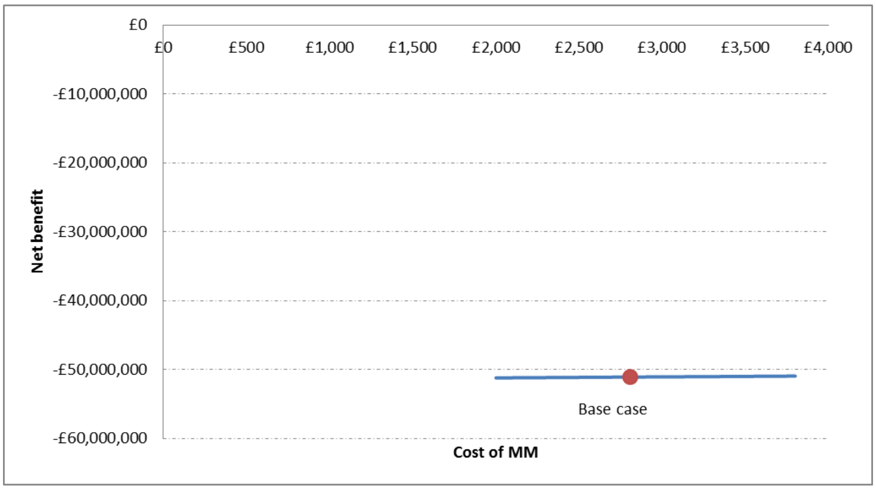


Figure 4.59: Cost of basal cell carcinoma

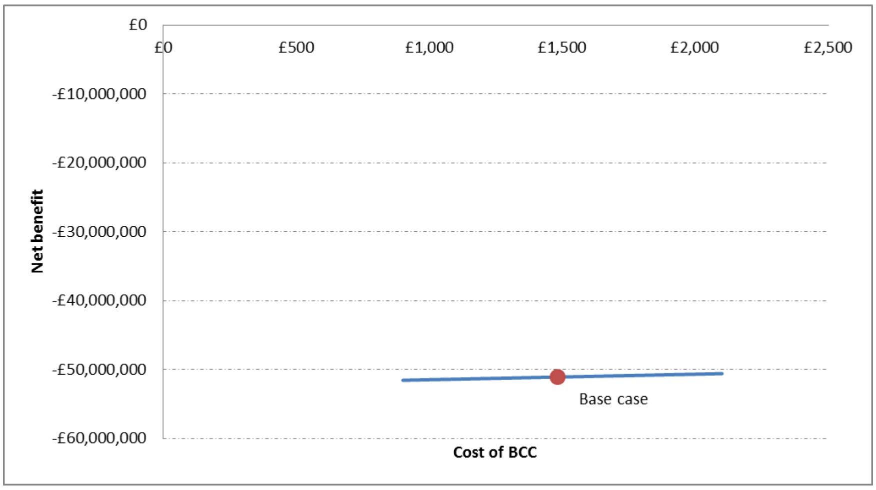


Figure 4.60: Cost of squamous cell carcinoma

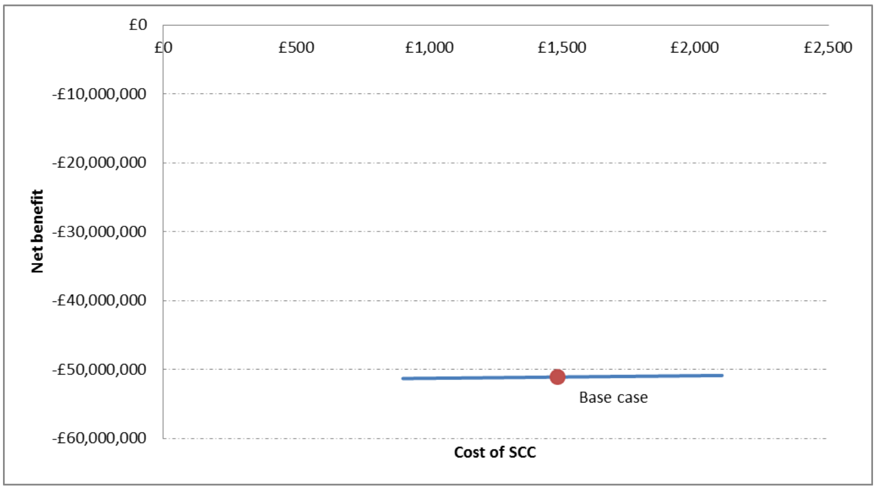


Figure 4.61: Cost of intervention

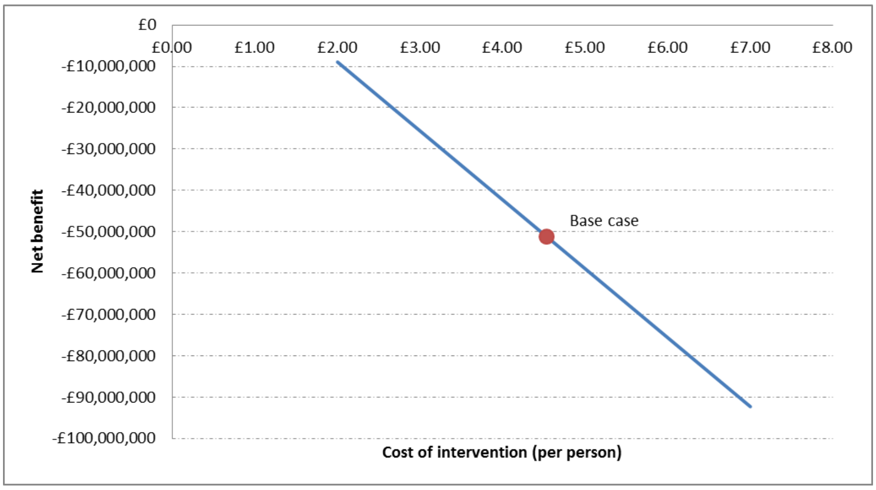


Figure 4.62: Relative risk of sunburn with intervention

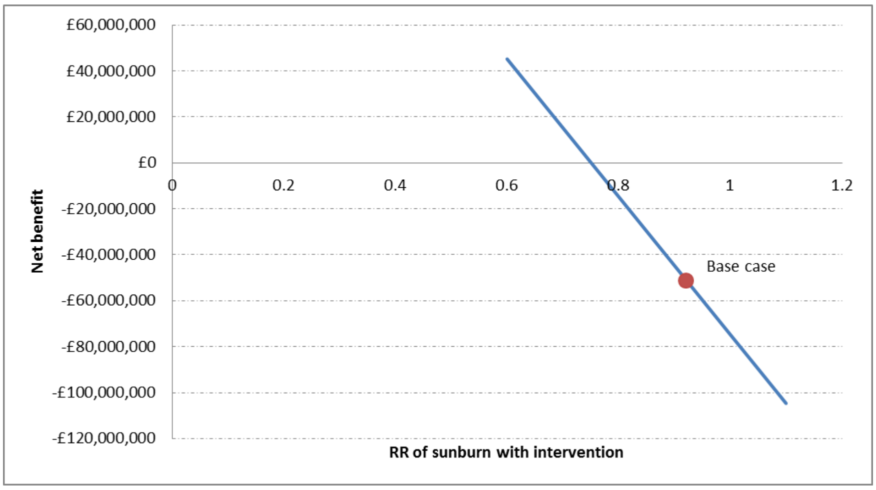


Figure 4.63: Ratio of relative risk of using protection practice

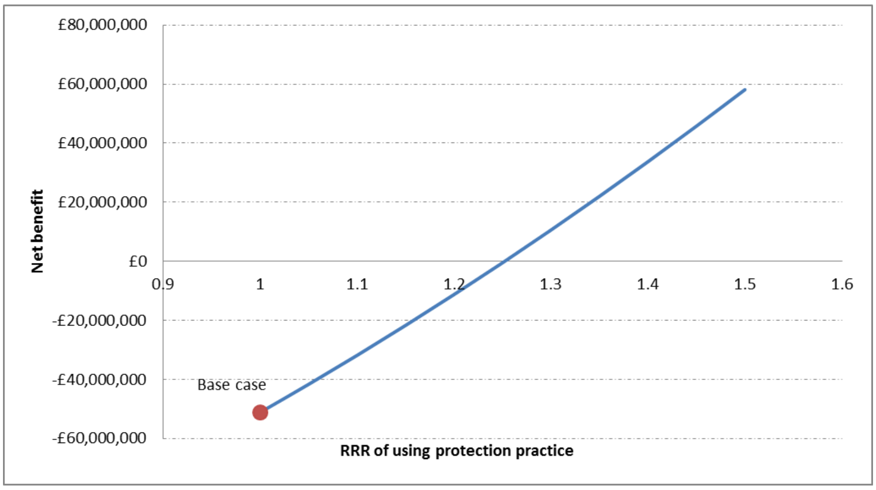


Figure 4.64: Risk ratio of sunburn incidence

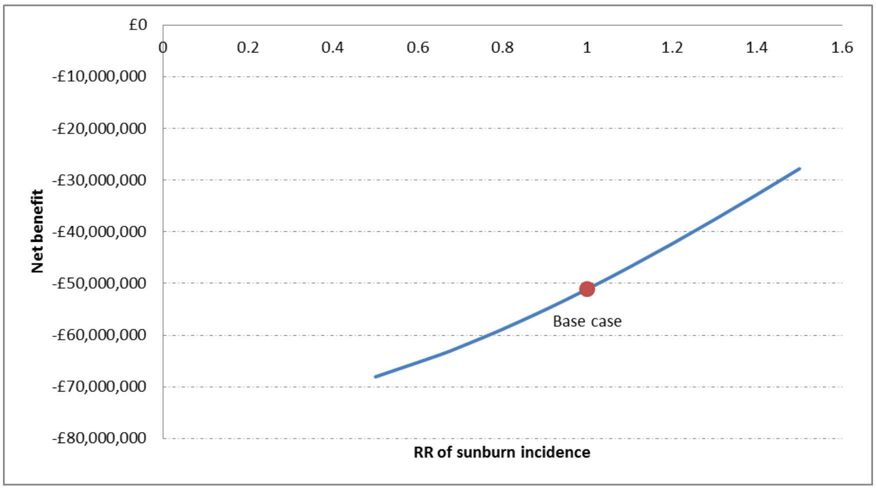


Figure 4.65: Risk ratio of malignant melanoma incidence

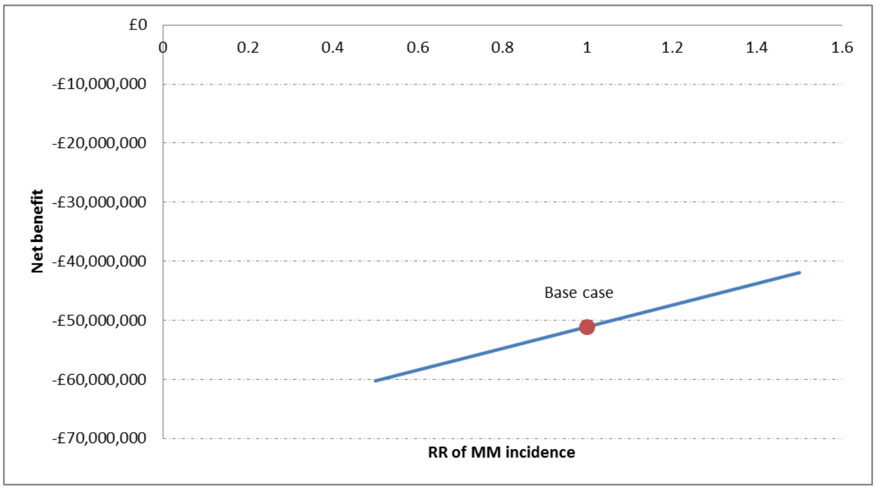


Figure 4.66: Risk ratio of basal cell carcinoma incidence

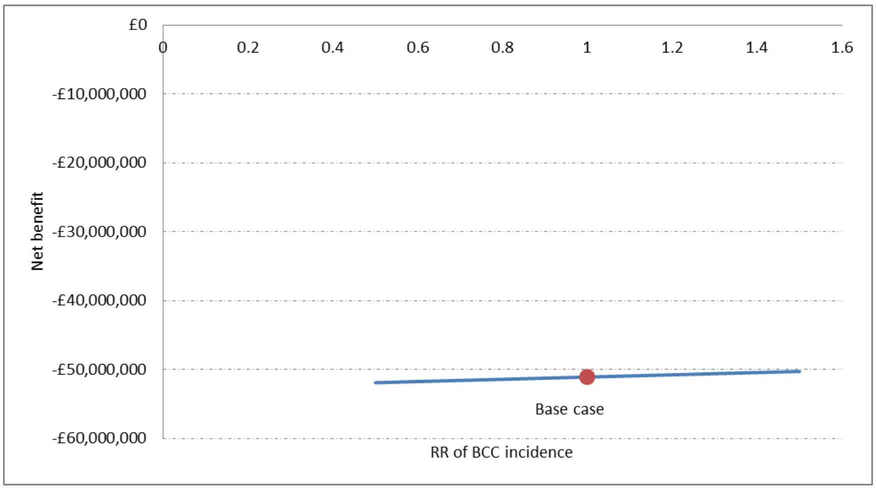


Figure 4.67: Risk ratio of standard erythema dose

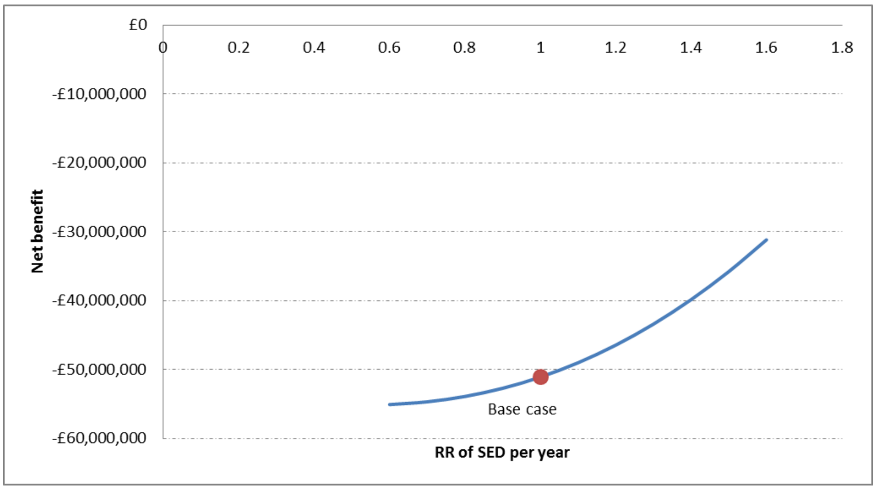


Figure 4.68: Additional years of full effectiveness

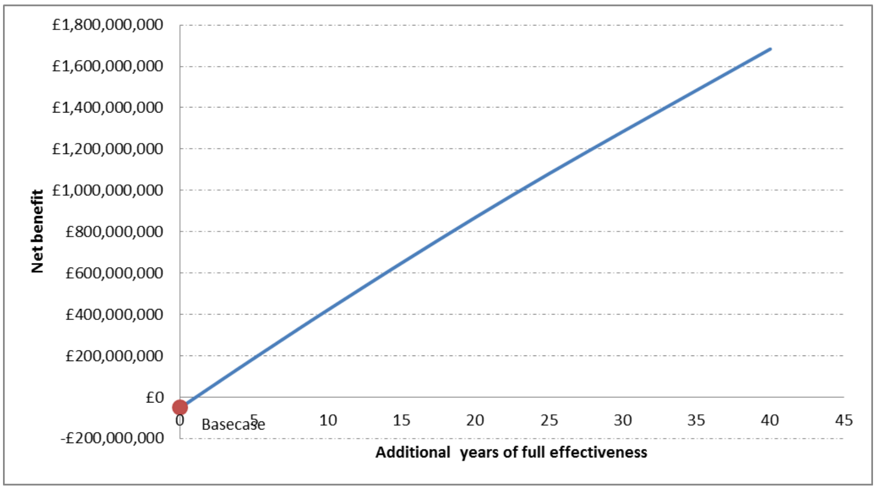


Figure 4.69: Discount rate costs

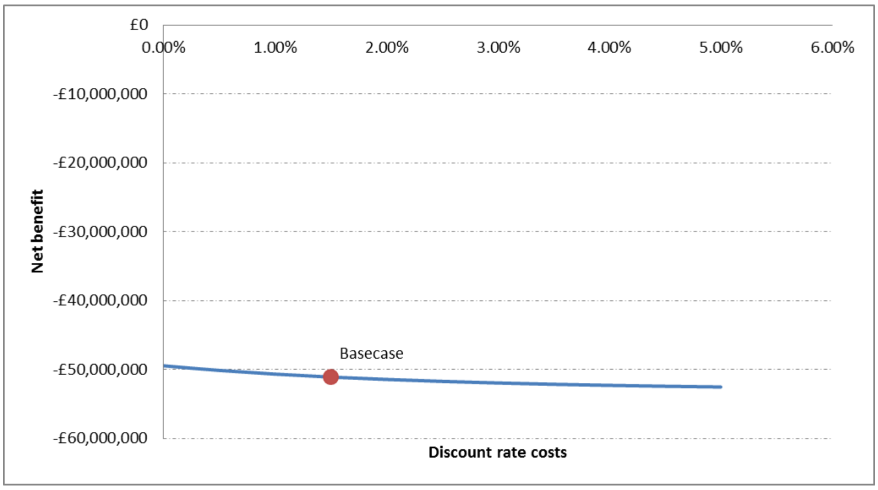
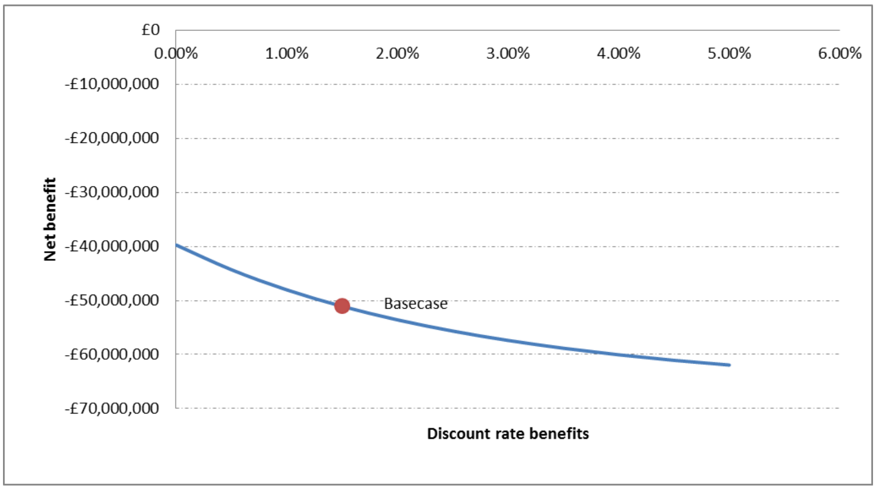


Figure 4.70: Discount rate benefits



4.2 PROBABLISTIC SENSTIVITY ANALYSIS

All of the input values used in the model are subject to a degree of uncertainty. One–way sensitivity analysis is one of exploring this, but is somewhat limited as it does not allow the exploration of the joint uncertainty of the input values (i.e. that we are uncertain about not just one, but all the input values). Probabilistic sensitivity analysis (PSA) is a way of attempting to account for the uncertainty in input parameters. In PSA, rather than assigning a single value to each parameter, a probability distribution is assigned to all parameters in the model. The ranges are determined by mean value and the standard deviation of the input. In all cases care was taken ensure that all parameters remain practical. For example, costs can never take negative values. The model is then run a number of times (10,000 in this case) each time drawing a value for each of the inputs from the specified probability distributions.

The distribution and values used for the mean and standard deviation used are described in Appendix D. It was not possible to calculate the standard deviation of estimates for all input values and, in some cases it would be inappropriate to use this value. Where this was the case a conservative approach was taken when deciding on the standard deviation values used such that the level of uncertainty was over-estimated.

Table 4.6 the results of the probabilistic sensitivity analysis for each the five interventions. Figures 4.71 to 4.75 present the respective scatter plot, plotting each of the cost-effectiveness estimates for the 10,000 runs of the model.

Table 4.6 Results of Probabilistic Sensitivity Analysis

Intervention	Probability of being cost-effective	Average ICER from PSA
‘Living with the Sun’	0.02%	£297,372
Photo-aging	3.21%	£333,539
Tailored messages	71.14	£15,978
Mass media	96.71%	Dominant
Text messages	8.87%	£65,982

Figure 4.71 Living with the sun scatter plot

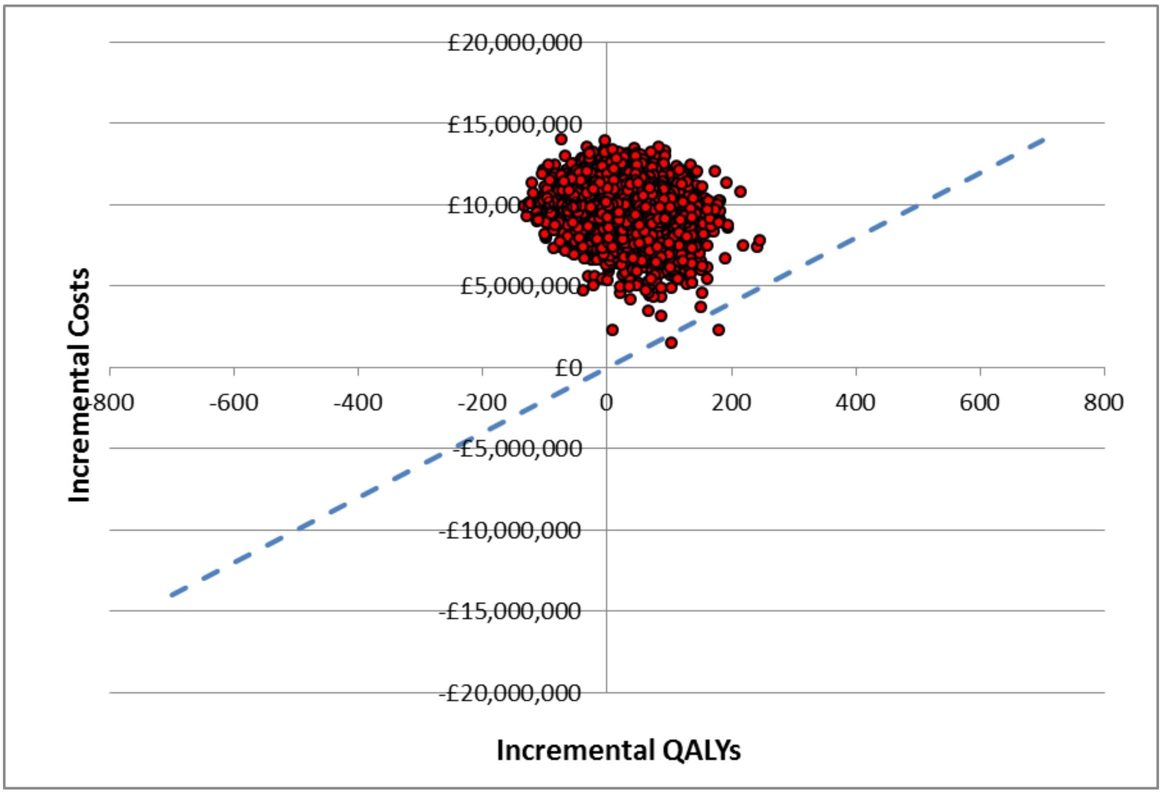


Figure 4.72 Photo-aging scatter plot

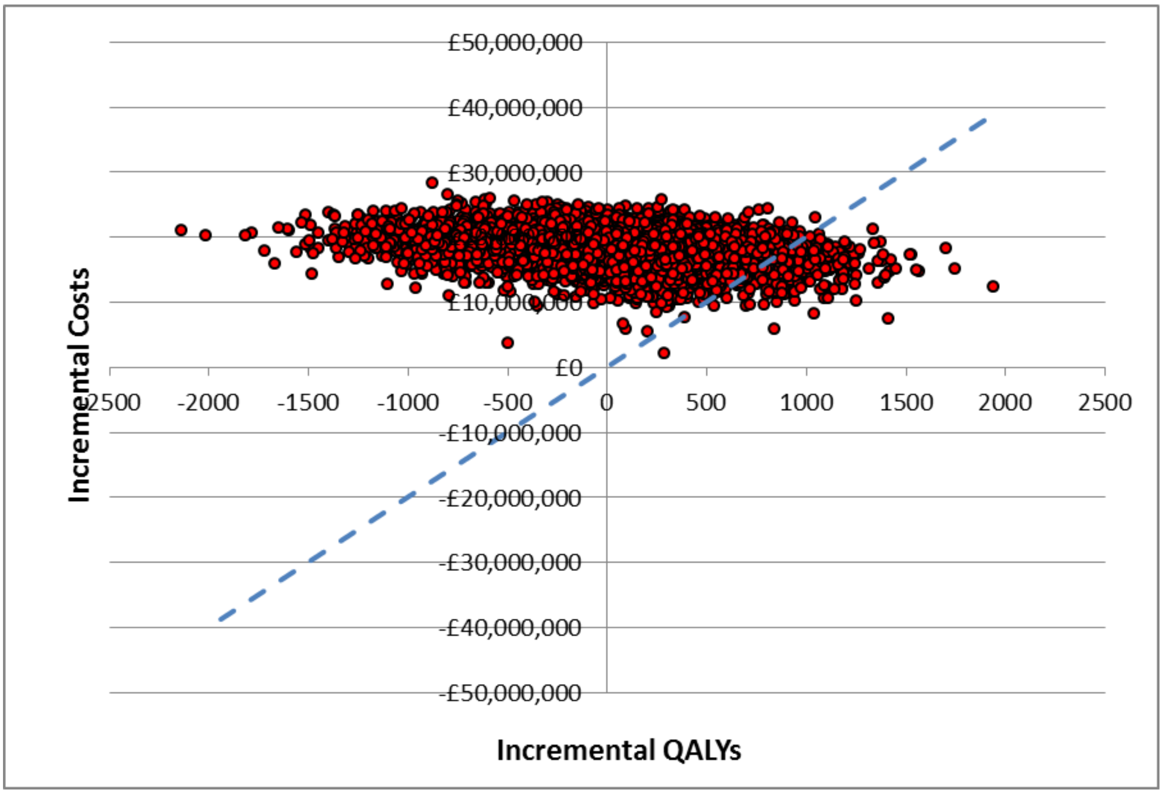


Figure 4.73 Tailored messages scatter plot

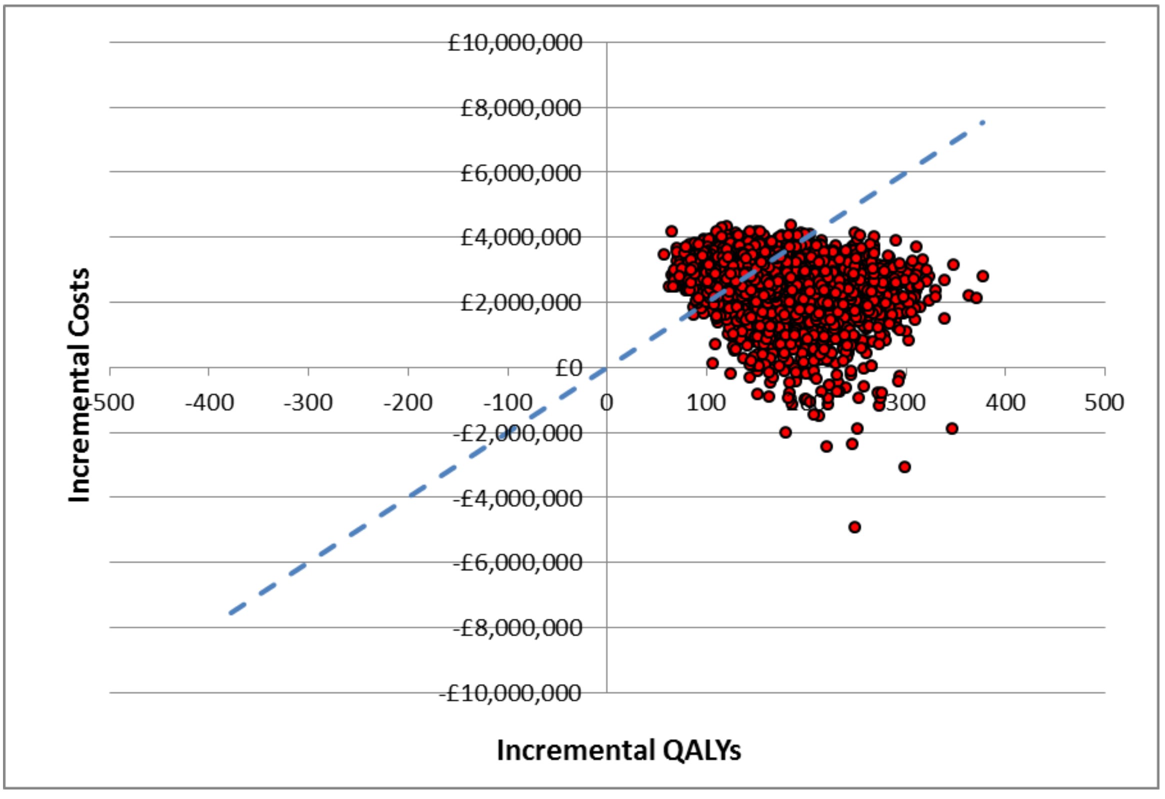


Figure 4.74 Mass media scatter plot

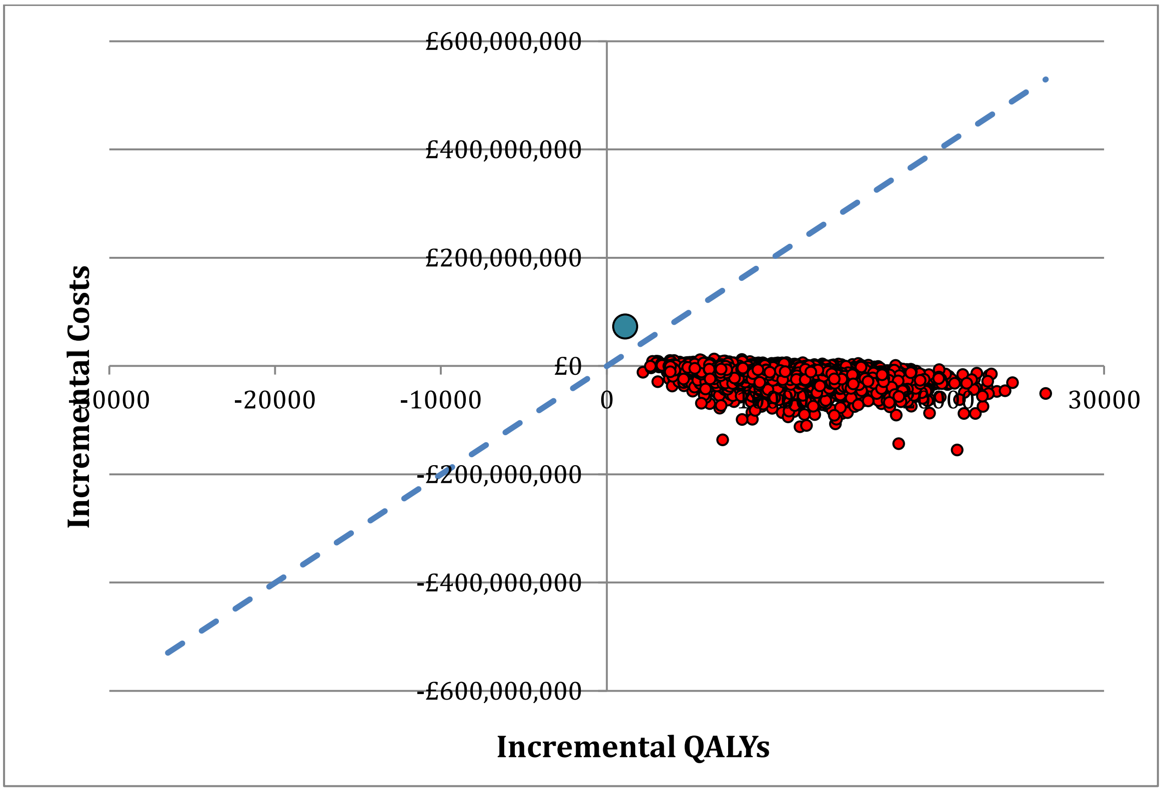
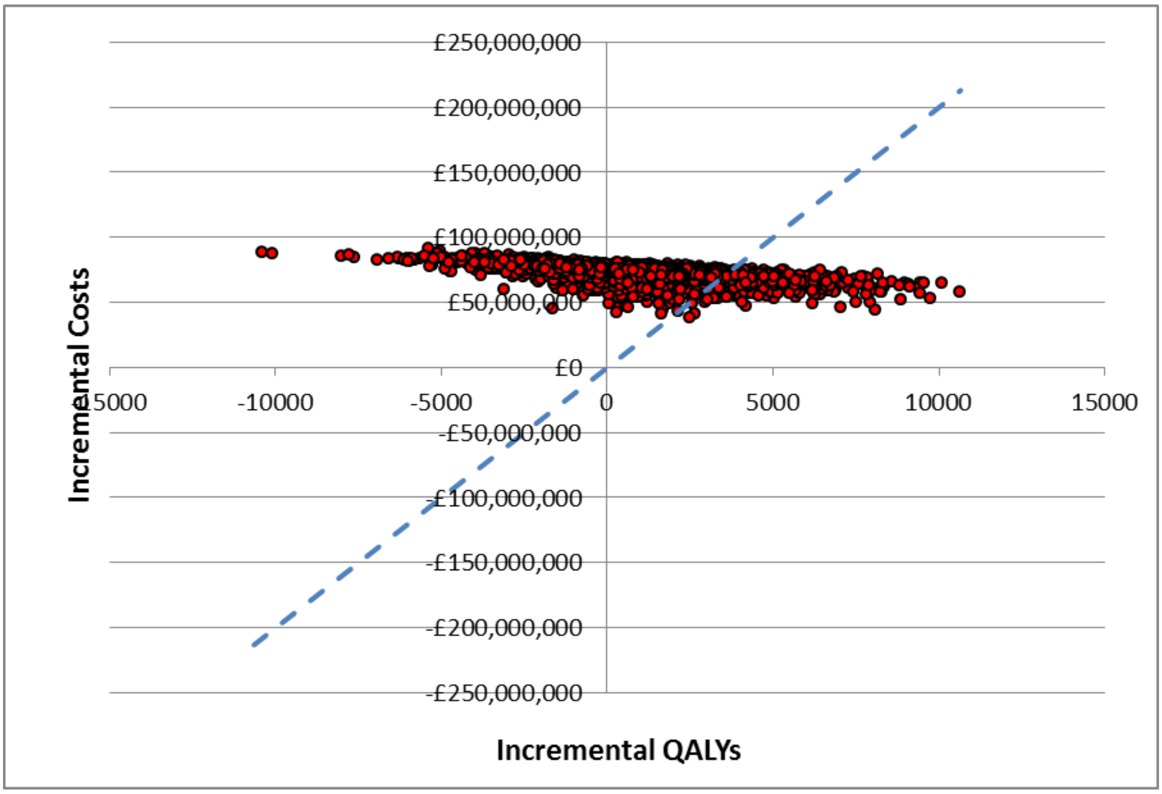


Figure 4.75 Text messages scatter plot



The ICERs obtained from the probabilistic are similar to those obtained from the deterministic analysis presented above. The Living with the sun, photo-aging and text messages intervention are all estimated to have an ICER far above the £20,000 threshold. The tailored messages and mass media intervention are both estimated to be cost-effective on average. The probability of the tailored messages intervention is only, however, 71%. This reflects the fact the estimated average ICER is close to the £20,000 threshold. There is a high likelihood that the mass media intervention is cost-effective. The likelihood that any of the other interventions are cost-effective is very low.

4.3 TWO-WAY AND THRESHOLD SENSITIVITY ANALYSIS

The one-way sensitivity analysis demonstrates that one of the key drivers in the cost-effectiveness of interventions is the cost of implementing the intervention and the effectiveness of the intervention. This section therefore describes a two-way sensitivity analysis describing the set of values for costs per head and effectiveness that an intervention would be cost-effective. It also present a threshold analysis in which the maximum cost per head at which each of the interventions consider would be cost-effective.

4.3.1 Two-way analysis

Table 4.7 presents the results of a two-way sensitivity analysis for a hypothetical intervention. This shows the cost-effectiveness estimates for a range of possible effectiveness and cost value. In constructing the table it was assumed that the intervention is applied to the whole population and the intervention effect lasts for one year. Changing these assumptions would change the range of values at which the intervention would be cost effective.

Intuitively, the maximum cost permissible for implementing the hypothetical intervention rises as effectiveness rises. So for example if the RR of using protection was 1.1 then the maximum cost per head of implementing the intervention could only be about £1.00, if however the RR was 1.4 a cost of up to £4.50 per head would be permissible.

Table 4.7: Two-way sensitivity analysis of a hypothetical intervention

Cost of Intervention per head	Relative risk of using protection: 1.10	1.20	1.30	1.40	1.50	1.60
£0.50	£28,873,253	£88,196,139	£151,035,751	£217,392,088	£287,265,151	£360,654,940
£1.00	£1,940,344	£61,263,231	£124,102,843	£190,459,180	£260,332,243	£333,722,031
£1.50	-£24,992,564	£34,330,322	£97,169,934	£163,526,271	£233,399,334	£306,789,123
£2.00	-£51,925,473	£7,397,414	£70,237,026	£136,593,363	£206,466,426	£279,856,214
£2.50	-£78,858,381	-£19,535,495	£43,304,117	£109,660,454	£179,533,517	£252,923,306
£3.00	-£105,791,290	-£46,468,403	£16,371,209	£82,727,546	£152,600,609	£225,990,397
£3.50	-£132,724,198	-£73,401,312	-£10,561,700	£55,794,637	£125,667,700	£199,057,489
£4.00	-£159,657,107	-£100,334,220	-£37,494,608	£28,861,729	£98,734,792	£172,124,580
£4.50	-£186,590,015	-£127,267,129	-£64,427,517	£1,928,820	£71,801,883	£145,191,672
£5.00	-£213,522,924	-£154,200,037	-£91,360,425	-£25,004,088	£44,868,975	£118,258,763
£5.50	-£240,455,832	-£181,132,946	-£118,293,334	-£51,936,997	£17,936,066	£91,325,855
£6.00	-£267,388,741	-£208,065,854	-£145,226,242	-£78,869,905	-£8,996,842	£64,392,946
£6.50	-£294,321,649	-£234,998,763	-£172,159,151	-£105,802,814	-£35,929,751	£37,460,038
£7.00	-£321,254,558	-£261,931,671	-£199,092,059	-£132,735,722	-£62,862,659	£10,527,129
£7.50	-£348,187,466	-£288,864,580	-£226,024,968	-£159,668,631	-£89,795,568	-£16,405,779
£8.00	-£375,120,375	-£315,797,488	-£252,957,876	-£186,601,539	-£116,728,476	-£43,338,688
£8.50	-£402,053,283	-£342,730,397	-£279,890,785	-£213,534,448	-£143,661,385	-£70,271,596
£9.00	-£428,986,192	-£369,663,305	-£306,823,693	-£240,467,356	-£170,594,293	-£97,204,505
£9.50	-£455,919,100	-£396,596,214	-£333,756,602	-£267,400,265	-£197,527,202	-£124,137,413
£10.00	-£482,852,009	-£423,529,122	-£360,689,510	-£294,333,173	-£224,460,110	-£151,070,322

4.3.2 Threshold analysis

Table 4.8 describes the results of a threshold analysis for each of the interventions. For the most part interventions must be very cheap to be cost effective. The tailored messages intervention standout as it can potentially be significantly more expensive while remaining cost-effective. There are two reasons for this. Firstly the tailored messages intervention is particularly effective at reducing the incidence of sunburn with is key driver of the model. Secondly, unlike the mass media intervention which is also estimated as being highly effective the effect of the tailored messages intervention persists for a number of years.

Table 4.8: Threshold analysis

	'Living with the Sun'	**Photo-aging**	**Tailored messages**	**Mass media**	**Text messages**
Maximum cost per at which intervention is cost-effective[a]	£1.38	£0.82	£5.89	£2.15	£1.78

[a] £20,000 per QALY threshold assumed.

Section 5: Discussion

5.1 DISCUSSION

The analysis indicates that two of the five interventions are likely to be cost-effective. The cost-effectiveness of these interventions is due to the lower costs of implementing these interventions per head and the fact that these were more effective at reducing the incidence of sunburn.

5.1.1 Results compared to previous skin cancer guidance

It is useful to compare the results obtained from this model with those of the model produce as part of the skin cancer guidance (PH32).[58] The skin cancer guidance model did not find any of interventions to be cost-effective there are a number of reasons for this.

Firstly, the skin cancer model did not include sunburn as a health condition. QALYs lost as a result of sunburn were therefore not accounted for in estimating cost-effectiveness. The reason for this exclusion was outside the scope of that particular guidance. The inclusion of sunburn in this model will act to increase the estimated cost-effectiveness of all the interventions.

Secondly, the interventions considered tended to act on increasing the use of all forms of sun protection. This contrasts with some of the interventions examined in the skin cancer model which focused on increasing the use of a single form of protection e.g. the use of hats. Interventions that act to increase all forms of sun-protection are much more likely to be cost-effective as there is greater scope for them to influence both the incidence of sunburn and total lifetime sun-exposure. This suggests that the guidance should focus on interventions that promote the use of range of protection practices or at least those forms of protection that substantially increase the overall level of protection.

The third difference between the current model developed as part of this guidance and the one developed as part of the skin cancer guidance are important differences in the model structure. The skin guidance model was based on a complex model of behaviour which aimed to predict both total lifetime sun exposure (in the same way SCC was modelled in this model) as well as the incidence of sunburn. In contrast this model took a much more direct approach calculating the RRs of experiencing sunburn directly from the effectiveness studies and using epidemiological evidence to link protection with the incidence of sunburn where this was not possible. This is particularly important as it was observed in the skin cancer guidance model, that even substantial increases in the use of sun protection resulted in only modest reductions in the number of sunburns. This contrasts with the current model where significant reductions in the incidence of sunburn were observed for a number of the investigated interventions. This difference between the two models in particular highlights the importance of sunburn as a driver of health gains in the context of sun exposure guidance and suggests that an important aim of any guidance should be to reduce the incidence of sunburn.

5.2 LIMITATIONS

The results of this economic evaluation should be interpreted with a degree of caution. Estimating the cost-effectiveness of interventions aimed at reducing sun exposure is complex and poses a significant methodological challenge.

The model is particularly subject to a high degree of structural uncertainty due to the reporting of behavioural outcomes rather than health outcomes. This means that within the model a series of steps are followed linking the outcomes reported in the studies with the health outcomes used in the model. The mechanisms via which the study outcomes are linked with the health outcomes make a number of simplifying assumptions and are based on limited epidemiological data. For example, in linking the study outcomes to the incidence of MM a linear relationship is assumed between the lifetime number of sunburns and the incidence of MM. This assumed relationship is problematic for a number of reasons. Firstly, it is likely that any relationship between lifetime number of sunburns and the incidence of MM is in fact likely to be non-linear, such that each additional sunburn increases the risk of MM by a greater amount. Secondly, the relationship between sun exposure and MM, is likely to be much more complicated that simply a function of lifetime number of sunburns, including life time total sun exposure and severity of sunburns experienced.

This process of linking study outcomes to MM is made yet more complicated and subject to a further layer of uncertainty when the studies do not report the reduction in the number sunburns as this must then be calculated by linking the use of sun protection practices with the incidence of sunburn. This relationship is based on a number further simplifying assumptions and limited epidemiological data. Similar structural uncertainty exists for all three types of skin cancer and too lesser extent also for sunburn. The impact of this structural uncertainty is that there is high degree of uncertainty regards the effect of each of the interventions on health outcomes and, therefore, the total health benefits that will be realised by implementing the interventions.

The model also has a number of important omissions in terms of the disease outcomes modelled. Firstly, it was not possible to include cataracts in the model due to lack of epidemiological data linking sun exposure to the incidence of cataracts in the population. This omission is likely to mean that the cost-effectiveness estimates are underestimating the true cost-effectiveness and this should be born in mind when interpreting the cost-effectiveness estimates. Secondly, it was not possible to include the positive effects of sun exposure which are associated with sun exposures role in the production of vitamin D. The omission of vitamin D was due to the lack of effectiveness studies examining the delivery of complex message about sun exposure and the lack of appropriate epidemiological data to model this complex behavioural model necessary to accurately model the impact of any intervention. The omission of vitamin D related conditions may act to both underestimate and overestimate the impact of any message delivered as part of the interventions examined. This is due to the fact that most interventions are designed to reduce sun-exposure and therefore may inadvertently increase vitamin D deficiency. However, if the messages are able to accommodate a complex message in which both risks and benefit of sun exposure are delivered it is possible that additional health gains may be made due to reductions in vitamin D deficiency and hence cost-effectiveness would be increased.

A further substantial assumption relates to the persistence of improved behaviour. It was therefore necessary to make assumptions based on minimal evidence, with regards to the duration of the effect of each of the interventions. In most cases this, however, had minimal effect on the cost-effectiveness estimates obtained unless the impact of the intervention lasted in excess of 10 years or more. In the case of the text messages intervention, however, a fairly small increase in the duration of effect (3 years) would be enough for the intervention to be cost-effective.

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APPENDIX A

Summary of Inputs

Table A.1: Hours of sun exposure and SED's

Input	Value used	Source
Number of hours in sun during winter	0.64	Diffey (2008)[72]
Number of hours in sun during summer	0.93	Diffey (2008)[72]
Number of hours in sun during holiday period	5	Diffey (2008)[72]
SEDs for 1 hour in the sun during winter	0.1	Diffey (2008)[72]
SEDs for 1 hour in the sun during summer	0.45	Diffey (2008)[72]
SEDs for 1 hour in the sun during holiday period	1.16	Diffey (2008)[72]
Probability of using protection (generic)	0.35	Matrix (2010)[58]

Table A.2: Utilities

Input	Value used	Source
QALY loss from sunburn	-0.0007	Guitera *et al*. (2004)[65] and Melia and Bulman (1995)[61]
QALY loss from squamous cell carcinoma	-0.28	Freedberg *et al*. (1999)[67]
QALY loss from basal cell carcinoma	-0.28	Freedberg *et al*. (1999)[67]
QALY loss from non-fatal malignant melanoma	-0.466	Freedberg *et al*. (1999)[67]
QALY loss from fatal malignant melanoma	23	Freedberg *et al*. (1999)[67]
Mortality from sunburn	0%	Assumption
Mortality from squamous cell carcinoma	0%	Assumption
Mortality from basal cell carcinoma	0%	Assumption
Mortality from malignant melanoma	25%	Assumption

Table A.3: Incidence

Input	Value used	Source
Incidence of sunburn	Varies by age	Melia and Bulman (1995)[61]
Incidence of basal cell carcinoma	Varies by age	
Incidence of malignant melanoma	Varies by age	ONS Cancer registry statistics and ONS Population statistics[5, 59]
Population size	Varies by age	

Table A.4: Costs

Input	Value used	Source
Cost of treating sunburn	£0	Assumption
Cost of treating squamous cell carcinoma	£1,480.15	Morris *et al*. (2009)[68] and HM Treasury (2010)[69]
Cost of treating basal cell carcinoma	£1,480.15	Morris *et al*. (2009)[68] and HM Treasury (2010)[69]
Cost of treating malignant melanoma	£2,807.63	Morris *et al*. (2009)[68] and HM Treasury (2010)[69]
Cost of 'Living with the Sun' intervention (per individual)	15.42	Department for Education (2014)[46] NUT (2012)[47] TES[75]
Cost of photo-aging (per individual)	12.48	NHS reference costs[43] TV Advertising[45], Guerillascope [44]
Cost of tailored messages (per individual)	£4.67	Assumption, Royal Mail (2014).[76]
Cost of mass media intervention	£0.09	TV Advertising[45], Guerillascope [44]
Cost of text messaging (per individual)	£4.53	Inteli SMS[51], Propects[52] TV Advertising[45], Guerillascope [44]

Table A.5: Inputs to Diffey model of squamous cell carcinoma

Input	Value used	Source
Alpha (age exponent)	5.1	Diffey (1992)[74]
Beta (dose exponent)	2.3	
Gamma (genetic susceptibility factor)	1.65E-12	

Table A.6: SPF values for different types of protection

Input	Value used	Source
Sunscreen	5	Matrix (2010)[58]
Shade	10	
Clothing	20	
Hat	10	

Table A.7: Proportion of body covered by different forms of protection

Input	Value used	Source
Sunscreen	100%	Assumption
Shade	100%	
Shade	64%	
Hat	9%	

Table A.8: Effectiveness of 'Living with the Sun'

Effectiveness of 'Living with the Sun'		
RR of sunburn	0.96	Sancho-Garnier (2012)[25]
RR of using sunscreen	1.05	
RR of using clothing	1.04	
RR of using shade	1.38	
RR of using hat	1.04	

Table A.9: Effectiveness of photo-aging

Effectiveness of photo-aging		
RR of sunburn	N/A	Mahler (2012)[21]
RR of using sunscreen	1.105	
RR of using clothing	1.105	
RR of using shade	1.105	
RR of using hat	1.105	

Table A.10: Effectiveness of tailored messages

Effectiveness of tailored messages		
RR of sunburn	0.81	Crane (2012)[24]
RR of using sunscreen	1.03	
RR of using clothing	1.07	
RR of using shade	1.00	
RR of using hat	1.004	

Table A.11: Effectiveness of Mass media

Effectiveness of text messages		
RR of sunburn	0.70	Dobbinson (2008)[26]
RR of using sunscreen	1.24	
RR of using clothing	1.47	
RR of using shade	1.00	
RR of using hat	1.32	

Table A.12: Effectiveness of text messages

Effectiveness of text messages		
RR of sunburn	N/A	Armstrong (2009)[22]
RR of using sunscreen	1.23	
RR of using clothing	1.23	
RR of using shade	1.23	
RR of using hat	1.23	

APPENDIX B

Summary of Assumptions

Table B.2: Summary of key assumptions of the model

Model area	Assumption
Link between sun exposure and incidence of malignant melanoma	It was assumed based on epidemiological evidence[3] that the incidence of MM was a function of lifetime number of sunburns. Interventions therefore acted to reduce the incidence of MM by reducing the number of sunburns.
Link between sun exposure and incidence of basal cell carcinoma	It was assumed based on epidemiological evidence[3] that the incidence of BCC was a function of lifetime number of sunburns. Interventions therefore acted to reduce the incidence of BCC by reducing the number of sunburns.
Link between sun exposure and incidence of squamous cell carcinoma	It was assumed based on epidemiological evidence[3] that he incidence of SCC was a function of total exposure to the sun. Based on algorithm developed by Diffey (1992)[74] lifetime total exposure was predicted for both the comparator and no-intervention arm. This used data on hours spent in the sun at different times of year, units of sun exposure for different times of year and adoption of sun protection practices in the population.
Link between use of sun protection and sunburn incidence	Sun protection practices were linked to the incidence of sunburn using a Danish study[70] that reported the likelihood of experiencing sun burn in a year given the use of various sun protection practices.
Duration of intervention effects	It is assumed that the initial effect occurs in the first year of implementation and decays in linear fashion over a period of three years.
Effectiveness of photo-aging intervention	It was assumed that this intervention had equal impact on the use of all forms of sun protection. (The relevant study reported on the use of protection generally.)
Effectiveness of text message intervention	It was assumed that this intervention had equal impact on the use of all forms of sun protection. (The relevant study reported on the use of sunscreen.) It was assumed that 69% of individuals would agree to receive the text message.

APPENDIX C

Summary of Quality Assessment of Candidate Studies

Table C.1: Summary of the methodological quality of included RCTs[1]

Study name	Section 1: Population (external validity)		
	Is the source population or source area well described?	**Is the eligible population or area representative of the source population or area?**	**Do the selected participants or areas represent the eligible population or area?**
Armstrong (2009)[22]	-	Not reported/unclear	Not reported/unclear
Crane (2012)[24]	++	+	-
Falk (2011)[34]	++	++	-
Glanz (2010)[32]	+	+	+
Glanz (2013)[30]	++	++	++
Gold (2011)[23]	+	-	-
Mahler (2013)[21]	+	+	+

[1] NICE quantitative intervention studies quality appraisal checklist (Appendix F). Checklist responses as follows:
++ Indicates that for that particular aspect of study design, the study has been designed or conducted in such a way as to minimise the risk of bias.
+ Indicates that either the answer to the checklist question is not clear from the way the study is reported, or that the study may not have addressed all potential sources of bias for that particular aspect of study design.
− Should be reserved for those aspects of the study design in which significant sources of bias may persist.
Not reported (NR) should be reserved for those aspects in which the study under review fails to report how they have (or might have) been considered.
Not applicable (N/A) Should be reserved for those study design aspects that are not applicable given the study design under review (for example, allocation concealment would not be applicable for case control studies)

Study name	Section 1: Population (external validity)		
Manne (2010)[31]	++	++	++
Moser (2012)[28]	+	Not reported/unclear	Not reported/unclear
Rat (2014)[33]	++	++	++
Reynolds (2008)[36]	+	+	+
Roberts (2009)[35]	+	Unclear	+
Sancho-Garnier (2012)[25]	+	++	+
Schuz (2013)[27]	Not reported/unclear	Not reported/unclear	Not reported/unclear

Table C.2: Section 2 **Method of allocation to intervention (or comparison) (internal validity)**

Study name	Section 2: Method of allocation to intervention (or comparison) (internal validity)									
	Allocation to intervention (or comparison). How was selection bias minimised?	Were interventions (and comparisons) well described and appropriate?	Was the allocation concealed?	Were participants or investigators blind to exposure and comparison?	Was the exposure to the intervention and comparison adequate?	Was contamination acceptably low?	Were other interventions similar in both groups?	Were all participants accounted for at study conclusion?	Did the setting reflect usual UK practice?	Did the intervention or control comparison reflect usual UK practice?
Armstrong (2009)[22]	++	++	++	N/A	Not reported/ unclear	Not reported/ unclear	N/A	++	-	-
Crane (2012)[24]	++	++	++	+	Not reported/ unclear	Not reported/ unclear	Not reported/ unclear	++	-	-
Falk (2011)[34]	Not reported/ unclear	++	Not reported/ unclear	N/A	++	Not reported/ unclear	Not reported/ unclear	+	++	-
Glanz (2010)[32]	+	++	Not reported/ unclear	Not reported/ unclear	++	++	+	++	+	+
Glanz (2013)[30]	++	++	++	++	++	++	+	++	++	++
Gold (2011)[23]	+	+	-	-	Not reported/ unclear	+	N/A	-	-	-
Mahler (2013)[21]	-	++	+	-	++	+	++	+	N/A	N/A
Manne (2010)[31]	+	++	Not reported/ unclear	Not reported/ unclear	++	N/A	N/A	++	++	++

Study name	Section 2: Method of allocation to intervention (or comparison) (internal validity)									
	Allocation to intervention (or comparison). How was selection bias minimised?	**Were interventions (and comparisons) well described and appropriate?**	**Was the allocation concealed?**	**Were participants or investigators blind to exposure and comparison?**	**Was the exposure to the intervention and comparison adequate?**	**Was contamination acceptably low?**	**Were other interventions similar in both groups?**	**Were all participants accounted for at study conclusion?**	**Did the setting reflect usual UK practice?**	**Did the intervention or control comparison reflect usual UK practice?**
Moser (2012)[28]	Not reported/ unclear	++	Not reported/ unclear	N/A	Not reported/ unclear	Not reported/ unclear	N/A	-	-	-
Rat (2014)[33]	++	++	-	Not reported/ unclear	Not reported/ unclear	++	N/A	++	+	+
Reynolds (2008)[36]	+	++	Not reported/ unclear	Not reported/ unclear	++	N/A	N/A	-	++	++
Roberts (2009)[35]	+	++	Not reported/ unclear	Not reported/ unclear	++	N/A	N/A	++	++	++
Sancho-Garnier (2012)[25]	+	+	Not reported/ unclear	+	++	+	+	+	++	++
Schuz (2013)[27]	++	++	++	+	++	Not reported/ unclear	Not reported/ unclear	-	+	+
Siegel (2010)[29]	+	-	Not reported/ unclear	Not reported/ unclear	Not reported/ unclear	N/A	N/A	Not reported/ unclear	++	Not reported/ unclear

Table C.3: Section 3 Outcomes (internal validity)

Study name	Section 3: Outcomes (internal validity)					
	Were outcome measures reliable?	**Were all outcome measurements complete?**	**Were all important outcomes assessed?**	**Were outcomes relevant?**	**Were there similar follow-up times in exposure and comparison groups?**	**Was follow-up time meaningful?**
Armstrong (2009)[22]	++	++	+	++	++	+
Crane (2012)[24]	+	+	++	++	++	++
Falk (2011)[34]	+	+	++	++	++	++
Glanz (2010)[32]	+	++	+	++	++	Not reported/ unclear
Glanz (2013)[30]	+	+	+	++	++	++
Gold (2011)[23]	+	-	+	++	++	+
Mahler (2013)[21]	+	+	++	++	++	++
Manne (2010)[31]	+	++	Na	+	++	++
Moser (2012)[28]	+	-	+	++	++	-
Rat (2014)[33]	-	+	+	+	++	++

Study name	Section 3: Outcomes (internal validity)					
	Were outcome measures reliable?	Were all outcome measurements complete?	Were all important outcomes assessed?	Were outcomes relevant?	Were there similar follow-up times in exposure and comparison groups?	Was follow-up time meaningful?
Reynolds (2008)[36]	+	-	N/A	++	++	++
Roberts (2009)[35]	+	++	N/A	++	++	++
Sancho-Garnier (2012)[25]	+	+	++	+	++	++
Schuz (2013)[27]	+	+	+	+	+	-
Siegel (2010)[29]	Not reported/ unclear	Not reported/ unclear	N/A	-	Not reported/ unclear	Not reported/ unclear

Table C.4: Section 4 Analyses (internal validity)

Study Name	Section 4: Analyses (internal validity)					
	Were exposure and comparison groups similar at baseline?	**Was intention to treat (ITT) analysis conducted?**	**Was the study sufficiently powered to detect an intervention effect (if one exists)?**	**Were the estimates of effect size given or calculable?**	**Were the analytical methods appropriate?**	**Was the precision of intervention effect given or calculable: Were they meaningful?**
Armstrong (2009)[22]	++	++	++	++	++	++
Crane (2012)[24]	++	++	++	++	++	++
Falk (2011)[34]	Not reported/ unclear	-	Not reported/ unclear	++	++	-
Glanz (2010)[32]	++	+	Not reported/ unclear	++	++	+
Glanz (2013)[30]	++	++	++	++	++	+
Gold (2011)[23]	+	-	-	++	++	++
Mahler (2013)[21]	+	+	++	++	+	+
Manne (2010)[31]	++	++	Not reported/ unclear	++	++	++
Rat (2014)[33]	+	++	+	+	++	++
Reynolds (2008)[36]	++	-	Not reported/ unclear	++	++	++

Study Name	Section 4: Analyses (internal validity)					
	Were exposure and comparison groups similar at baseline?	**Was intention to treat (ITT) analysis conducted?**	**Was the study sufficiently powered to detect an intervention effect (if one exists)?**	**Were the estimates of effect size given or calculable?**	**Were the analytical methods appropriate?**	**Was the precision of intervention effect given or calculable: Were they meaningful?**
Roberts (2009)[35]	Not reported/ unclear	++	Not reported/ unclear	++	++	++
Sancho-Garnier (2012)[25]	++	++	++	++	++	++
Schuz (2013)[27]	Not reported/ unclear	-	+	+	+	N/A
Siegel (2010)[29]	Not reported/ unclear	Not reported/ unclear	Not reported/ unclear	++	+	++

Table C.5: Sections 5 Overall Quality Assessment

Study Name	Section 5: Summary		
	Are the study results internally valid (i.e. unbiased)?	Are the findings generalisable to the source population (i.e. externally valid)?	Overall quality assessment
Armstrong (2009)[22]	++	-	+ (Some of the criteria has been fulfilled and the conclusions are unlikely to alter for the criteria that has not been fulfilled or not adequately described)
Crane (2012)[24]	++	-	+ (Some of the criteria has been fulfilled and the conclusions are unlikely to alter for the criteria that has not been fulfilled or not adequately described)
Falk (2011)[34]	Unclear	-	- (Few or no criteria have been fulfilled and the conclusions are likely to alter)
Glanz (2010)[32]	++	+	+ (Some of the criteria has been fulfilled and the conclusions are unlikely to alter for the criteria that has not been fulfilled or not adequately described)
Glanz (2013)[30]	++	+	++ (All or most of the checklist criteria have been fulfilled and the conclusions are unlikely to alter where the criteria hasn't been fulfilled)
Gold (2011)[23]	-	-	- (Few or no criteria have been fulfilled and the conclusions are likely to alter)
Mahler (2013)[21]	+	-	- (Few or no criteria have been fulfilled and the conclusions are likely to alter)
Manne (2010)[31]	++	++	++ (All or most of the checklist criteria have been fulfilled and the conclusions are unlikely to alter where the criteria hasn't been fulfilled)
Moser (2012)[28]	-	-	- (Few or no criteria have been fulfilled and the conclusions are likely to alter)
Rat (2014)[33]	+	+	+ (Some of the criteria has been fulfilled and the conclusions are unlikely to alter for the criteria that has not been fulfilled or not adequately described)

Study Name	Section 5: Summary		
	Are the study results internally valid (i.e. unbiased)?	Are the findings generalisable to the source population (i.e. externally valid)?	Overall quality assessment
Reynolds (2008)[36]	-	+	- (Few or no criteria have been fulfilled and the conclusions are likely to alter)
Roberts (2009)[35]	+	+	+ (Some of the criteria has been fulfilled and the conclusions are unlikely to alter for the criteria that has not been fulfilled or not adequately described)
Sancho-Garnier (2012)[25]	++	++	++ (All or most of the checklist criteria have been fulfilled and the conclusions are unlikely to alter where the criteria hasn't been fulfilled)
Schuz (2013)[27]	+	-	+ (Some of the criteria has been fulfilled and the conclusions are unlikely to alter for the criteria that has not been fulfilled or not adequately described)
Siegel (2010)[29]	-	-	- (Few or no criteria have been fulfilled and the conclusions are likely to alter)

APPENDIX D

Summary of Distributions and Values Used in Probabilistic Sensitivity Analysis

Appendix D1 Distributions and parameter values used in PSA for 'Living with the Sun'

Parameter	Point estimate	Standard deviation	Distribution
Costs			
Cost of sunburn	£0.01	0.5	Log normal
Cost of MM	£2,807.63	£1,123.05	Gamma
Cost of BCC	£1,480.15	£592.06	Gamma
Cost of SCC	£1,480.15	£592.06	Gamma
Multiplier for cost of intervention	1.00	0.1	Gamma
Effectiveness			
RR of sunburn with intervention	0.96	0.054	Lognormal
Multiplier for RRR of using protection with intervention	1.00	0.1	Gamma
Risk ratio of sunburn incidence	1.00	0.2	Gamma
Risk ratio of MM incidence	1.00	0.1	Gamma
Risk ratio of BCC incidence	1.00	0.2	Gamma
Risk ratio of SED per year	1.00	0.2	Gamma
Addition years of full effectiveness	0.01	1	Log normal

Appendix D2 Distributions and parameter values used in PSA for photo-aging

Parameter	Point estimate	Standard deviation	Distribution
Costs			
Cost of sunburn	£0.01	0.5	Log normal
Cost of MM	£2,807.63	£1,123.05	Gamma
Cost of BCC	£1,480.15	£592.06	Gamma
Cost of SCC	£1,480.15	£592.06	Gamma
Multiplier for cost of intervention	1.00	0.1	Gamma
Effectiveness			
RR of sunburn with intervention	0.98	0.1	Lognormal
Multiplier for RRR of using protection with intervention	1.00	0.1	Gamma
Risk ratio of sunburn incidence	1.00	0.2	Gamma
Risk ratio of MM incidence	1.00	0.1	Gamma
Risk ratio of BCC incidence	1.00	0.2	Gamma
Risk ratio of SED per year	1.00	0.2	Gamma
Addition years of full effectiveness	0.01	1	Log normal

Appendix D3 Distributions and parameter values used in PSA for tailored messages

Parameter	Point estimate	Standard deviation	Distribution
Costs			
Cost of sunburn	£0.01	0.5	Log normal
Cost of MM	£2,807.63	£1,123.05	Gamma
Cost of BCC	£1,480.15	£592.06	Gamma
Cost of SCC	£1,480.15	£592.06	Gamma
Multiplier for cost of intervention	1.00	0.1	Gamma
Effectiveness			
RR of sunburn with intervention	0.81	0.069694	Lognormal
Multiplier for RRR of using protection with intervention	1.00	0.1	Gamma
Risk ratio of sunburn incidence	1.00	0.2	Gamma
Risk ratio of MM incidence	1.00	0.1	Gamma
Risk ratio of BCC incidence	1.00	0.2	Gamma
Risk ratio of SED per year	1.00	0.2	Gamma
Addition years of full effectiveness	0.01	1	Log normal

Appendix D4 Distributions and parameter values used in PSA for mass media

Parameter	Point estimate	Standard deviation	Distribution
Costs			
Cost of sunburn	£0.01	0.5	Log normal
Cost of MM	£2,807.63	£1,123.05	Gamma
Cost of BCC	£1,480.15	£592.06	Gamma
Cost of SCC	£1,480.15	£592.06	Gamma
Multiplier for cost of intervention	1.00	0.1	Gamma
Effectiveness			
RR of sunburn with intervention	0.89	0.076531	Lognormal
Multiplier for RRR of using protection with intervention	1.00	0.1	Gamma
Risk ratio of sunburn incidence	1.00	0.2	Gamma
Risk ratio of MM incidence	1.00	0.1	Gamma
Risk ratio of BCC incidence	1.00	0.2	Gamma
Risk ratio of SED per year	1.00	0.2	Gamma
Addition years of full effectiveness	0.01	1	Log normal

Appendix D5 Distributions and parameter values used in PSA for text messages

Parameter	Point estimate	Standard deviation	Distribution
Costs			
Cost of sunburn	£0.01	0.5	Log normal
Cost of MM	£2,807.63	£1,123.05	Gamma
Cost of BCC	£1,480.15	£592.06	Gamma
Cost of SCC	£1,480.15	£592.06	Gamma
Multiplier for cost of intervention	1.00	0.1	Gamma
Effectiveness			
RR of sunburn with intervention	0.92	0.1	Lognormal
Multiplier for RRR of using protection with intervention	1.00	0.1	Gamma
Risk ratio of sunburn incidence	1.00	0.2	Gamma
Risk ratio of MM incidence	1.00	0.1	Gamma
Risk ratio of BCC incidence	1.00	0.2	Gamma
Risk ratio of SED per year	1.00	0.2	Gamma
Addition years of full effectiveness	0.01	1	Log normal