Chapter 13
Measuring Health Benefits of Green Space in Economic Terms

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Abstract Health benefits attributable to green space include increased physical exercise resulting in reduced incidence of coronary heart disease, cerebrovascular illness (stroke), and colon cancer; psychological benefits from reduction in stress; and improved air quality resulting in a reduction in respiratory diseases. Reduction in mortality and morbidity due to improved physical exercise are quantified; and various economic methods to value preventable fatalities and diseases are outlined. The economic value of health benefits of a 1% reduction in the sedentary population is estimated; together with the health benefits of reduced air pollution due to trees. A major problem in the estimating economic benefits is linking green space to increased physical exercise of those in need of physical exercise to improve their health. Some policy conclusions are drawn on the location of green space to maximize health benefits.

13.1 Introduction

This chapter, which is a development of an earlier more detailed study by CJC Consulting (2005), assesses the extent to which health benefits associated with green space can be quantified in economic terms. Health benefits may include the opportunity for increased physical activity, the relief of psychological stress with an associated improvement of mental health; and a reduction in health problems associated with polluted air. These effects are examined separately and in each case the aim is to quantify the benefits so that these can be compared with the cost of provision. The provision costs include both investment to extend the resource

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through tree planting or open space creation, and investment to increase access and use of existing green space including organized health programs.

This systematic economic approach contrasts with a considerable volume of research based on associative effects. For example, Mitchell and Popham (2008) related mortality with exposure to green space in England. After removing income differences, they showed that death rates from all causes and from circulatory diseases were lower in groups with a higher exposure to green space. More greenery, especially in the area of residence, was associated with lower all-cause and circulatory disease mortality. Ellaway et al. (2005) found that higher levels of greenery and lower levels of graffiti and litter in residential environments are associated with being physically active and not overweight and obese. Residents in high 'greenery' environments were 3.3 times as likely to take frequent physical exercise as those in the lowest greenery category. In contrast Sugiyama et al. (2007) found that perceived neighborhood greenness was more strongly associated with mental than physical health.

However, such studies are limited because they do not explain the associations found and are subject to the confounding effects of green space 'quality' and variation in the social and economic characteristics of the population in different locations (e.g., Nielsen and Hansen 2007). Nor do they provide the basis for decisions regarding additional investment in green space.

13.2 Benefits from Physical Activity

The Department of Health (2004b) has reported on the evidence relating to physical activity and its impact on health. It estimates the cost of physical inactivity in England at £8.2 billion per year with an additional £2.5 billion cost for the inactivity element in obesity. The Public Health White Paper (Department of Health 2004a) has 'reducing obesity', 'increasing exercise' and 'improving mental health' as three of its six overarching priorities, and an action plan for physical activity (Department of Health 2005). The Department of Health (2004b) concentrates on the preventative effects of physical activity and concludes that 'for general health, a total of at least 30 min a day of at least moderate intensity physical activity on five or more days of the week reduces the risk of premature death from cardiovascular disease and some cancers. It is estimated that only around 37% of men and 25% of women currently achieve this level of activity in the UK (Joint Health Survey Unit 1999), and that 23% of men and 26% of women are sedentary (take less than one 30 min period of moderate activity per week) (POST 2001). Green spaces such as woodland with public access can increase the opportunities for people to engage in physical activity.

Research suggests that increased exercise would principally reduce the incidence of

- Coronary heart disease (CHD). Inactive people have nearly twice the risk of developing CHD than active people. Persuading sedentary people to take regular light exercise (e.g. walking) could reduce deaths from CHD by 14%.

- Cerebrovascular illness (stroke). Increasing physical activity could reduce the number of strokes by around 25%, although existing data are not conclusive regarding a relationship between physical activity and stroke (NCCDPHP 1999).
- Cancer. Physical exercise is associated with decreased risk of certain types of cancer. The risk of colon cancer is three times higher for sedentary people than it is amongst the most active members of the population.

The impact of obesity on Standardized Mortality Ratios (SMRs) for different age groups has been documented by Bender et al. (1999). No excess mortality was associated with a body mass index (BMI) of at least 25 but less than 32 for the 50–74 age group. But SMRs did increase significantly in higher BMI categories. So health benefits in terms of reduced mortality would flow to those taking additional physical activity who are moderately or severely obese, and who lose weight in addition to taking physical exercise.

13.3 Approach to the Economic Analysis of Health Benefits

Health benefits of green space can be measured using

- Cost effectiveness analysis (CEA): which assesses costs in relation to health effects measured in physical terms (e.g. number of deaths averted, and illness episodes avoided)
- Cost utility analysis (CUA): which assesses costs in relation to utility (rather than a money measure of benefit). The utility of a health improvement (on a scale of 0 = dead to 1 = perfect health) is often estimated by a standard reference gamble (SRG); or in terms of quality adjusted life years (QALYs). A QALY is a period of time in perfect health that is equivalent to a year in a state of ill health (see Sox et al. 1988; Drummond et al. 2005).
- Cost benefit analysis (CBA): which assesses health improvements in economic or monetary terms

This chapter concentrates on CBA. Early CBA studies adopted a ‘human capital’ approach to measure health benefits. The human capital approach to the value of avoidable illness and death is based on the notion that morbidity and premature death results in lost output to the economy from that individual. This opportunity cost approach can readily value lost output from the ill health and premature death of economically active people. But clearly under this approach there is no lost output from the preventable fatality of economically inactive people (e.g. children, housewives and those retired), since there is no reduction in recorded gross domestic product (GDP) by their death. However, non-working people provide some economic benefits e.g. child-care, housework, etc., but these benefits are not measured in the market. Moreover these people are willing-to-pay to avoid the risk of illness and premature death. These deficiencies rendered the human capital approach theoretically unappealing. Hence the human capital methodology has been replaced by an approach based upon the individual's willingness-to-pay (WTP) to avoid the risk of death or injury. This can be measured through

- Insurance: how much people are willing to pay to insure against a risk (Freeman and Kunreuther 1997)
- Hedonic wage model: estimating wage premiums for additional risks (Marin and Psacharopoulos 1982; Viscusi and Aldy 2003; Black and Kniesner 2003)
- Contingent valuation: asking people to state how much they are willing to pay for reducing or avoiding risk or conversely how much they are willing to pay for health improvements (Krupnick et al. 2002; Van Houtven et al. 2006).
- Choice experiments: in which individuals trade-off various health gains against a cost to them (Ryan and Skåtun 2004; Cameron et al. 2008).

Most recent studies have used contingent valuation and choice experiments to value people's WTP to reduce the risk of death and illness from various types of disease; and also to assess people's WTP for health improvements.

13.4 Quantifying the Health Benefits from Physical Activity

The health impact of increased physical activity is estimated as the proportion of a disease in the population that could be eliminated if increased physical activity were undertaken.

13.4.1 Reductions in Mortality

Studies investigating the impact of increased physical activity invariably use a population attributable fraction (PAF) to estimate the proportion of deaths, or other measure of disease burden, caused by a particular risk factor. PAF represents the proportion of a disease in the population that could be eliminated if the exposure were removed from the population. PAF is the number of actual deaths from disease *X,* minus the number of deaths from disease *X* if all people were regularly active, divided by number of actual deaths from disease *X*.

The impact of physical activity on deaths, and averted hospital admissions, depends upon the proportion of sedentary people in the population. Swales (2001) estimated the health impact of increased physical exercise in Northern Ireland (NI). He assumed 20% of the population was sedentary, which increased the risk of premature death or illness from CHD, stroke and colon cancer. On assumptions about the relative risk from lack of physical activity of CHD, stroke, and colon cancer, he estimated excess deaths due to physical inactivity to be 1,271 due to CHD, 709 due to stroke; and 82 due to colon cancer; or 2,062 in total. With a sedentary rate of 15% the respective excess deaths would have been 1,031, 600, and 65; or 1,696 in total. Since the proportion benefiting from the physical activity policy in NI (as elsewhere in the UK) is unknown, Swales assumed that the physical activity strategy in NI would reduce the sedentary population by 5% units from 20% to 15% of the population: a reduction in 366 deaths (= 2,062–1,696).

The calculation of excess deaths requires an estimate of PAF, and the relative risk (RR) for each disease. RR is subject to uncertainty: different studies have estimated different RRs for a specific disease. Moreover, the RR depends upon the 'with-without' perspective: how much physical exercise takes place to that which would occur in its absence, and without green space. For example, for colon cancer, US Department of Health and Human Services (1996) found different mean RRs depending upon the comparators often with fairly wide confidence intervals (CI): RR = 3.6 (95% CI: 1.3–9.8) for least active relative to most active at work and leisure; 1.8 (95% CI: 1.0–3.4) low activity relative to high (work and leisure); and for sedentary relative to active: 1.6 for men (95% CI: 1.1–2.4) and 2.00 for women (95% CI: 1.2–3.3). Some studies adjusted for one of more confounding factors such as age, sex, BMI (body mass index), smoking, diet (e.g. various factors such as energy intake, fiber, protein, fat, etc.) in the calculation of RR; other studies do not. Results also have wide statistical confidence intervals (CI). Thus, some uncertainty surrounds the RR rate to be adopted for CHD, stroke, and colon cancer.

We assume the only population benefiting is sedentary population; and that the colon cancer RR, for sedentary relative to active, is 1.6 (to account for the probability the population benefiting may not actually become fully 'active', but only become irregularly active). The RR of 1.6 is slightly lower than that used by Swales (2001) which was 1.8 for colon cancer; but higher than that employed in some American studies. A RR of 1.4 was used by Walker and Colman (2004) for colon cancer in a study of the cost of physical inactivity in Halifax, Nova Scotia. Swales (2001) used a RR of 2.0 for CHD and 3.0 for stroke. We also adopt a RR of 2.0 for CHD; but for stroke an RR of 1.4. The National Centre for Chronic Disease Prevention and Health Promotion (1999) concluded that because of different pathophysiologies, physical activity may not affect ischemic and hemorrhagic stroke in the same way. Thus the NCCDPHP report concluded that existing data do not unequivocally support an association between physical activity and the risk of stroke. Nevertheless some studies have revealed an inverse association between physical activity and stroke. A RR of 1.4 for stroke was also used by Walker and Colman (2004); whilst a stroke RR of 1.6 was used by Bricker et al. (2001) for physically and irregularly inactive population. There are no data on RR by age groups, so, following Swales (2001) the same RR from physical inactivity is applied for each age group respectively, for each disease.

PAF was calculated on the above RR for CHD, stroke, and colon cancer, with a sedentary rate of 23% for men and 26% for women. The number of avoidable deaths attributable to physical inactivity is estimated by multiplying the deaths attributable to each inactivity related disease by the PAF for that disease.

This analysis for the UK as a whole suggests that there are 12,055 male excess deaths from CHD attributable to lack of physical exercise (see Table 13.1), and 10,931 excess female deaths, or 22,992 excess deaths per year in total. Note that excess deaths increase with age, so that there are proportionately more excess deaths amongst older age groups.

Table 13.1 UK deaths by coronary heart disease: males and females

	All ages	<35	35–44	45–54	55–64	65–74	75+
Males							
Population	28,581,233	13,420,047	4,334,429	3,854,688	3,061,093	2,300,533	1,610,443
Deaths	64,473	131	950	3,376	8,035	16,426	35,555
Excess deaths	12,055	24	178	631	1,502	3,072	6,648
Females							
Population	30,207,961	13,255,941	4,442,961	3,921,713	3,157,716	2,635,541	2,794,089
Deaths	53,003	45	191	735	2,406	8,035	41,591
Excess deaths	10,937	9	39	152	496	1,658	8,582

National Statistics (2002) Census 2001: First results on population for England and Wales. The Stationery Office, London (for population). British Heart Foundation (2004) Statistics Database. www.heartstats.org (for deaths by cause, age, and sex) (reports data from the Office for National Statistics 2003). Deaths Registered by Cause and Area of Residence (personal communication); Scotland General Register Office (2003), Northern Ireland General Register Office (2003)

Analogous calculations for cerebrovascular illness (stroke) and colon cancer shows that there are; 6,093 excess deaths from strokes, and 2,069 for colon cancer, in addition to the 22,992 excess deaths from CHD due to inadequate physical activity.

13.4.2 Averted Deaths

How many of these deaths could be averted from increased physical activity from the provision of green spaces depends upon the extent to which green spaces induce physical activity amongst the sedentary population. Unfortunately research on the probability of exercising as a result of the provision of green space (e.g., Ellaway et al. 2005) needs to be extended before the effect on reducing the proportion of sedentary population can be reliably estimated. If green space reduced the sedentary proportion of the population from 23% to 22% for men, and from 26% to 25% for women, then it would have the effect of saving 1,063 lives in the UK that would otherwise have been lost as a result of CHD, stroke, and colon cancer (Table 13.2).

However, it is unlikely that the same proportion of people aged 75+ would either be capable of taking, or could be induced to undertake, the recommended amount of moderate physical exercise five times per week. Hence, following Swales (2001), we might arbitrarily exclude potential physical exercise benefits to these very elderly people. When this is done, a 1% unit decrease in the proportion of sedentary population saves only 343 lives from CHD, stroke and colon cancer. However, it is likely that some 75+ year old sedentary people could be encouraged to undertake increased levels of physical activity. A study by Brown et al. (2000) of different female age groups and activity levels, suggested that low-to-moderate levels of exercise are associated with a range of health benefits for women of all ages. Munro et al. (1997) also suggest from available evidence that physical activity for the over-65s is cost effective for the NHS.

Table 13.2 UK deaths averted by green space provision reducing sedentary population from 23% to 22% for males, and from 26% to 25% for females

	All ages	<35	35–44	45–54	55–64	65–74	75+
CHD							
Male lives saved	429	1	6	22	54	109	237
Female lives saved	336	0	1	5	15	51	264
Stroke							
Male lives saved	85	0	1	2	5	16	61
Female lives saved	138	0	1	2	4	13	118
Colon							
Male lives saved	41	0	1	2	7	12	19
Female lives saved	34	0	0	1	4	8	21
Total	1,063	1	10	34	89	209	720

13.4.3 Reductions in Morbidity

The incidence of CHD and stroke by age and sex are reported by the Office for National Statistics (2000) from a sample survey of 211 GP practices, with 1.4 million patients (2.6% of the population), in England and Wales (Table 13.3). The rates of CHD and stroke by age groups were applied to the UK population age distribution to derive estimates for the UK as a whole. These are presented in Table 13.3.

The same procedure was used to estimate excess morbidity, as that used to calculate excess mortality. It was assumed the same RR, prevalence or risk, and proportion of sedentary population moving from inactive to active would pertain for morbidity as for mortality. On this basis the excess morbidity cases (EMC) are those documented in Table13.3. If green space results in the proportion of the sedentary males and females in the population falling by 1% unit then this would have the effect of reducing morbidity cases in the UK by 14,414 for CHD and by 445 for stroke. Again, excluding those aged 75+ from the analysis reduces these estimates to 8,910 for CHD and 224 for stroke. A similar analysis for colon cancer indicates that a 1% decrease in the sedentary population would lead to 137 fewer cases.

13.5 Valuing Reduced Mortality and Morbidity

13.5.1 Reduced Mortality

The benefits and costs to society from avoidable illness and deaths include lost utility or WTP to avoid illness and death, plus non-pecuniary benefits and costs to family members and friends through avoided pain and suffering. WTP estimates of the value of a statistical life (VOSL) saved, i.e. the value of a preventable fatality (VPF), and estimates for the value of reduced incidence of illness, have been established in the UK and other countries.

The VPF was originally established in the UK in the mid 1980s when the human capital approach was replaced by a WTP approach to avoid the risk of death. Research by Jones-Lee et al. (1985) employed a contingent valuation (CV) method to assess the population's WTP for a small reduction in the (already small) probability of a traffic accident and the risk of death in such an accident. A significant number of WTP responses in the survey for the Jones-Lee et al. (1985) study were inconsistent or invariant to the size of the risk change; and the standard deviation of the mean WTP value was extremely large. Since that study, CV methodology has advanced considerably (see Bateman et al. 2002; Haab and McConnell 2002), and the application of this methodology would increase the accuracy and robustness of any new study. Nevertheless the approach and WTP value to avoid the risk of death was accepted by government and has been used ever since (with updating to reflect increases in gross domestic product (GDP)) to value preventable fatalities not only in transport but also, with suitable adjustment, in other sectors of the economy (H. M. Treasury 2009).

Table 13.3 Prevalence of coronary heart disease and stroke by age and sex (UK)

Age	0–34	35–44	45–54	55–64	65–74	75–84	85+	CR	ASR
CHD males									
Rate/1,000	0.1	4.9	30.2	94.5	184.0	230.5	233.8	42.0	37.2
No. cases	1,342	21,239	116,412	289,273	423,298	299,744	72,486		1,223,794
EMC	9	142	776	1,928	2,821	1,997	483		8,155
CHD females									
Rate/1,000	0.1	1.7	13.0	49.3	111.5	166.6	180.0	32.4	21.9
No. cases	1,325	7,553	50,982	155,675	293,863	329,879	146,524		985,802
EMC	8	48	324	988	1,866	2094	930		6,259
Stroke males									
Rate/1,000	0.2	0.5	1.2	3.5	8.1	16.3	20.5	2.3	2.0
No. cases	2,684	2,167	4,626	10,714	18,634	21,197	6,356		66,377
EMC	9	7	16	36	63	71	21		223
Stroke females									
Rate/1,000	0.2	0.4	0.9	2.0	5.4	11.3	20.4	2.2	1.4
No. cases	2,651	1,777	3,530	6,315	14,232	22,375	16,606		67,486
EMC	9	6	12	21	47	74	55		222

Office for National Statistics (2000) for rates; 2001 Population Census for age distribution. CR = crude rate (all ages); ASR = age standardised rate (all ages); EMC = excess morbidity cases. Number of cases and EMC are estimates

The VPF for road deaths used by Government is £1.312 million (third quarter 2003 prices). This includes human cost, lost output, and medical costs (Table 13.4). These values can be updated to current prices using the UK GDP deflator. (see http://www.hm-treasury.gov.uk/data_gdp_index.htm).

These values were derived in the road accident context. The VPF amount is applied to value avoided deaths in other contexts e.g. by the Health and Safety Executive (HSE) for work related deaths. The road accident VPF figure is weighted to reflect cognitive psychological aversion to different types of death associated with voluntariness of risk, immediacy, knowledge, control over risk, newness of risk, chronic-catastrophic, common-dread, severity of consequences. However, there is no agreement on how the basic VPF ought to be adjusted to reflect cognitive psychological aversions to different types of death. The HSE, Department of Environment, Food and Rural Affairs, Department for Transport, Home Office and HM Treasury jointly commissioned research by Chilton et al. (2002) to assess whether the VPF estimate was affected by differing dimensions of risk : the number (likely to be killed in a single event); personal control (how much personal control people have over risks); voluntariness (how much choice people have in being exposed to the risks); media-attention (how much media

Table 13.4 Value of preventable fatality, accidents, and illness

	Description	Values (2003 Q3 prices)
Fatality		£1,312,260
Injury: permanent incapacitating	Moderate severe pain for 1–4 weeks. Thereafter some pain, gradually reducing, but may reoccur when taking part in some activities. Some permanent restrictions to leisure and possibly some work activities	£207,200
Serious	Slight to moderate pain for 2–7 days. Thereafter some pain/discomfort for several weeks. Some restrictions to work and/or leisure activities for several weeks/months. After 3–4 months, return to normal health with no permanent disability	£20,500
Slight	Injury involving minor cuts and bruises with a quick and complete recovery	£300
Illness: permanently incapacitating illness	Same as for injury	£193,100
Other causes of illness	Over 1 week absence. No permanent health consequences	£2,300 + 180 per day of absence
Minor	Up to 1 week absence. No permanent health consequences	£530

Department of Transport (2004); Health and Safety Executive (2004). All values are average figures and include human cost, lost output, and medical costs. The difference between the values for a permanent incapacitating injury and a permanently incapacitating illness accounts for the large human cost attributed to injuries due to their short-term effect. The "human cost" (i.e. WTP) element for a fatality is £860,380. There may be some variation in these costs depending on the type of morbidity attention the risks receive); expert-knowledge (how much experts know about the risks); uneasiness (how uneasy people feel about the risks); number-per-year (the number of deaths per year resulting from each of the risks); age-groups-affected (the ages of people affected); and household benefit (the benefits of the safety programs to respondents and their households). The research revealed that trade-offs between preventing deaths in different hazard contexts were much less pronounced than had been thought (the VFP varied by less than 20% between the different contexts) (see Chilton et al. 2002).

So, can the values in Table 13.4 be used to value excess deaths and reduced illness by engaging in more physical activity? Values are likely to vary according to factors such as dread (of particular risk or type of death), voluntariness, and other factors listed above. Dread effects vary substantially by cause of death. For expected utility maximizers, Chilton et al. (2006) list these as pedestrian accident 1.0; accident in the home 0.81; automobile driver/passenger accident 1.67; train accident 8.65; fire in public place 5.80. However, the disutility of these dread effects is offset by a lower baseline risk for these activities (800 in 50 million for pedestrian; 40 in 50 million for rail accident; 30 in 50 million for fire in a public place). Unfortunately these dread effects are for accidents rather than death by diseases.

Cameron et al. (2008) used a choice experiment to investigate how individual WTP in the USA for health risks varied with the type of health threat. They estimated the value of a statistical illness profile (VSIP) i.e., the marginal utility of a series of health states (latency, illness years, and lost life years) in relation to the marginal utility of income. The VSIP for a one in 1 million reduction in the risk of a heart attack was much higher than for a similar traffic accident risk of sudden death. WTP to reduce cerebrovascular illness (stroke) was only three-quarters of that for heart disease; and WTP to reduce colon cancer risk was only half that for heart disease, for a person with an annual income of $42,000. The WTP values for risk reduction in all these diseases varied with latency of illness, illness time, and the age of the person (which reduced WTP).

A WTP study of residents in Ontario and the USA provided more evidence on the effect of age and baseline health on WTP for mortality risks. The study, by Alberini et al. (2004), found some support for the notion that WTP declines with age (as in the Cameron et al. 2008 study), but only for the very oldest residents. A 5 in 1,000 risk reduction resulted in a 25% reduction in WTP over the age 70. They found no support for the idea that people with chronic heart or lung conditions or cancer are willing-to-pay less to reduce the risk of dying than people without these illnesses. WTP should be higher the lower the chances of survival, and the greater the discounted value of lifetime utility. Older people with chronic diseases have lower chances of survival (so WTP↑), but fewer expected life years (value of lifetime utility) to look forward to (so WTP↓). The net result depends on which effect dominates. There is thus some controversy on the effect of age on WTP. This has implications for valuing the health effects of green space, depending on the age profile of users.

13.5.2 Reduced Morbidity

The economic costs of CHD are high. Liu et al. (2002) and the British Heart Foundation (2005) have estimated the cost of CHD at £7,055 million per year in 1999 prices. This comprises £1,730 million in terms of health care costs, and £5,325 million in terms of production and/or informal health care costs. However, £701.2 million of this was attributable to production loss due to mortality, and some of the health care costs will also be incurred on patients who subsequently do not survive. Inpatient care at £917.2 million, and medication at £582.4 million, comprised the two largest items of health care costs. Total medical costs (£1,730 million) divided by the number of CHD occurrences (2,209,596) is £783 per CHD patient. So, if green space induced a 1% unit reduction in the sedentary population this would save £11.28 million in medical costs per year associated with CHD; or £6.97 million (= 8,910 × £783) if people aged 75+ are excluded.

Increased physical activity will also induce reductions in productivity loss due to morbidity (estimated to be £2,207 million per year in 1999 prices) plus savings in informal care costs (estimated to be £2,416 million in 1999 prices). This amounts to (a mean of) some £2,903 per CHD incident. If it is assumed that green space results in 14,414 less CHD incidents, then the reduction in productivity and informal health care costs amounts to some £41.845 million per year; or £25.866 million (= 8,910 × £2,903) if the population aged 75+ is excluded.

The welfare value from improvements to health due to physical exercise is likely to be larger than the above estimates. The above estimates are based on costs incurred as a result of CHD, not people's WTP to avoid CHD. A more accurate estimate of the benefit of reduced morbidity from CHD would be obtained by mapping the value of people's WTP to avoid different degrees of severity of CHD.

The direct health care cost of stroke to the UK has been estimated to be £1,655 million (British Heart Foundation 2005). Dividing these medical costs by the number of stroke occurrences (133,863) gives a cost of £12,363 per stroke patient. This presumably reflects the longer care treatment time for stroke patients. There are no estimates for productivity costs and informal care costs for stroke, but these are also likely to be very substantial per patient compared to CHD costs. So, again, a 1% reduction in the sedentary population would save £5.5 million (= £12,363 × 445) in medical costs per year associated with stroke; or £2.769 million (= 224 × £12,363) if the population aged 75+ is excluded.

It has been estimated that the hospitalization costs of each colon cancer patient are £3,000 (Health First Europe 2005). There would be additional medical costs to the health service in terms of General Practitioner time and costs that might add say another £650 per patient. If so, this would suggest savings in medical costs of around £0.5 million for reduction in the prevalence of colon cancer.

The benefits of increased physical activity due to green space for CHD, stroke, and colon cancer, increase the probability of immediate survival. Unlike reductions in air pollution due to green space the effect of physical exercise on CHD, stroke, and colon cancer, is not to simply add 1, 2, or 3 months on to a person's life at the

Table 13.5 Annual value of health benefits from a 1% unit change in the sedentary population (£m) (UK)

	Mortality		Morbidity		Total	Total[b]
	Cases (no)	Cost (£m)	Cases (no)	Cost (£m)	Cost (£m)	
CHD	766	1,005.19	14,414	41.85	1,047.04	372.31
Stroke	223	292.63	445	[a]5.50	298.13	60.51
Colon cancer	74	97.12	137	[a]0.50	97.62	46.18
Total	1,063		14,996		1,442.79	479.00

[a]Indicates that costs are initial medical costs only and do not include long term treatment costs and more importantly lost output (wages) as a consequence of being partially or wholly incapacitated

[b]Total excluding those aged 75+ for CHD and stroke and 70+ for colon cancer

end of his/her life. It affects the probability of survival now. Hence the appropriate valuation approach is similar to the case for valuing mortality and morbidity as a result of road accidents.

Table 13.5 presents a summary of possible benefits of green space provision with respect to reductions in mortality and morbidity, assuming green space induced physical exercise such that proportion of the sedentary males and females in the population fell by 1% (from 23% to 22% for males; and from 26% to 25% for females).

The value ranges from £479 to £1,442 million per year depending on whether older people (75+) are excluded or included in the analysis. This range can be regarded as a minimum set of values for two reasons. First, for stroke and colon cancer morbidity the health value is for savings in medical costs only, and does not include other benefits such as reductions in lost working time (e.g. wages). Second, the morbidity benefits should be based upon people's WTP to avoid contracting these diseases. Typically such an approach to valuation produces higher estimates of benefits than simply counting medical costs saved and lost wages. Unfortunately due to a lack of information both on the severity distribution of the incidence of CHD, stroke, and colon cancer across the population, and information of people's WTP to avoid these different degrees of severity, it is not possible to operationalize this approach at the current time.

These benefits of increased physical activity are larger than those estimated by the Government Strategy Unit (2002). The 'Game Plan' estimated the total cost of physical inactivity in England to be £1.89 billion per year. This was based upon direct health care costs of physical inactivity, loss of earnings due to sickness absence, and earnings lost due to premature mortality. Set against these benefits were sports injury costs of £996 million per year, giving a net benefit of around £500 million per year from eliminating physical inactivity in England. The difference between the 'Game Plan' estimates and those in this report can be partly explained by the methodology adopted (estimates in this report are based on WTP to avoid the risk of death and illness, and these will be significantly greater than lost earnings), and geographical coverage (UK in this report compared with England in the 'Game Plan'). Note, we have not adjusted our benefit estimates for the costs of injury associated with the use of green space. Since the predominant activity is walking, these costs are expected to be relatively minor.

13.6 Psychological Benefits

Psychological health benefits from green space have been discussed in detail in Chapter 5. Here, we briefly review the literature in order to assess the extent to which benefits can be subjected to economic analysis.

Psychological benefits may be associated with physical activity (not included in the previous analysis) or related to the visual impact of green space. It includes benefits for significant psychological disease such as depression, as well as more subtle gains in vitality, general mental state, and experience of social inclusion, as found by in studies of housing projects in America (Kuo and Sullivan 2001a). Kaplan and Kaplan (1989) also developed a theory of green space having 'restorative' psychological benefit for many people, explaining the preference many people express for access to nature.

A more rigorous study was undertaken by van den Berg et al. (2003) in The Netherlands. Participants were rated for depression, tension and anger or a mood scale. Videotapes of four walks (street along a canal, street without a canal, woodland without water, woodland with water) were shown to 114 participants. Participants rated these four environments. They then completed a mental concentration test. Participants with higher levels of stress had higher preferences for natural environments and lower preferences for built environments; whilst the natural environments were associated with more positively toned changes in mood states and marginally better performance in concentration. Hartig et al. (2003) also analyzed psycho-physiological stress recovery and directed attention restoration in natural and urban field settings in California, using repeated measures of ambulatory blood pressure, emotion and attention collected from 112 randomly assigned young adults. Sitting in a room with tree views promoted a more rapid decline in diastolic blood pressure than sitting in a viewless room; and walking in a nature reserve promoted greater stress reduction than afforded by walking in urban surroundings.

Pretty et al. (2007) assessed the effect of green exercise on mental health using 263 participants. Data were gathered on six mood measures (anger, confusion, depression, fatigue, tension, and vigor) for each individual, and a total mood disturbance (TMD) score calculated. Participants engaged in an activity: walking, cycling, conservation, horse riding, boating, woodland activities, and fishing. Green exercise activity was more effective in reducing TMD and improving self-esteem following participation. However, the reduction in TMD scores following participation in the green exercise activities was similar for all of the ten case studies, irrespective of whether the activity occurred in a forest.

In the urban environment there is good evidence from a study of two housing areas in Greenwich, London (Guite et al. 2006) that the extent of access to green open spaces has a significant effect on scores for mental health and vitality. Dissatisfaction with the green space surrounding the block (particularly the absence of trees) was one of several elements in the local environment affecting mental health. One of the areas studied had been the subject of a design award when built in the 1980s but few residents liked it, in part because of a lack of attractive green space.

Trees are known to produce psychological benefits in terms of improving medical recovery rates (Ulrich 1984) and also in reducing crime (Kuo and Sullivan 2001b). There is also some evidence to suggest that woodland can be therapeutic in reducing anxiety and stress. Milligan and Bingley (2007) gathered evidence on this from young people, aged 16–21, using qualitative and psychotherapeutic techniques to facilitate access to memories, fantasies, and recalled multi-sensory awareness of the past. The study identified woodland as therapeutic for young people, but also found certain types of wooded areas (particularly those enclosed, dark and dense), as intimidating.

Viewing woodland and greenery seems to lead to a feeling of well-being thus aiding medical recovery rates; and to increase in levels of concentration, i.e. positive psychological benefits. There is evidence that the quality of the space proximate to where people live is important for their mental well-being. There are therefore positive effects both in recovery from mental health problems and as a prophylactic measure. The only negative impact is some evidence of negative psychological effects in some studies of woodland (e.g., Bullock 2008).

However, there are no data available that allow an economic analysis of the psychological benefits from green space. Neither the public's WTP to reduce the risk of psychological disease nor their WTP to increase the probability of recovery from mental health problems are known. Nor is it known how access to green space affects these probabilities. However, if green space does provide 'restorative' psychological benefits, but ones that cannot as yet be priced, there is only one economic conclusion that can be drawn: existing green space provides social benefits for the treatment and prevention of some psychological conditions where access is available at negligible cost. Where additional access or provision of green space is not cost-free it is not possible at present to quantify the benefits such that costs and benefits to society can be compared.

13.7 Cost and Benefits of Green Space Provision

To take the economic analysis further on the cost side it is necessary to differentiate between autonomous use of green space, which is cost free unless there is increased space provision, and use created through increased accessibility or health promotion programs, which requires investment.

13.7.1 Autonomous Use

Autonomous use that produces health benefits requires regular accessibility and this is self-evidently maximized by proximity of the green space to population centers. But the characteristics of green spaces are also important in determining the likelihood of positive health behavior.

There has been limited research on the effect of woodland and other green space on the probability of engaging in physical exercise of sufficient duration (30 min, 5 days per week) and intensity (e.g. brisk walking). Estimating such an effect would ideally need to take into account substitutes (alternative physical exercise opportunities available locally in urban areas – see Townshend and Lake 2009), distance to the wood or green space, attractiveness of the wood vis a vis alternatives, and any concerns about safety (of walking in a wood as distinct from say a suburban street). Factors confounding the relationship between physical activity and green space are the socio-economic composition of the population and self-selection. Wealthier more educated people, who tend to take more exercise, often live in areas with more green space or make more recreational visits to woodland. People who have a greater propensity to exercise may choose to live in neighborhoods that offer greater opportunities for exercise. These factors need to be standardized in any assessment of the impact of green space and woodland on physical activity.

Humpel et al. (2002) assessed 19 studies and concluded that physical environment factors (accessibility, opportunities and aesthetic attributes) had a significant association with physical activity. (Giles-Corti and Donovan 2002; Giles-Corti et al. 2005) used direct studies of behavior to assess the effect of attractiveness and accessibility of public open space on physical activity within the 408 km^2 of metropolitan Perth, Western Australia. Interviews were conducted with 1,803 adults, aged 18–59, on access to public open space and physical activity, specifically investigating the effect of distance, attractiveness, and size of public open space. 28.2% of respondents reported using public open space for physical activity. Those with good access to large, attractive open spaces, were 50% more likely to achieve high levels of walking. Attractiveness features which influenced use for walking were trees, water features, bird life and size and the absence of dedicated sports space.

In the USA, Cohen et al. (2006) studied 1,556 grade 6 girls who were randomly selected from six middle schools in each of six field site areas across the USA. The girls wore accelerometers for 6 days to measure metabolic equivalent–weighted moderate-to-vigorous physical activity, a measure accounting for the volume and intensity of activity. Each park within half a mile of an adolescent girl's home was associated with a 2.8% (17 min) increase in non-school moderate/vigorous physical activity per 6 days. Beyond half a mile each park increased moderate/vigorous physical activity by 1.1% of 6.7 min per 6 days. For the average girl with 3.5 parks within one mile of home, parks increased total non-school moderate/vigorous physical activity by 36.5 min per 6 days, or approximately 6%.

The above results together with those of Ellaway et al. (2005) and Wang et al. (2004) strongly suggest that attractive, accessible green space will be used to increase physical activity, and is thus likely to provide health benefits to the users. But not all studies reach this conclusion. Maas et al. (2008) investigated whether physical activity (with respect to walking and cycling during leisure time and for commuting purposes, sports and gardening) was related to the amount of green space, and whether there was a relationship between this and self-perceived health. The study covered 4,899 people; and the amount of green space within a 1-km and a 3-km radius around the postal code coordinates was calculated for each individual. Multivariate analyses found no relationship between the amount of green space in the living environment and whether or not people met Dutch public health recommendations for physical activity. Indeed, people with more green space in their living environment walked and cycled less often and fewer minutes during leisure time; although people with more green space spend more time gardening.

The most detailed attempt to value individual attributes of urban green space has been made by Bullock (2008). He used choice modeling to determine the values attributed to both existing and new (hypothetical) green spaces by households in Dublin. The preferences of respondents were for well-maintained areas with good facilities (paths, seating, trails, playgrounds etc.). There were consistent preferences for mixed open areas and trees but generally not for 'more wooded areas' unless these were areas that the residents were familiar with. The study strongly supports the benefits derived from scattered trees in mixed open areas but is less supportive of new urban and peri-urban woods.

The above studies suggest that improving the quality and accessibility of the physical environment can increase physical activity levels, although the amounts may be quite small. However, the health benefits of woodland and green space depend on the extent to which it results in sedentary individuals increasing their level of physical activity. This cannot be assessed by simply observing how many people use green space, since some of the users may not be in need of additional exercise or they may have substituted green space activity for activity elsewhere. It requires a controlled to monitor the location, duration and intensity of the physical activity. Of course, such a controlled trial may also be subject to a Hawthorne effect (McCartney et al. 2007).

13.7.2 Created Use Through Health Programs and Increased Access

A huge number of schemes have been developed in the UK and other countries in recent years to encourage people (and especially sedentary people) to become more active. Some, but not all, of the schemes are closely linked to the prescription of exercise by doctors. The outdoor schemes largely concentrate on walking. Natural England (2008) in conjunction with the National Heat Foundation has a large-scale scheme to encourage walking (*Walking the Way to Health*) with sites throughout England. In Scotland the Forestry Commission acting on a cost-benefit review of the public estate (CJC Consulting 2004) created a Woods In and Around Towns (WIAT) initiative to extend locally accessible woods (Forestry Commission 2010). This has health benefits as a key objective.

An example of one local medically-driven scheme is the Chopwell Wood Health project (CWHP) in the north of England (Powell 2005). The overall aim was to improve the health and well-being of local communities through use of a local woodland. The main health element was a doctor referral scheme for patients that would benefit from more physical activity (to cycle, walk, undertake T'ai Chi or carry out conservation work). There is evidence to suggest that participants in an intervention group were almost twice as likely to increase physical activity as a control group (without physical exercise encouragement) 6 months later, and 25% of the intervention group who received an information pack were regularly active 12 months later (Mutrie et al. 2002). Assuming physical activity saves between two and six lives per 1,000, the expected preventable fatalities from the first cohort of 12 participants who completed the CWHP will be between 0.024 and 0.072 lives saved. At £1.3 million per life saved the expected (capitalized) health value of the CWHP will be between £31,200 and £93,600 for mortality reductions. In addition there will be some expected savings in medical costs from morbidity and avoided production losses due to reduced absence from work from the other participants on the program. These net benefits might be expected to exceed the low costs of the health program which relies on largely autonomous use of existing local green space.

Nevertheless, health schemes using green space are very difficult to evaluate in cost-benefit terms because they rarely provide enough information, and are not established with suitable control procedures. Many of the participants in such schemes may already be taking adequate levels of physical activity or may substitute organized programs for previous autonomous use. In addition, they may not adhere to a program in the longer term. Health benefits at the margin will then be reduced. Anecdotal evidence from many schemes indicates that participants feel there are benefits in well-being but part of this may reflect the social and psychological benefits from increased social contact (Maas et al. 2008).

Whilst a cost-benefit framework can be used to appraise investment in new or improved green space, estimating the probability that a sedentary person will use the green space for at least moderate physical activity for at least 30 min on 5 or more days per week is not well documented. Table 13.5 indicates a benefit of £1,442.79 million per year for a 1% unit shift in the UK sedentary population, which is £2,423 per person (if the oldest age group is excluded this reduces to £804.4). Using the £2,423 per year social benefit obtained by shifting a person from sedentary to active status, the net benefit per year (B, £) from an investment in green space and any associated health programs can be summarized as:

$$B = R(p_1 + p_2) * 2{,}423 - (c_p + c_h)$$

where:

R = the size of the target sedentary population

p_1 = the probability of autonomous use such that the guidelines are reached

p_2 = the probability of health program uptake such that the guidelines are reached (created use)
C_p = the cost of the new green space provision (£ per year)
C_h = the cost of the health program (£ per year)

This benefit estimate excludes any psychological health benefit. It is also partial because there may be substantial benefits to the active population reflected in their WTP for access to green space which are additional to these health effects.

In relation to applying the equation, provision costs are relatively simple to estimate but quantifying the probability that sedentary people will achieve active status through green space investment is not. Much would depend on the size and location of the green space and its attractiveness for walking and whether it linked to other areas to provide longer linear walks (Giles-Corti et al. 2005). The 1% reduction in the sedentary population (an implied probability of 0.038–0.043, Table 13.2) is not easily achieved and would be demanding for most additional green space. This is an area in which more carefully controlled research is clearly needed so that guideline estimates for different contexts become available.

A lack of data on uptake probabilities limited the NICE (2006) assessment of the cost-effectiveness of outdoor health (walking and cycling) programs. They concluded that "evidence for the effectiveness of community-based walking and cycling programs in increasing physical activity is equivocal." However, they did find that other brief intervention in primary care and exercise referral (e.g. exercise in gyms) was cost effective. The cases reviewed, however, were those where the participants increased exercise as part of treatment for medical conditions.

Improved access to existing green space is likely to be much less costly than the creation of new space. In the case of woodlands, new planting takes many years before benefits are fully realized and an emphasis on making existing woods more accessible and attractive has clear merit. Where government has transferred access rights to the public on previous private land such as open land and the coastline in England, cost-benefit analysis has underpinned the prior appraisal (Entec UK 1999; Asken 2007). Such studies find difficulty in incorporating the health benefits from improved access because the extent to which the access will increase the activity levels of the sedentary population is unclear.

13.8 Air Pollution Benefits

Trees, woodland, and to a less extent other green space, reduce air pollution, and thereby reduce the incidence of diseases exacerbated by air borne pollutants. This section only assesses the impact of trees, since trees are by far the most important element of green space for absorbing air pollutants.

Trees improve air quality by

- Absorbing gaseous pollutants such as nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and ozone (O_3)

- Intercepting particulate matter (PM) such as dust, pollen, and smoke
- Releasing oxygen (O_2) through photosynthesis
- Transpiring water and shading surfaces, thus lowering local air temperatures, thereby reducing O_3 levels (McPherson et al. 1999; Vargas et al. 2007)

The air quality improvement effect of trees is proportionately greater in urban than rural areas per unit area of trees, since in urban areas trees are closer to sources of air pollution, and because woodland around urban areas is smaller and more fragmented there are greater edge effects. Trees at the edge of woods capture more pollutants than those in the middle of forests. By providing shade urban trees can also with suitable planting reduce summertime electricity consumption and reduce carbon emissions from summertime electricity use (Donovan and Butry 2009).

13.8.1 Air Pollution Adsorption Effect of Trees

Trees are effective in removing NO_2, SO_2, O_3 and particulate matter (e.g., PM_{10}), from the air. Trees also remove carbon dioxide (CO_2) from the atmosphere. Since CO_2 is a greenhouse gas, the non-market benefit of CO_2 removal is mainly in terms of the value of carbon sequestration in reducing global warming. The layered canopy structure of trees, which has evolved to maximize photosynthesis and the uptake of carbon dioxide, provides a surface area of between two and twelve times greater than the land areas they cover (Broadmeadow and Freer-Smith 1996).

Particulate matter is captured through deposition on leaf and bark surfaces and this is the main dry absorption route. The process of dry deposition is complex, depending upon tree type. Deposition varies depending on the density of the foliage, leaf form, tree spacing and surface topography. Particulate capture occurs when an air stream is disrupted as it passes the aerodynamically rough plant surfaces, while the particle continues in a straight line and strikes the obstacle, either through direct interception or electrostatic attraction. Retention can be helped by rough, pubescent, moist and/or sticky surfaces. Beckett et al. (1998) found evidence that increased stickiness of surface particularly facilitates greater coarser particle capture, while surface roughness has a greater influence on the uptake of finer particles. Some particles may be absorbed into the tree but most are retained on the plant surface. Some particles will be re-suspended, but others will be washed off (particularly soluble particulates) or fall with leaves or twig fall. Re-suspension of fine particulates is less likely as they are easier embedded within the leaf boundary layer (Beckett et al. 2000b).

Tree types vary in their ability to capture air pollutants. Beckett et al. (2000b) found that coniferous species captured more air borne particles than did broadleaved trees, with pines capturing significantly more material than cypresses. They also found that trees situated close to a busy road captured significantly more material from the largest particle size than trees situated at a rural background site. However, Beckett et al. (2000a) found little variation between the urban (park site in Brighton) and more rural site (situated on the outskirts of Brighton on the South

Downs) in the weight of particles from the two smallest particle size fractions (i.e. the particulate matter sizes most damaging to human health). Cavanagh and Clemons (2006) point out that theoretically greater deposition should occur over coniferous woodland due to a typically larger leaf surface area of pines (e.g., pine has 479 g foliage per m^2 of ground area, whilst oak has 106 g foliage per m^3 ground area). Dochinger (1980) found coniferous forests were more effective in removing particles than deciduous forests. Bark captures more particles per square meter than leaves. However, leaf area is greater than bark surface (6 m^2 leaf area per m^2 ground compared to 1.7 m^2 bark).

Some trees emit volatile organic compounds (VOCs). Rates of emission depend on tree species. These VOCs can contribute to the formation of secondary pollutants such as ozone (O_3) peroxyacetyl nitrate (PAN) and secondary particulates following the reaction with oxides of nitrate in sunlight. Urban Tree Air Quality Scores (UTAQS) can be calculated taking into account positive and negative changes in O_3, NO_2, HNO_3, NO, and PAN. Stewart et al. (2002), using O_3 to represent all air pollutants, found that trees with the greatest capacity to improve air quality were ash, common alder, field maple, larch, Norway maple, Scots pine, and silver birch. By contrast, crack willow, English oak, poplar, sessile oak, and white willow are trees that have the potential to worsen air quality. A subsequent study including more pollutants (O_3, No_2, HNO_3, NO, and PAN) confirmed this, with pine (Austrian, Corsican and Maritime), larch, silver birch and Norway maple having the greatest potential to improve air quality, whilst English oak, white willow, crack willow, aspen (*Populus tremula*), sessile oak, red oak, can worsen downwind air quality if planted in large numbers (Donovan et al. 2005). A simulation in the West Midlands metropolitan area, assuming existing woodland cover plus 20% for each tree species in turn found that some species (oaks, willows, and poplars) could be detrimental to air quality during stagnant summer time conditions. Species most likely to improve air quality were alder, field maple, hawthorn, larch, laurel, Lawson cypress, Norway maple, pine and silver birch.

13.8.2 Epidemiological Impact

Air borne pollutants, principally particulate matter of 10 μm (PM_{10}) or less, NO_2, SO_2, and O_3, affect lungs and exacerbate respiratory and heart diseases, and PM_{10} may carry carcinogenic compounds into the lungs. Research has focused on PM_{10}, but the finer fractions such as $PM_{2.5}$ and $PM_{1.0}$ are becoming recognized in terms of health effects. Particles are carried into the lungs where they can cause inflammation and a worsening of the condition of people with heart and lung diseases. Moderate concentrations of SO_2 can result in reduced lung function particularly in people suffering from asthma. Higher SO_2 levels result in tightness in the chest and coughing, requiring medical attention and/or hospital admission. O_3 irritates the airways of the lungs, increasing the symptoms of those suffering from asthma and lung diseases. These health impacts can be compounded when SO_2, PM_{10} and other air pollutant concentrations are all high.

The finer particles $PM_{2.5}$ (between 2.5 and 10 μm in diameter) originate primarily from fuel combustion and are so small that they stay in the air for long periods. Air borne concentrations of PM_{10} are higher in urban areas due to increase automobile wind disturbance and eddies formed around buildings. PM_{10} fall out near the point source, while $PM_{2.5}$ tends to remain air borne. Trees near urban areas therefore tend to capture PM_{10} rather than $PM_{2.5}$. Because $PM_{2.5}$ tends to be dispersed more than PM_{10} trees are less effective in capturing these particles (e.g. relative to rainfall). For example, in a study of trees in Oakville (Canada), the urban forest, of 1.9 million trees, filtered all of the local industrial and commercial emissions of particulate matter (PM_{10}) but only 7% of $PM_{2.5}$. However, epidemiological effects of $PM_{2.5}$ can be dangerous because their smaller size permits them to penetrate the lower lung.

The epidemiological impact of air pollution absorption by trees is difficult to estimate. It requires the matching of exposure to air pollution with morbidity and mortality effects attributable to air pollution. Estimates are typically based on cross sectional studies, relating spatial variations in air quality to morbidity and mortality effects from respiratory illnesses. However, there are lagged effects in the relationship; variations in meteorological conditions; substantial coupling between different pollutants making it difficult to separate out the effect of any one pollutant; differences in people's exposure to air pollution over their lifetime; and different genetic and behavior patterns.

Nevertheless, it has been estimated that small particular matter of less than 10 μm ($<PM_{10}$), SO_2, and O_3 contribute most to increased mortality and respiratory hospital admissions. For PM_{10} the Department of Health (1999) estimated that deaths brought forward increased by 0.75% per 10 $\mu g/m^3$ (24 h mean) and respiratory hospital admissions increased by 0.80% per 10 $\mu g/m^3$ (24 h mean). Respective rates for SO_2 were +0.60% and +0.50% per 10 $\mu g/m^3$ (24 h mean); and for O_3 +0.60% and +0.70% per 10 $\mu g/m^3$ (8 h mean). Mortality and respiratory hospital admissions increase with age of the population.

13.8.3 Health Benefits

The health benefits of improvements in air pollution comprise reductions in deaths and illness, and reductions in medical costs. Medical costs are the easiest to measure. The benefits of reductions in deaths and illness are more difficult to measure for a number of reasons. First, air pollution reduction mainly results in delay in death of people who already suffer from respiratory illnesses. There is considerable uncertainty about the extent to which air pollution reduction will increase the months or years of life of people who are already ill. Second, the value of a preventable fatality (VPF) (see above) is based on people's WTP to marginally reduce an already small probability of death. However, this value is that for the 'average citizen', whose life is cut short by, on average, many years due to un unforeseen accident. In contrast, deaths attributable to air borne pollution tend to be older people whose life is cut short by a few months. A lower value of life therefore tends to be used to account for this difference.

Moreover, in terms of morbidity it is argued that a reduction in air pollution may only marginally improve the quality of life for someone who is already seriously ill with respiratory problems: again suggesting a lower value for WTP for an improvement. On the other hand, WTP to avoid a particular risk can vary with the risk, e.g., type of health effect (lingering or sudden), risk context (voluntary or involuntary), attitude to risk (younger people are less averse to risk), etc. The Department of Health (1999) therefore modified the Department for Transport's VPF to take these other factors into account. They adjusted the road VPF of £847,580 (1996 prices) to an air pollution risk context value of £2 million. This value was then modified for other factors such as age, impaired health state, latency, etc. The Department of Health (1999) estimated that the WTP for a small reduction in risk per death brought forward had an upper-bound of £1.4 million and a lower-bound of £32,000–110,000 for 1 year, and £2,600–9,200 for 1 month delay in the probability of death from air pollution.

The benefits of reduced morbidity comprise reductions in public costs e.g. cost to health provision (NHS); private costs to households e.g. for medicines, etc.; lost output of people prevented from working due to ill-health; welfare costs (reflecting on the pain and discomfort of illness). The Department of Health (1999) estimated NHS costs of £1,400–2,500 for a respiratory hospital admission; and about £1,500–1,700 for a cardiovascular admission. No estimates were provided for private costs and lost output. Lost output would be small, and indeed zero for those >65 who were retired. However, the Department of Health (1999) report did not mention that there would be some lost 'black economy' output as a consequence of the illness of these individuals (loss of casual part-time jobs, inability to undertake own home improvement jobs, loss of services e.g. in terms of looking after grand-children, etc.). These might amount to 10% of wage rate individual obtained whilst in employment.

Department of Health (1999) assumed an 11 day average hospital admission and a change in the quality of well-being (QWB) score from 0.6–0.47 [on a scale of 1 = normal and 0 = dead]. This produced a cost of £170–735 (at 1996 prices), or an estimated cost for a hospital admission avoided of about £530 (updated to 2002). On the basis of these figures, Powe and Willis (2004) calculated the air pollution absorption of woodland (>2 ha) in Britain reduced the number of deaths brought forward by five to seven per year and hospital admissions by four to six. This suggests the benefits of air pollution absorption by woodland >2 ha is some £900,000 per year. However, the health benefits from air pollution absorption within smaller woodlands (<2 ha), not included within the Powe and Willis (2004) study, might be much greater. Many of these woods and trees are located closer to urban populations, closer to sources of pollution, and with larger edge effects, and will have a proportionately greater air pollution capture effect, per unit area, than that for larger blocks of forest located at distance from urban areas.

There is some debate about the amount by which latency and an impaired health state reduces WTP to reduce risk. In a recent contingent valuation study in Italy on WTP for reductions in the risk of dying from cardiovascular and respiratory causes, the most important causes of premature mortality during heat waves and air pollution episodes, Alberini and Chaibai (2007) found that older individuals were willing to pay less for a given risk reduction than younger individuals: persons 60–69 and persons aged >70 had WTP amounts 58% and 41% of those aged 30–59. They also found that persons with cardiovascular problems were willing to pay, *ceteris paribus*, about 45% more than persons in better health. The latter finding goes against the use of QALY measures, as used in the Department of Health (1999) estimates, which discount the value of lives saved and the value of extended lifetimes, of persons in poor health, from improvements in air quality. Thus the health benefits of woodland and green space may be much greater than that indicated by the Department of Health's approach to estimating the health benefits of air quality improvement.

13.8.4 Woodland and Green Space Location

Woods which are located close to the source of pollution capture more pollutants than those located at greater distance. Trees at the edge of woods and forests capture more pollutants than those in the middle of forests. Thus urban trees characterized by rows of single trees, small clusters of trees, and small urban woods, are particularly effective in capturing air borne pollutants.

Higher estimates have been suggested for urban areas. Stewart et al. (2002) estimated that doubling the number of trees in the West Midlands could reduce excess deaths due to particulates by up to 140 per year. The West Midlands air pollution absorption model (McDonald et al. 2007) indicated that increasing total tree cover in the West Midlands from 3.7% to 16.5% reduces average primary PM_{10} concentrations by 10% from 2.3 to 2.1 μg/m^{-3} whilst in Glasgow increasing tree cover from 3.6% to 8% reduces PM_{10} concentrations by 2%.

Unfortunately the study by McDonald et al. (2007) did not estimate what alternative measures would reduce PM_{10} values by an equivalent amount to that which could be achieved by tree planting in the West Midlands and Glasgow conurbation. An interesting research project would be to compare the cost of achieving a reduction in PM_{10} through woodland planting compared with the economic cost of achieving an equivalent reduction by some alterative means e.g. restricting vehicle usage in these urban areas.

The results of the Powe and Willis (2004) and McDonald et al. (2007) appear to conflict. The former underestimates (probably substantially) the excess deaths from reduced air pollution because they only included 2 ha woodland blocks within a 1 km^2 block. The latter group used much more detailed information on small groups of trees of less than 2 ha and the location was urban. But their method of estimating excess deaths was less precise and may have overestimated the impact.

13.9 Conclusions

The health benefits from increased physical activity of sedentary people can be measured in economic terms. The annual value of decreased morbidity and mortality from a 1% unit reduction in the percentage of sedentary people in the UK was estimated at £1.44 billion (a mean of £2,423 per additional active person per year). This figure is reduced to £479 million if older people are excluded. Seventy percent of the benefit was related to reduced mortality from CHD.

There is evidence for psychological benefits in both recovery from, and prevention of, mental illness but there is a lack of quantitative information on which an economic analysis of these effects can be based.

The net benefit from additional green space provision or programs to increase physical activity on existing green space depends on provision costs and success in changing sedentary behavior over the long term.

Green space can provide health benefits from the absorption of pollutants when green space is suitably located. However, there is disagreement between studies in the size of the benefits and more detailed research is needed.

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