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Estimating lost amenity due to landfill waste disposal

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Abstract

The increasing quantities of waste produced by society have implications not only for waste management but also for the social and environmental impacts that these activities generate. This paper examines the impacts that a well-established United Kingdom (UK) landfill site has on the people who live around it and uses a stated preference choice experiment to estimate the magnitude of these impacts in monetary terms. It is found that many residents experience minimal impacts having learnt to live with the landfill site. Willingness to pay for reducing impacts is relatively low and any reduction in landfill operations is likely to have little effect on the amenity of local people. © 1998 Elsevier Science B.V. All rights reserved.

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1. Introduction

In a society that is producing ever increasing amounts of solid waste, the identification of appropriate methods of waste management become increasingly important. The disposition or re-use of solid waste materials can offer a variety of costs and benefits to society, and in addition to health and safety issues, the environmental and social impacts of waste management must be considered when designing socially optimal waste management strategies.

The waste management process has a number of stages. The volume and toxicity of waste can be reduced at source through more effective design, manufacture and packaging of products. Waste volume can also be reduced through recycling and waste transformation, where material is converted either into another product (e.g. compost) or into energy via combustion (e.g. through incineration) or collection of combustible biogas. Any remaining material (waste or ash) must be disposed of in landfill sites. Integrated Solid Waste Management systems attempt to manage society's waste in a way that meets public concerns over environmental and health issues, while at the same time operating within budgetary constraints and satisfying a growing body of regulation.

From an economic perspective, optimal solid waste management systems would be those that ensure that society gains the maximum benefit from the disposal of its waste. Key health and safety objectives must always be met by any waste management strategy; however, alternative approaches may be available that satisfy these objectives. Once these key objectives have been met, the choice of management strategy should be determined by maximising the ratio of societal benefits to management costs. Thus, management strategies may need to address public concerns about the externalities that surround waste management and the need for the sustainable use of resources. They may also need to address possible new European Union directives which are likely to stress the importance of reducing the volume of material disposed in landfill sites, particularly organic carbon, and may recommend the incineration of putrescible material before landfill disposal.

Options which, at the same time as satisfying legal requirements, minimise the impact on landscape, produce least disruption (i.e. noise, litter and odour) and support sustainable resource use may maximise benefits. Such options may also involve the greatest costs. The determination of strategies that provide the highest net benefits to society should ensure optimal waste management. This study attempts to evaluate the social impacts of solid waste disposal in landfill sites by estimating the social costs that this disposal method has for the people who live closest to the site. To get a clearer picture of the long-term impacts of this practice a well-established landfill site was chosen as a case study and a questionnaire survey was undertaken across a sample of local residents to determine the negative impacts that the landfill site will have on them. These impacts were measured in monetary terms by the use of a stated preference choice experiment technique.

2. The externalities of waste management

The problems associated with the management of solid waste in today's society are complex because of the quantity and diverse nature of the wastes, the development of sprawling urban areas, the funding limitations for public services in many large cities, the impacts of technology, and the emerging limitations in both energy and raw materials. The activities associated with the management of solid waste may be grouped into six functional elements; generation, storage, collection, transfer, processing and disposal. They all create externalities, but it is, however, the processing and disposal functions which create greater concerns.

The options which are currently of most significance in the UK are landfill, incineration, composting and the production of refuse derived fuel (RDF), and the externalities associated with each of these may be considered separately.

Landfilling of solid waste accounts for over 80% of solid waste disposal in the UK although this should decrease in the future as a result of government policy, including the implementation of the landfill tax and the requirement that 25% of municipal solid waste is recycled. Externalities include the production of greenhouse gases (and explosive gas), the toxicity and health problems associated with the discharge of leachate to surface or ground water and the noise, visual and odour impacts during the operational phases.

Incineration is essentially a pre-treatment process to reduce the volume of solid waste before landfilling the residue, as well as a potential source of revenue from combined heat and power installations. There are three types of discharge each of which create actual or perceived problems: (i) stack emissions, including dioxins and furans, acid rain, greenhouse gases, mobilised heavy metals and particulates which all have potential impacts on community health and agricultural production; (ii) waste water from quenching of high temperature residue which contains high concentrations of heavy metals and other water pollutants; and (iii) the residual ash, which contains a high concentration of non-combustible substances. In addition, the process has a visual impact due to the requirements for high stacks discharging visible smoke and vapour.

Composting is considered by many to be an ideal solution to many of the solid waste disposal problems since it produces a saleable product. Problems exist with marketing the end product and there is some uncertainty with regard to its agricultural and horticultural acceptability. There is also the need to dispose of the non-compostable residue to landfill after separation. There are, however, a number of municipal composting plants in operation and many more are being considered in the UK. Externalities associated with processing plants would be mainly odour and visual, as well as some noise.

Solid waste in the UK contains approximately 30% material which has a sufficiently high calorific value for consideration of its use as a fuel after separation and pelletisation. Although there is a high capital cost, the potential use of the product makes it a reasonably attractive alternative process. Future landfill costs and requirements for low cost fuel may make RDF plants more acceptable. The nature of the overall operation results in some air pollution from combustion, plus noise, odour and visual impacts on the surrounding area and the need to dispose of the non-burnable residue.

3. Estimating the economic costs and benefits of waste management plans

The costs of the various technologies used in waste management are well documented. Similarly, the monetary benefits of recycled products and the products of waste transformation, such as compost or heat energy, can be measured using market prices. The impact of different forms of waste management on global warming through the production of greenhouse gases, such as methane, may also be enumerated [8].

Less well known are some of the potential non-market benefits that may arise from changes in waste management. These are a mixture of use and non-use benefits which share the characteristic that while they increase the welfare of the general public they do not attract a market price. Use benefits include those arising from reductions in the level of environmental disamenity (e.g. noise, visual disamenity, odour) and reductions in levels of stress and anxiety from living near to a waste disposal site, while non-use benefits may result from the satisfaction that certain desired waste management strategies have been adopted rather than less preferred ones, or from the desire to leave a cleaner environment for future generations. Both use and non-use non-market benefits can be estimated through the use of appropriate welfare economic techniques. These techniques rely on the monetarisation of the changes in welfare, or utility, that are the consequences of different forms of waste management.

Blore and Nunan [3] investigated public attitudes and preferences for the location of new landfill sites in Bangkok, and suggested that expressed preference techniques such as contingent valuation offer a viable, low-cost methodology for gathering relevant information for decision makers dealing with waste management issues.

Conventional contingent valuation exercises concentrate on the valuation of a particular 'event' such as an overall reduction in the disamenity offered by a landfill site. Contingent valuation researchers concentrate on providing adequate information for the respondent to judge the consequences of the change and thus decide on their willingness to pay for the change or their willingness to accept compensation if the change is likely to reduce their welfare.

In environmental economics, another form of expressed preference technique, choice experiments, are beginning to be used in preference to contingent valuation. Choice experiments have been popular in the transportation and marketing literature for some years and have only recently been used in environmental valuation exercises. The methodology is based on the notion that value is derived from attributes of a particular good or situation. Individuals are presented with sets of alternatives and are asked to choose their most preferred alternative. Repeated choices from various sets of alternatives reveals the trade-offs that an individual will make between decreasing income and increasing the levels of individual attributes. Thus, rather than examining the entire change as a package, researchers examine the response of the individual to changes in the attributes of the situation.

While this task may seem more complex than basic contingent valuation, it allows for increased flexibility in the analysis because the attributes themselves can be valued, rather than just the overall change. The valuation of attributes is a significant advantage of choice experiments over contingent valuation. If there is some uncertainty about the final attribute levels, choice experiment results can be used to determine the values for each possible outcome. Contingent valuation, on the other hand, tends to provide one value for the expected quality change.

4. Estimating the social costs of a landfill site using choice experiments

Choice experiments involve: (1) initial screening of the attribute and levels of attributes for the situation at hand, (2) development of an experimental design that constructs the combinations of attributes that will be presented to the respondents, (3) analysis of the choices made [2]. Since each individual is asked to choose one alternative from the choice set, random utility theory is used to model the choice as a function of attributes.

Random utility theory is based on the hypothesis that individuals will make choices based on the attributes of the alternatives (an objective component) along with some degree of randomness (a random component). This random component arises either because of randomness in the preferences of the individual or the fact that the researcher does not have the complete set of information available to the individual. The utility functions can be specified as:

$$U_i = V_i + e_i$$

where U_i is the overall utility, V_i is the objective component and e_i is the error component. If an individual chooses alternative i over j, then U_i must be greater than U_j. Based on repeated observations of choices, one can examine how the levels of various attributes affect the probability of choice. If the random term is assumed to have a Type I extreme value distribution then a Logit model can be employed to examine the factors explaining the choice of one alternative over another.

Since choice experiments are based on Random Utility Theory, welfare economic principles developed for Random Utility Models can be employed [5] to analyse the welfare impacts of a change.

In examining complex situations, choice experiments may involve several attributes, each with several levels, and require respondents to make repeated choices from sets of alternatives [1]. In simpler situations, choice experiments analysis resembles referendum-type contingent valuation in that respondents are asked to choose between a base case and an alternative. The difference between referendum-type contingent valuation and these simple choice experiments is that the attribute levels are varied and different values can be determined for each level of attributes. For example, individuals are asked to make a choice between one situation which does not require the payment of additional tax and another situation which does. The latter situation also contains enhanced environmental attributes. If only one of these questions is posed to an individual, the value of the enhanced environmental conditions can be determined. Following Hanemann [5,6] let the utility of the situation without the enhancement (and no tax increase) be represented by

$$V(Y, 0)$$

where V is utility, Y is income and 0 indicates no environmental enhancement. Let the improved situation be represented by

$$V(Y-\text{Tax}, 1)$$

where 1 indicates the enhanced environmental condition. In the random utility setting, the individual is asked to choose between

$$V(Y, 0) \text{ and } V(Y-\text{Tax}, 1)$$

If the individual chooses the second option, then she is willing to pay at least 'Tax' for the environmental improvement. Analysis of such comparisons over various 'Tax' amounts reveals the probability of supporting the environmental improvement, as a function of the Tax payment required. One form of welfare measure is the amount of Tax that would result in 50% of the sample supporting the program.

Extending this simple choice to multiple attributes is relatively easy. Rather than representing the environmental enhancement by a single value (1 or 0) let the enhancement be separated into two attributes, or two arguments in the utility function. Now the utility function without any improvements can be written as $V(Y, 0, 0)$ and this situation can be compared to $V(Y-\text{Tax}, 1, 0)$, $V(Y-\text{Tax}, 0, 1)$ and $V(Y-\text{Tax}, 1, 1)$. Each improvement can be compared to the base situation and the marginal value of improvements can be analysed.

Here, the negative externalities generated by a landfill site formed the set of attributes used in a paired choice. Respondents were faced by two options each offering a different combination of reductions in the level of disamenity as a result of each of the following: (i) noise, (ii) odour, and (iii) windblown dust and litter. Each option was also assigned a cost in terms of paying additional council tax which would be the price of achieving the given combination of disamenity reductions.

Thus, in the choice experiment section of the questionnaire respondents were given a sheet similar to that shown in Fig. 1 and asked to choose one of the two alternatives. Having made their choice respondents were shown three more cards and asked to choose their preferred choice from each. Cards were chosen at random from an orthogonal set of 64 choice cards. The second alternative on each card always cost more than the first but offered a higher level of amenity in at least one of the attribute categories (this strategy was adopted to prevent the definition of paired choices where a less expensive alternative offered unambiguously higher levels of disamenity reduction).

It was hypothesised that respondents would choose the alternative that maximised their utility and hence their level of welfare. Within a random-utility framework, this process can be seen in terms of respondents assessing the utility offered to them by the available levels of the component attributes and through any interactions between them, and choosing the alternative that offers them the greatest utility. By modelling respondents' choices it is possible to determine the trades-off that they make between different attributes in the selection process. If cost is one of the attributes used, it becomes possible to estimate the trade-offs that respondents make between their utility for money and their utility for other attributes. This trade-off can be interpreted as a monetary value, for example, respondents' mean marginal willingness to pay for a unit increase in the level of a given attribute.

5. Study site and sample survey

The site chosen for this study was Crawcrook Quarry and Landfill Site at Crawcrook near Gateshead in the County of Tyne and Wear in the North-East of England. Sand and gravel have been extracted from the site for over 50 years and since the late 1980s worked out areas of the quarry have been used for landfill. This historical context means that the site has become well integrated into the settlement (population 9184, according to the 1991 Census) with residents familiar with its effects.

	Alternative 1	**Alternative 2**
Reduction in number of **days per year** with **noise** disturbance from the site and site traffic	**30**	**80**
Reduction in number of **days per year** when you can **smell** the site from your home	**40**	**80**
Reduction in number of **days per year** with windblown **dust and litter** from the site landing on your property	**10**	**20**
Annual **Increase** in Council Tax for your household	**£7.50**	**£25**
FIRST CHOICE (tick one box)		

Fig. 1. Example of a choice card.

The site is scheduled for the disposal of non-toxic household, commercial and industrial wastes (paper, plastic, rubble, ash, garden waste, etc.) up to a maximum of 1200 tonnes per day (approximately 120 lorry loads). In common with other landfill sites its licence requires weekly site inspections and monitoring of leachate and other pollutants.

The site is adjacent to areas of housing on its eastern and southern sides and the occupants of approximately 400 dwellings located in this area and along the main lorry route could be adversely affected by negative externalities generated by the landfill operations. These dwellings and the households occupying them formed the sampling frame for the survey. Over 100 houses were targeted in a random sample and questionnaires delivered to their occupants with an explanation of the purpose of the study.

The survey was conducted by a team of postgraduate students who had previously undertaken a pilot exercise in this area and whose involvement in the questionnaire design process meant that they were highly familiar with the survey vehicle.

The main body of the questionnaire was a straightforward document designed to be filled in by the respondent. Questions related to issues of household waste (e.g. How much did households produce? How was it disposed of? Did respondents use recycling centres?); opinions about waste disposal issues; opinions about the Crawcrook landfill site (e.g. Did they experience problems? Had they complained about it?); and household details (e.g. How long they had lived at their current address; age; income; household composition; occupation; education).

Respondents were left for at least 2 days to fill in the questionnaire and familiarise themselves with a short factsheet about waste management and the Crawcrook landfill site in particular. When the completed questionnaires were collected the interviewer invited respondents to take part in the choice experiment exercise. This ensured that respondents had considered the underlying issues before making their choices.

6. Empirical results

The four choices made by each of the 73 respondents provided 292 observations with which to model the choice decision. The choice was modelled based on a comparison between the utility which the respondent has for the set of attributes embodied in each choice. The respondent is assumed to have chosen the alternative that offered her the highest utility. The majority of respondents chose the cheaper of the two options regardless of the promised level of disamenity reduction, and informal debriefing suggested that this reflected the low levels of disamenity experienced by most of the residents living close to the Crawcrook site. The fact that some disamenity was still associated with site operations was evidenced by the occasional selection of an alternative that demonstrated a willingness to pay for higher disamenity reductions.

Table 1
Attribute coefficients in basic choice experiment models

Variable	Coefficient (t-value)	
	Specification 1	Specification 2
NOISE: reduction in number of days per year with noise disturbance from the site and site traffic	−0.0069 (−1.26)	–
LITTER: reduction in number of days per year with wind-blown dust and litter from the site landing on property	0.0129 (2.66)	0.0128 (2.68)
ODOUR: reduction in number of days per year when you can smell the site from respondent's home	0.0105 (2.20)	0.0103 (2.22)
COST: annual increase in council tax for your household	−0.0909 (−4.17)	−0.1142 (−9.15)
Number of observations	292	292
Unrestricted log likelihood	−130.91	−131.71
Restricted log likelihood	−202.40	−202.40
Likelihood ratio test statistic	142.98	141.38
Pseudo R^2	0.35	0.35
% Correct predictions	71.91	71.58

t-Values are shown in parentheses.

The likelihood ratio test statistic is computed as twice the difference between the unrestricted and restricted log-likelihood values: asymptotically this statistic has a chi-squared distribution with n degrees of freedom [4]. At the 95% confidence level the critical value of the chi-squared distribution is 7.81 with 3 d.f.

Pseudo R^2 is computed as 1−(unrestricted log-likelihood/restricted log-likelihood) and is according to McFadden [7] an alternate measure of goodness-of-fit for probabilistic choice models.

The second column of Table 1 reports the coefficients of a simple random utility model that was estimated on the basis of the 292 observed choices. Positive coefficient values indicate that increasing the attribute value (e.g. further reducing disamenity) increases an individual's welfare and consequently that they have a positive utility for that increase. Negative coefficient values indicate that respondents have a negative utility for increasing the associated attribute vale (e.g. an increase in their council tax bill) based on the reduction in welfare that it would represent for them.

In the basic specification of the model the low t-value shows that at the 10% significance level there is no evidence to reject the null hypothesis that the coefficient value on the variable NOISE is zero. This means that over the sample the reduction in noise associated with the site does not influence respondents' decisions over which alternative to choose. The positive, statistically significant coefficient values for ODOUR and LITTER suggest that respondents have a positive utility for reducing these externalities. Similarly, the negative, statistically significant coefficient value on COST reveals that, as expected, respondents associate paying additional council tax with a reduction in their welfare and that this has a negative effect in their utility functions. These results seem logical and consistent with the findings of the pilot survey, where it was clear that noise was the least important of the externalities associated with the Crawcrook landfill site. This may reflect the fact that the majority of houses near the site are located well away from the lorry route and experience little noise from the site. The effects of odour and litter can be experienced at greater distances from the site and are not restricted to particular areas.

The model was re-specified with the variable NOISE excluded and is shown in the third column of Table 1. The discrete choice probabilities are homogenous of degree zero in the parameters, implying that any attributes which are the same for all outcomes will drop out of the probability model. Thus, individual characteristics, such as age or income, cannot be treated as standard explanatory variables. Such individual specific variables can only be entered into the model interactively by using the equivalent of dummy variable interaction terms. Individual specific variables were incorporated as single alternative specific variables, related to the choice of alternative one.

Table 2 reports the coefficients of the discrete choice model estimated incorporating a several alternative specific variables. These coefficients are all significant at the 10% significance level. The signs on the coefficient must be interpreted in terms of their effect on the estimated utility from choosing any given alternative. For example, respondents who are retired or unemployed are found to have a greater utility for choosing alternative one which is always less costly than alternative 2. Those respondents who stated that they thought the landfill site at Crawcrook was a nuisance had a greater utility for the second, more costly, option. This is logical as those respondents would be more likely to be willing to pay larger sums when the

Table 2
Attribute coefficients in basic choice experiment models

Variable	Coefficient (*t*-value)	
	Specification 3	Specification 4
LITTER: reduction in number of days per year with wind-blown dust and litter from the site landing on property	0.01409 (2.81)	0.0153 (3.00)
ODOUR: reduction in number of days per year when you can smell the site from respondent's home	0.0113 (2.31)	0.0103 (2.08)
COST: annual increase in council tax for your household	−0.0797 (−5.46)	−0.0925 (−5.54)
RETIRED*ALT 1: head of household is retired (entered interactively with alternative one)	1.0394 (3.31)	1.0833 (3.41)
UNEMPLOYED*ALT 1: head of household is unemployed (entered interactively with alternative one)	1.3474 (1.74)	1.6146 (2.04)
NUISANCE*ALT 1: landfill site regarded as a nuisance (entered interactively with alternative one)	—	−0.56319 (−1.78)
Number of observations	292	292
Unrestricted log likelihood	−124.72	−123.15
Restricted log likelihood	−202.40	−202.40
Likelihood ratio test statistic	155.36	158.5
Pseudo R^2	0.384	0.392
% Correct predictions	73.29	73.29

Table 3
Willingness to pay (£ per day) for marginal reductions in disamenity

	Specification			
	1	2	3	4
Marginal WTP to reduce number days when respondent suffers from dust and windblown litter from the site	0.14	0.11	0.18	0.17
Marginal WTP to reduce number days when respondent can smell the site from her home	0.12	0.09	0.14	0.11

second alternative offered larger reductions in disamenity across a number of attribute categories.

A variety of other individual specific variables were entered into the model, but none of these proved to be statistically significant at even a 15% significance level. These included variables indicating higher levels of affluence, whether the house was on the lorry route, the number of occupants at home during the day and variables indicating the respondent's opinion of landfill sites in general.

Table 3 reports respondents' willingness to pay (WTP) for the marginal improvements in amenity defined by unit reductions in the number of days when the various negative externalities are experienced. The marginal WTP measures are obtained by dividing the coefficient of a given attribute by the coefficient on COST; this provides a measure of the trade-off respondents would make between improving amenity levels and reducing their disposable incomes. Marginal WTP for a reduction in the number of days where a disamenity is experienced is low—between 9 and 14 pence per day. This is consistent with the results of the pilot survey where respondents revealed themselves to be unwilling to pay large sums for improved amenity levels. Thus, many respondents are unwilling to pay for any improvement, regarding the current level of disamenity as negligible, while the minority are willing to pay relatively small amounts. Taken across the whole sample this results in low marginal WTP values. However, when aggregated these values become more a little more substantial. For example, overall WTP for 50 fewer days with smells from the site and 50 fewer days with windblown litter from the site could be as much as £13 per year.

7. Conclusions

This study was designed to examine the impact on local residents of a well established landfill waste disposal facility. It used a discrete choice experiment to estimate what, if anything, respondents would be willing to pay to reduce the level of disamenity arising from the site. This was used to look at costs of the landfill site in terms of lost amenity value to local residents.

Overall, the discrete choice models confirmed the impressions gained from talking to local people about the landfill site and from other responses to the questionnaire.

People living close to the landfill site have become used to the disamenity levels and learnt to accept them: indeed many moved into their current houses fully aware of the likely levels of disamenity. This meant that the majority of residents found little to complain about with regard to the site and had little incentive to pay for measures that will reduce existing levels of disamenity. Consequently, respondents were found to have a low WTP for reducing disamenity generated by the landfill site and for these households it seemed unnecessary to forgo large sums to diminish a level of disamenity which is already acceptable.

Noise was the least significant of the landfill disamenities examined, with no evidence that respondents would be willing to pay to reduce current noise levels. The problems caused by dust and litter seemed to be slightly more important than the problem of odour; however, there is no significant difference between coefficient values. The highest levels of welfare improvement would probably be experienced by households who sometimes found the site a nuisance (around a third of the sample).

The choice experiment results were encouraging in that they were consistent with the opinions voiced by people living around the landfill site and suggested that only small welfare gains would result from decreasing the noise, dust and litter coming from the site. The ability of respondents to relate realistically to the choice experiment format is a great advantage of this technique, as is the fact that this realism is translated into the resulting welfare estimates.

The relatively small impact of externalities from this landfill site should perhaps not be so surprising. Landfill sites require planning permission and Policy M1 of Gateshead Metropolitan Borough Council's development plans states that planning permission will only be granted if the adverse effect on the environment and amenity is less than any environmental gains arising from the landfill site. Policy M3 specifically requires the effects of a landfill site on local amenity (based on the scale and likely duration of operation, visual impact, dust, noise, traffic, days and hours of operation, or other potential disturbances—both site specific and/or within its zone of influence) to be minimised and this is achieved through planning conditions detailing how the landfill site will be operated (e.g. by specifying the tonnage of waste permitted onto the site in any period, hence controlling the number of vehicles using the site, screening of the site to minimise visual amenity and so on).

Gateshead has five landfill sites in rural areas of the borough, with other potential sites for landfill. Hence, given the supply of available sites, planning permission is unlikely to be granted for a site that would give rise to extensive environmental disamenities. However, other local authorities with more limited supplies of landfill sites and more pressing demands for waste disposal, might be granted planning permission for sites with greater environmental impacts.

This case study suggests that local residents' familiarity with long-established waste disposal sites mitigates against much of the disamenity associated with their operation. It does not reveal the levels of welfare loss associated with the establishment of the facility, but even this may have been low given that residents were at that time used to the disamenity associated with the site in its previous incarnation as a quarry.

It is more interesting to speculate about the levels of disamenity that would arise from opening a new landfill disposal facility close to a residential area, utilising a site that had not been used commercially for some years. It might be fair to speculate that initial welfare losses could be great, but would diminish as residents become inured to the effects of the site. An ex ante choice experiment could produce high estimates of welfare losses if an element of strategic behaviour enters in respondents' behaviour. An ex post experiment shortly after the site opened would give a more realistic measure of the initial disbenefits of the site. Over the life of the site these disbenefits would decrease until they reach a steady state akin to that encountered here.

At present, there is no evidence available to measure the rate at which disbenefits would decrease: however, this could be established by further studies. Knowledge of the life cycle of disbenefits would provide planners with better information to use in the assessment of the overall welfare losses associated with proposed landfill developments for any project appraisal procedures used to assess their feasibility. Armed with such information, decisions on the location of any new landfill sites or changes to the operation of existing sites would be more reliable.

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