THE ECONOMICS OF RESOURCE RECOVERY: THE CASE OF LUBRICATION OIL

by

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Abstract

Environmental concern and the possibility of energy shortages have drawn attention to means for recovering material and energy resources from waste products. The focus of this thesis is on the application of cost-benefit analysis as a methodological technique for evaluating the economics of resource recovery: namely used lubrication oil.

The study initially focuses on the general concern of the economics of resource recovery. This is undertaken primarily by a review of existing literature. An investigation of cost-benefit analysis as advanced by Pearce, Pearce and Dasgupta, Canadian Treasury Board Secretariat, Winch, Nath, Anderson, and Settle, to name a few, reveal a comprehensive and systematic framework for the evaluation of public investment alternatives.

Items for inclusion in the analysis are all costs and benefits to every member of a defined society whose welfare would be affected by the project if implemented. Many goods and services do not enter into the market system, causing difficulty in deriving monetary values for some of the components, especially

environmental concerns. For example, the case study reveals two areas:

1) benefit of pollution abatement stemming from resource recovery of used lubrication oil, and

2) costs associated with the improper disposal of the waste products from the recycling process of used lubrication oil.

An attempt is made to apply the cost-benefit framework to the case of lubrication oil recycling in the Province of British Columbia. Adequate quantitative data were not available, particularly on the social costs and benefits, to fully employ the cost-benefit technique, therefore restricting the analysis in that only an identification of costs and benefits was prepared.

When quantification of costs and benefits is not possible, a detailed description of the unquantifiable items indicates to the decision maker the extent of the components. Included in this study is a presentation of the environmental impacts of used oil disposal.

The limitations of the cost-benefit analysis as an evaluation technique arise because of limited information and data needed to evaluate, in monetary terms, environmental improvement. Future research could involve a "simulation" of the market to determine a plausible shadow price that gives an indication of what the market price of the item would have been if it had been normally traded. A determination of the price that consumers would be willing to pay for the benefits of pollution control with the knowledge that some pollution would be produced by the recycling activity would aid the analyst in placing values on the costs and benefits.

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CHAPTER 1

I. Introduction

Interest in resource recovery has been growing recently in response to the potential environmental damage due to improper disposal of wastes and the continuing prospects of energy shortages. One of the resources with which society should appropriately be concerned is lubricating oil. Used lubricating oil can be recycled in order to (1) conserve petroleum –a non-renewable resource and (2) protect the environment. Large quantities of used automotive and transportation lubricants and industrial oils are currently discarded or re-used in ways that may cause human and natural environment hazards while failing to utilize either the energy potential or lubricative capacity which remains in the oil.

II. Economics of Resource Recovery

The decision to recycle is primarily governed by economic conditions. An economic evaluation of recycling activity involves an identification and assessment of the costs and benefits. Project acceptance is based on a evaluation which shows that a project's expected benefits be in excess of estimated costs.

The existing literature on the economics of resource recovery is largely general in nature. The economics of waste paper recycling has been examined by Turner, Grace and Pearce (1977). Spofford (1971) has reviewed briefly paper residuals, returnable vs. non-returnable containers, and municipal composting. The economics of the recovery of materials from industrial waste has been presented by Bridgwater (1975), while Abert, Alter and Bernheisel (1974) have examined the economics of resource recovery from municipal solid waste.

Even though past research has dealt with the economics of resource recovery of particular commodities, attention has not been placed on the specific costs and benefits of the activity. In the case of used lubrication oil, research has examined the market economics of lube oil re-refining per se; however, little attention has been paid to the social costs and benefits. Mascetti and White (1978) present an assessment of the economics of producing re-refined oil, using figures for the investment requirements and lube oil manufacturing costs as they pertain to seven re-refinery processes. There is no mention of the social costs and benefits attributable to lube oil re-refining.

In consideration of the research, this thesis will attempt to examine the economics of resource recovery; namely, the examination of overall costs and benefits of lubrication oil re-refining.

III. Objectives

The three objectives of this study are:

1) to investigate the economics of resource recovery

2) to present the concept of cost/benefit analysis relevant to a resource recovery project

3) to assess the potential of this technique for environmental policy planning in a case study of used lubrication oil in the Province of British Columbia.

The study will develop and assess cost/benefit analysis as it pertains to planning in environmental management. The concept of cost/benefit is straightforward but, its application to the recovery of used lubrication oil is complicated by the lack of published data required to quantify the costs and benefits. The analysis presented herein is based on a case study of used lubrication oil in the Province of British Columbia.

IV. Concept of Benefit-Cost Analysis

Benefit-cost analysis is one economic methodology frequently used by government agencies to enhance decision making processes. Such analysis considers all the expected social costs and benefits over a project's lifetime in order to calculate the discounted net social benefit.

In this study, the technique is used to identify the costs and benefits pertaining to the recovery of used lubrication oil. The Province of British Columbia was chosen as the geographic frame for the study. The technique as applied herein provides a systematic and quantitative approach for identifying the major costs and benefits relevant to the issue of resource recovery of used lubrication oil.

V. Used Lubrication Oil Studies

Some of the data found in this thesis were extracted from two relatively exhaustive studies of used lubrication oil funded by research grants from the Department of Energy, Mines and Resources, Ottawa. These studies were conducted jointly by the Department of Civil Engineering and the School of Community and Regional Planning at the University of British Columbia during the summer of 1979 and the spring/summer of 1980.

The studies are entitled:

Used Oil Practices and Disposal Methods by the Do-It-Yourself Oil Changer in the Greater Vancouver Area by J.I.N. King and W.K. Oldham, and Used Oil Inventory for the Province of British Columbia by J.I.N. King.

Contents of the studies include:

- present used oil disposal practices in British Columbia
- environmental impacts of used oil disposal
- lubricating oil inventory for British Columbia
- volume of potentially recoverable lubrication oil

The purpose of the studies was to determine lubrication oil volumes and used oil disposal practices in British Columbia. Volumes of potentially recoverable lubrication oil are calculated, with user surveys forming part of the data base.

A consideration apart from the volume of used oil collected is that of the end use of the oil. Many methods of disposal or re-use of used oil create risks of polluting air, water, or soil. The hazards created by discharge into the environment vary depending upon the quantity of used oil discharged, the means of disposal, and the type of impurities contained in the oil. With regard to the latter point, road oiling, for example, deposits lead and other heavy residues. Industrial use of oil-derived fuels is of concern due to the possibility of high ash and metallic constituents in used crankcase oil resulting in fine particle emissions of potentially harmful materials upon combustion. Oil re-refining also may cause environmental degradation with improper disposal of waste products.

VI. Summary

As indicated above, there are many known sources of pollution stemming from the disposal or re-use of used lubrication oil. Benefit-cost analysis provides the analyst with a technique for identifying the costs and benefits associated with the recovery of used lubrication oil, in that a reduced level of pollution (i.e. net social benefit) is anticipated from the activity.

CHAPTER 2

I. Introduction

Millions of pounds of potentially valuable resources are discarded every year in urban and industrial wastes. Concern for environmental protection and resource conservation has drawn attention to possible means for recovering materials and energy resources from waste products. It has been cited that "our economic system recycles insufficiently to spare us the consequences of solid waste pollution and resource exhaustion" (Carlsen, 1973; 653). Recycling tends to be considered only when other courses of action are obviously unsatisfactory, either because of a shortage of natural raw materials or because of environmental considerations (Barton, 1979; 13).

Recycling is not an end in itself, but must be economically and ecologically defensible (Pearce and Walter, 1977; 31). At present, narrow economic considerations are the major criterion of recycling feasibility (Clark, 1971; Henstock, 1976; Bridgwater, 1975).

In the past, the availability of raw materials at a price comparable to, or lower than a recyled product constrained the level of activity in resource recovery. Many recovery methods have been proposed but then rejected on economic grounds. It has generally been cheaper to dump the wastes and pollute water and the atmosphere, than to process them (Barton, 1979; 22). However, the trend is changing as the high cost of materials and of environmental damage associated with increased residuals has become evident (Walter, 1975; 31).

II. The Solid Waste Problem

Private enterprise has not recycled to the technological limit in the past. The reason for this is two-fold. First, in the past relatively cheap virgin resources were available; for example, petroleum. Secondly, society has not been faced with the full costs of production and consumption attributable to waste disposal. The collection of municipal refuse for example, is funded from general municipal taxes and not on an individual basis. Hence, there has been no reason for the individual to decrease the level of refuse. With increased amounts of waste generation due to economic growth, there is demand placed on land requirements for disposal.

Pearce (1976) and Georgescu-Roegen (1975) present the case that the environment can recycle few waste elements by a "natural" process, and they stress the need to tailor the disposal of wastes to the receiving capacity of the environment. Thus, the solid waste problem, in part, stems from the environment's inadequate capacity to absorb growing waste loads. In particular, there seems to be an inadequate cheap supply of land for disposal, despite the fact that over 80 percent of the population is spatially concentrated in urban areas (Goddard, 1975; 4).

Increased spatial competition has been cited as an inflationary factor to land prices, thus magnifying the opportunity costs of utilizing land for waste disposal (Carlsen, 1973; 60).

> Population density and material affluence have combined both to increase the magnitude of the waste disposal problem and the public's perception of the environmental pollution accompanying many disposal methods. Heightened public concern has resulted in more public expenditures as well as more public regulation in the area of waste management (McFarland, 1972; 11).

Hence, the solid waste problem is one of supply and demand. It results from an imbalance between the economic supply of and disposal mechanism for waste materials, and from a divergence between the value to consumers of an additional unit of waste generation and the costs of managing that waste (collection and disposal). The problem can further be defined as an excess supply of waste materials resulting from a mismatch between costs and benefits of material use in general, and/or generating and managing waste materials in particular (Goddard, 1975; 4).

Increased production and consumption of commodities have resulted in ever increasing quantities of wastes. A direct consequence of the volumes of industrial and urban wastes is the increasing public expenditure on finding solutions to handle wastes. The potential threat to the environment is documented as a major reason for analyzing the impact of resource recovery on lessening the quantities of residuals and wastes (Walter and Maltezou, 1974; Henstock, 1976; Pearce, 1976; Spofford, 1971; Barton, 1979; Goddard, 1976).

III. Theory of Externalities

It is a fundamental principle of economic theory that the free operation of perfectly competitive markets will lead to an efficient allocation of resources in the absence of externalities[1]

(Dewees et al, 1975; 7), public goods and decreasing returns to scale. Thus when prices fall, quantity demanded increases and conversely when prices rise, activity demanded falls to bring the economy back into equilibrium.

As Dewees explains, a principal cause of environmental degradation is the failure of the market system to account fully for environmental quality. The private firm rarely evaluates the damages associated with the impacts of its activity on the quality of the environment, whereas, society as a whole (in theory), certainly would. In the private sector of the economy, decision makers are intent on profit maximization, ignoring such external consequences, since they are not reflected in the market prices of their transactions. From the private firm's point of view, market prices reflect "all" its costs and benefits. However, from society's point of view, market prices generally do not capture all the relevant social costs and benefits, especially where the allocation of public goods - such as the atmosphere, water and land - are involved.

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1. An externality arises when an economic activity performed by one person generates an effect, beneficial or otherwise, on some other person who is not party to the activity (Winch, 1971; 123).

IV. Environmental Policy Objective

The causes of environmental pollution have created pollution levels which are greater than that which is socially desirable. Scott and Graham (1972: 54) define pollution as "the impairment of the quality of water, soil or air, so that the enjoyment of subsequent use by others is reduced and prevented." This thesis defines the solution to the environmental problem in terms of a single criterion: maximizing social welfare. The objective of maximizing social welfare is to achieve a pollution control level such that any further control would impose abatement costs greater than the savings in pollution damage or welfare benefits that would result (Dewees et al, 1975; 16).

V. Optimal Pollution Level

Social welfare is maximized when pollution is controlled until the point at which the marginal costs to the polluter of further control is just equal to the marginal social damage costs of further emissions. In short, the optimal pollution level is that at which the marginal benefits of further emission control just equals the marginal costs of that control.

If monetary values for all "costs of control" and "benefits of control" can be estimated for each different pollution level, they could be represented in curves such as those presented in Figure 1. As the level of pollution rises , the cost of pollution (curve CP) will begin rising and continue rising at an increasing rate. The cost of control curve (cc) represents the levels of pollution in the presence of controls. To reduce pollution below point b, costs will increase. The control curve eventually becomes vertical at a level of pollution where further expenditure is incapable of reducing pollution. The optimal pollution level -p* -is the point where the costs of pollution and the costs of control are equalized.

Goddard (1975; 84) presents two reasons for the rate of resource re-use to be below the optimal re-use ratio:

(1) unpriced resources i.e. no specific price attached to collection and disposal services;

(2) uncontrolled externalities e.g. pollution.

A rate of resource re-use below the optimal re-use ratio occurs

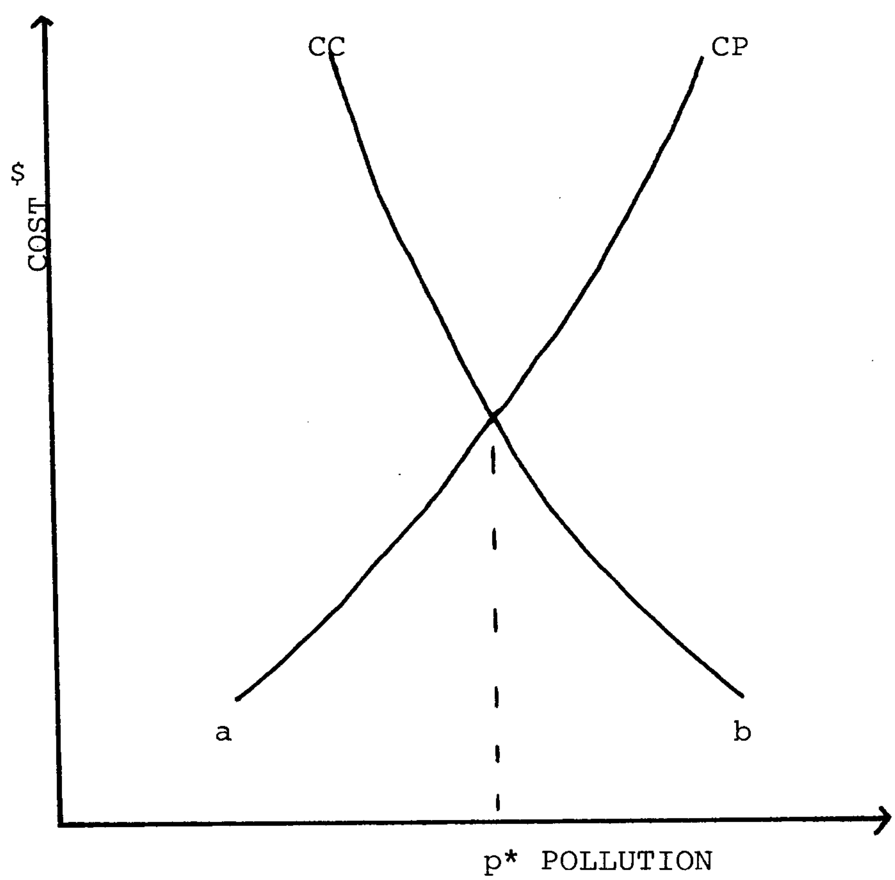


FIGURE 1

TOTAL COSTS OF POLLUTION

because existing recycling activity is based on the private sector decision of profit maximization, which ignores social costs of waste disposal. Consequently, where externalities occur, the private market optimum does not conform to the social optimum.

When the private sector evaluates the economic feasibility of recycling activities, the decision is based on the difference between the cost to the firm of using virgin materials and the cost to the firm of using recycled materials. Other factors to be examined are the availability of a consistent supply of residuals of a specified quality and quantity, plus processing and/or reprocessing technology.

What the private decision ignores are the social costs and benefits associated with recycling. The social benefits include:

(1) reduction in pollution due to the decrease in residuals disposed of directly into the environment,

(2) extension in the raw resource life,

(3) reduction in public costs associated with land disposal, releasing land for alternative social uses.

Because of the above, the optimum level of recycling is generally greater than the actual level. However, the pollution associated with recycling effort must not be ignored. "We must therefore watch our step so as not to substitute a greater but distant pollution for a local one" (Georgescu-Roegen, 1975; 171). It should not be overlooked that recycling processes can have their own environmental impacts, even to the extent that the net result is the reverse of that intended (Barton, 1979; 23).

A hypothetical analysis is shown in Figure 2, where it is illustrated that the private and the social optima do not coincide. The socially optimal re-use rate (r soc) is where all social costs, are minimized. Whereas, the private optimal re-use rate (r priv) is where the marginal cost of employing reclaimed resources in the production process is just equal to the marginal reduction in costs of using virgin materials. The private and socially optimal recycling rates do not necessarily coincide although they could be made to do so were the recycling technologies themselves more polluting than was the disposal of wastes from the manufacturing process employing virgin materials (Henstock, 1976; 711).

The private objective is, given an unchanged level of revenue, to minimize the total cost of resources -i.e. to minimize

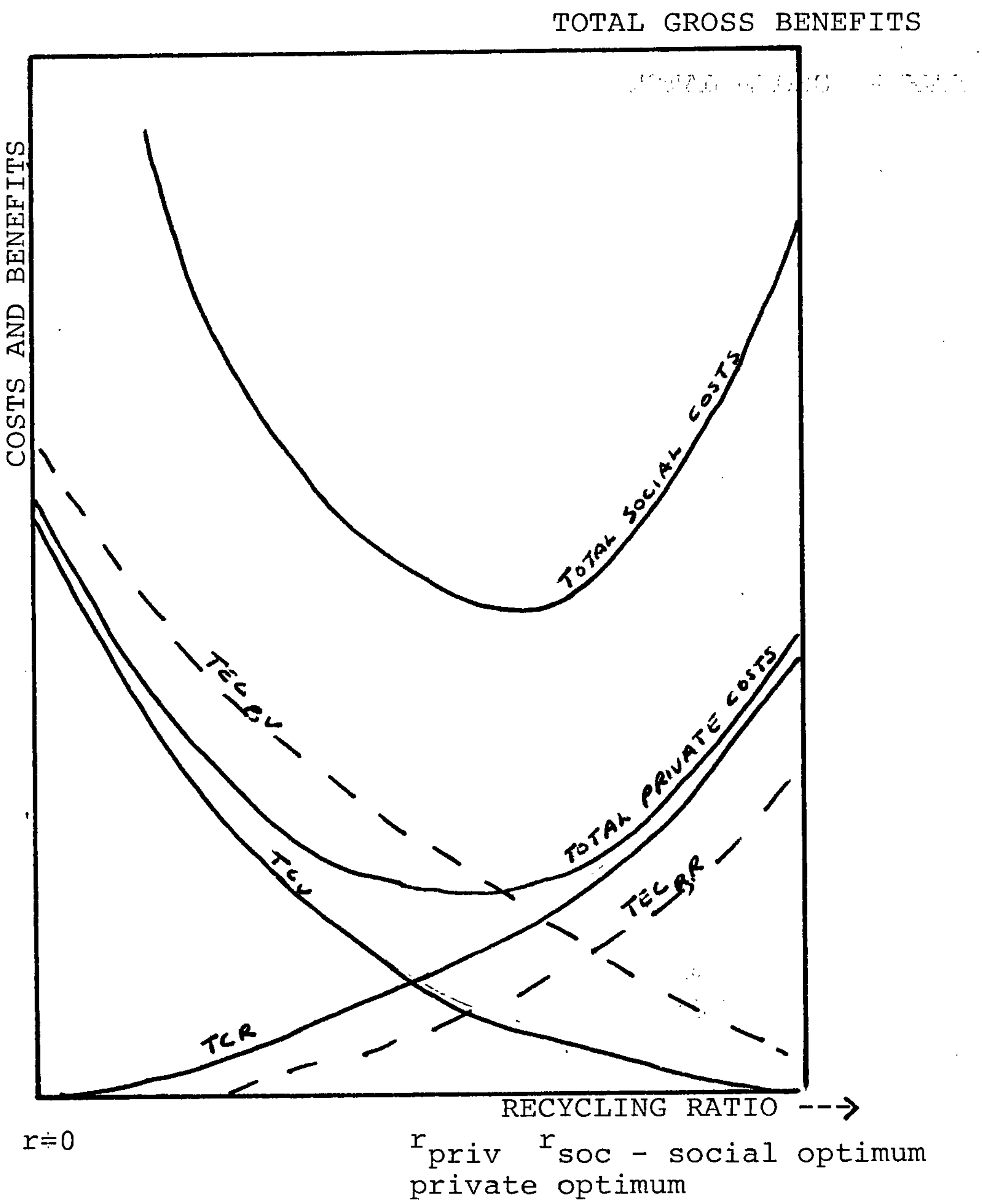


FIGURE 2

PRIVATE AND SOCIAL OPTIMAL RECYCLING RATES

SOURCE:Henstock,1976;711
Pearce,1976;174.

$$C = TCv(X) + TCr\ (X)$$

where TCv and TCr are the total costs of virgin and recycled resources respectively. Labour costs are included in $TC_v(X)$ and $TC_r(X)$.

The social objective is to minimize

$$S = TCv(X) + TCr(X) + TECp,e(X) + TECp,v(X)$$
$$+ TECp,r(X) - BERL(X) - L(X)$$

where TECp,e is the total external cost associated with individual manufacturing firm ; TECp,v is the total external cost of pollution from the use of virgin materials; TECp,r is the total external cost of pollution from the recycling process; and BERL and L are the present values of gains in the resource life and in land respectively. Disposal costs are included in TCv and TCr. The above discussion is taken, in part, from Henstock (1976) and Pearce (1976).

An activity (recycling) generating social benefitis (pollution reduction) will not take place on an optimal scale if those benefits are not appropriated via the charging of a price (Pearce, 1976; 320). To-day's prices generally do not reflect all the social costs associated with residuals generation and disposal, although with the current emphasis on air and water quality standards, prices are starting to include at least a portion of these costs (Spofford, 1971; 571). In many cases, a fee is imposed on the producer for his use of the environment's assimilative capacity, as a factor input to his production process.

One way to achieve a more efficient allocation of air, water and land resources is to place the cost of the "externalities" (by means of a charge or tax) on those who discharge the residuals. If a fee were imposed on residuals discharged to the environment, relative prices of factor inputs to production would shift and process changes and/or re-use might well be stimulated (Spofford, 1971; 571). Imposing this "effluent charge" would tend to induce alternative combinations of raw material inputs, production processes, types of product outputs, materials re-use, and residuals handling, modification and disposal. Pearce (1979) presents this issue.

The imposition of a tax, T, in that

$$T = TEC_{P,V} + TEC_{P,R}$$

will raise the level of recycling to the social optimum. Figure 3

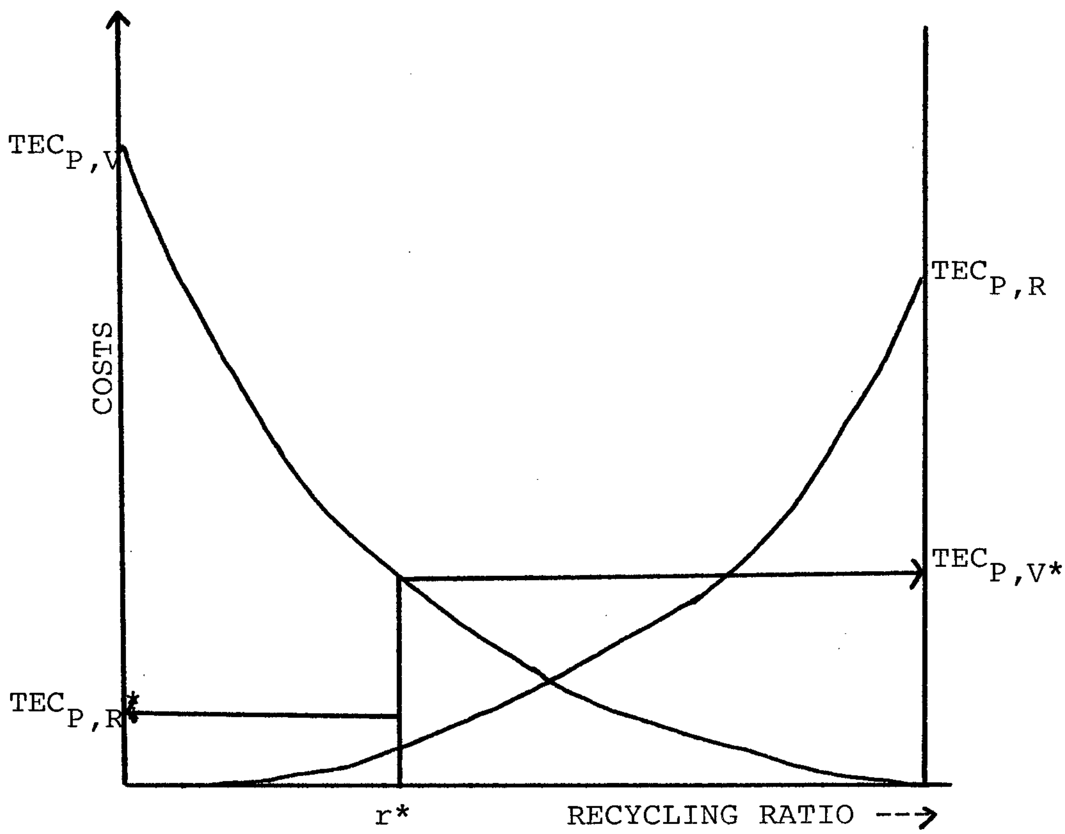


FIGURE 3

TOTAL TAX ON POLLUTION

SOURCE: Pearce in
Marquand, 1974

illustrates the effect of a tax for the arbitrarily chosen recycling rate, r*. The cost of the "externalities" are equal to $TEC_{P,R*}$ (r = o to r = r*) and $TEC_{P,V*}$(r = r* to r = 1) and thus the tax is equal to the sum of these.

Figure 4 presents the implication of a tax on an imperfectly competitive market, where

D = demand curve

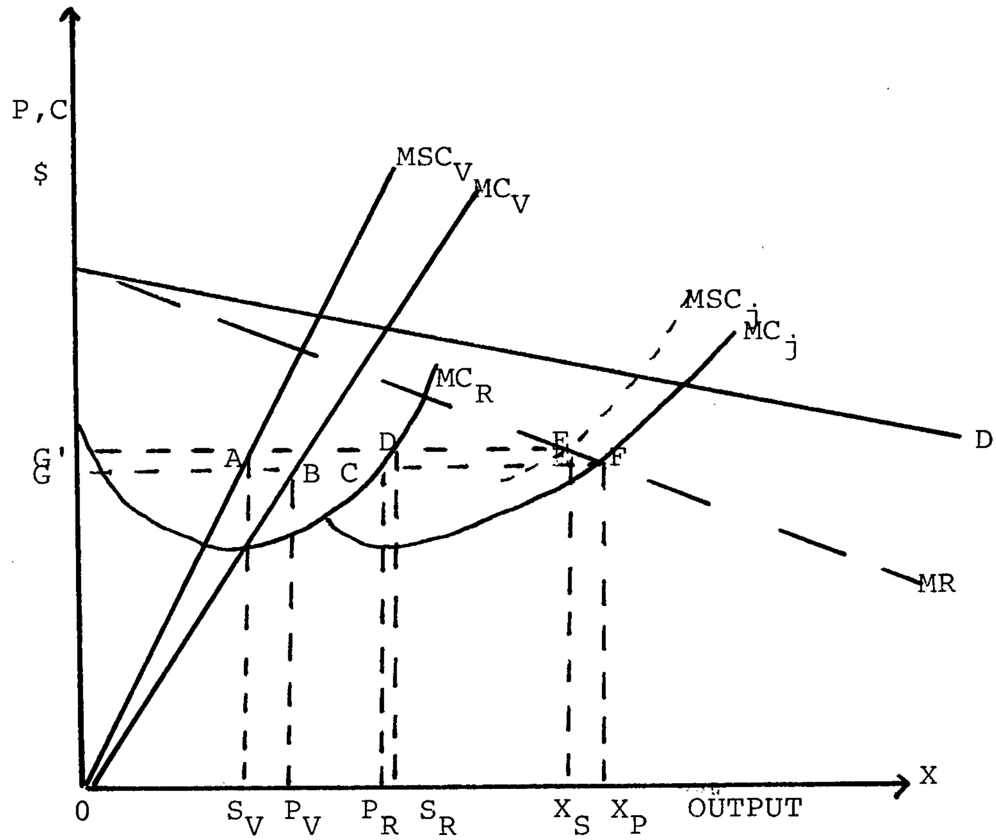
MR = marginal revenue curve

MC_V = margin cost of virgin materials to the firm

MC_R = marginal cost of using recyled inputs

MC_j = summation of MCV and MC_R

The firm's objective in the analysis is to maximize profits. Profit maximization is at point F where output equals X_P. The marginal cost to the firm (MC_j) at point X_P (or point F on the MC_j curve), equals OP_V = GS for virgin materials plus OPR = GC for recycled materials. The price at X_P would be equal to the distance OG in Figure 4. It is assumed that there are external costs associated with the use of virgin materials and none with the use of recycling inputs. Thus, MSC_V equals marginal externality associated with the use of virgin materials and MSC_j equals



FIUGRE 4

POLLUTION TAX AND RECYCLING

SOURCE:Pearce in
Marquand,1974

marginal cost of using virgin and recycled materials (allowing for an external cost of using virgin materials). The joint marginal social cost curve (MSC_j) of using virgin and recycled inputs at point X_S, is determined by summating OS_V = G'A and OS_R = G'D. The imposition of a tax equal to the total external cost will secure X_S, the social optimal output level. The tax, effects a lower output for the private firm, X_S, thereby changing the recycling ratio. The pollution tax changes the input levels to OS_R for recycled and OS_V for virgin inputs to achieve the social optimum level. The new price level, at X_S, is equal to OG' in Figure 4.

The analysis illustrates that the imposition of a pollution tax, in the instance of external costs associated with the use of virgin materials, adjusts the firm's level of output, and also alters the level of recycling activity.

VI. Summary

Population growth and natural resource exploitation have combined both to increase the magnitude of the waste disposal problem and society's perception of the environmental pollution which accompanies waste disposal. This concern has drawn attention to resource recovery. The decision to recover resources from solid wastes is based primarily on economics. Consequently, it is important to investigate the costs and benefits associated with recycling.

CHAPTER 3

I. Introduction

Interest in resource recovery projects has increased dramatically in the past few years. Concern is place on the benefits attributable to resource recovery. Herein lies the problem: that of deciding on the desirability of specific recovery projects.

Benefit-cost analysis is a tool that can be used to assist in such decisions. It consists of the systematic assessment of the direct and indirect, tangible and intangible, benefits and costs of a project to determine economic feasibility (Auld, 1972; 53). The basic criterion of benefit-cost analysis is to maximize social benefits net of costs. The analysis is used to establish what the general welfare of society would be with and without a proposed project in order to establish what additional benefits and costs it generates. In theory, items for inclusion in the analysis are all the gains and losses of every member of society whose well-being would be affected by the project if implemented (Lichfield, Kettle, Whitbread, 1975; 58).

In general, a project is worthy of being undertaken whenever the present value of the associated stream of net benefits from a project (discounted at the appropriate social rate of discount) is greater than the present value of the costs (Davidson, 1967; 345).

II. Benefits

Benefits encompass those consequences of policy that increase welfare. Freeman (1979; 3) defines the benefit of an environmental improvement as the sum of the monetary values assigned to these effects by all individuals directly or indirectly affected by that action.

The existence of externalities means that not all costs will be included in market-price transactions. Generally, market prices will not include all benefits since such externalities are not usually included (Pearce, 1978; Spofford, 1971; Anderson and Lee, 1977; Winch, 1971). A common reason for this is the failure of the private market system to allocate efficiently common property rights in economic goods such as clean air and unpolluted water (Spofford, 1971; 568 and Pearce, 1971; 54).

In the absence of a market price, one requires a judgment about value. It is not enough, however, to demonstrate that such externalities exist. Some measurement, however imperfect, about the magnitude of these externalities is essential (Pearce, 1976; 110).

The objective of cost-benefit analysis is to guide the decision maker in the choice of capital projects and expenditures which will maximize the gains to social welfare. Social welfare has been related to some aggregation of individuals' preferences, and these in turn are represented by the individuals' willingness to pay for commodities. Market prices of a commodity are used as a measure of benefits although substantial modifications have to be made to allow for market imperfections and for situations in which no markets exist for the product of the project i.e. outdoor recreational services. Figure 5 will illustrate the case in point.

Market demand prices for output are derived by a summation of the individual demand curves such as d_1 and d_2 to obtain the market demand curve. As indicated, P_1 is the market demand prices associated with output Q_1. The total revenue, or effective payment

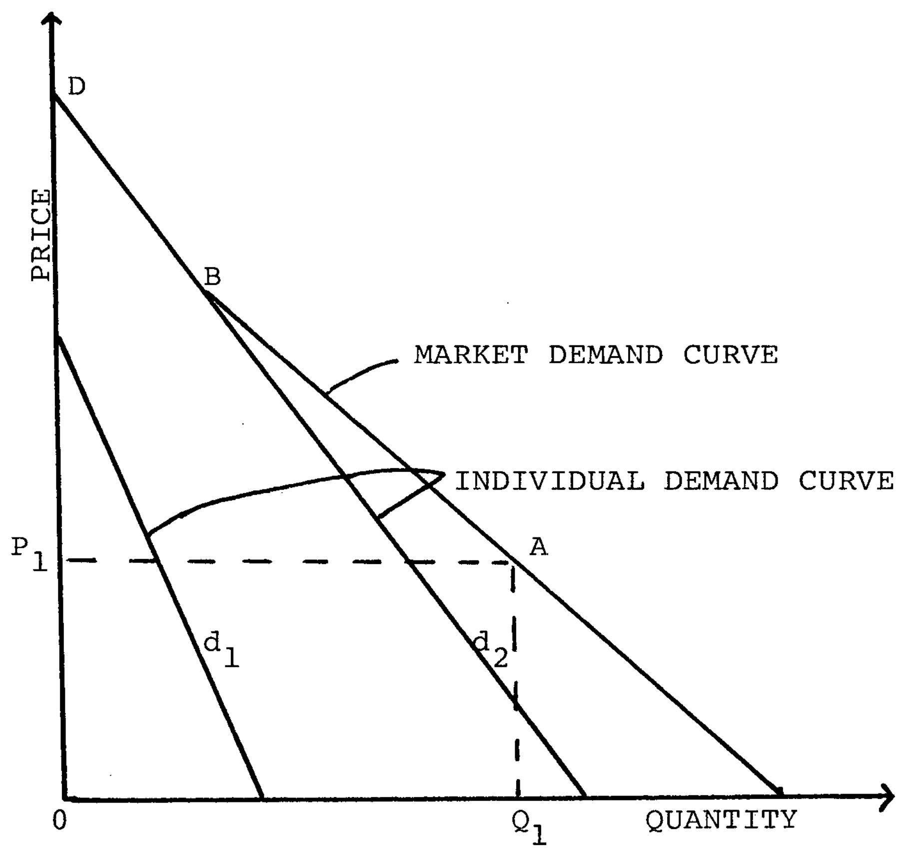


FIGURE 5

DEMAND FOR A PRIVATE GOOD

SOURCE: Davidson (1967) in Dorfman and Dorfman for the good, that individuals would pay for Q_1 would, in a competitive market, be equal to the rectangle OP_1AQ_1. It is not, however, a measure of their willingness to pay (WTP) and hence of their true preference for the good. It is usual to approximate the willingness to pay by adding to the effective payment, the consumer surplus (or S) polygon P_1DA. The argument is that there are some consumers who would have paid more than P_1 for the product. The total willingness to pay is therefore illustrated by the area $ODBAQ_1$ in Figure 5, so that

$$\text{Total WTP} = P_1 . Q_1 + S$$

i.e. the total WTP for any good is equal to the purchase price multiplied by the amount purchased, plus the consumer surplus (S). A consumer surplus is the excess of consumer's willingness to pay for a good or service over and above its market price. In the case of Figure 5, the market price of the benefits would underestimate total benefits unless the consumer surplus is equal to zero. That is, persons who are not direct beneficiaries of a project obtain some "overspill" benefit or utility from a good or service for which they have not paid. A consumer surplus that is equal to zero would be relevant only if a government project would not provide a significant change in the total output of a particular market.

If a large government project is undertaken, the effect will be to increase supply sufficiently to drive down market price, and therefore to change the willingness to pay. The benefits, or willingness to pay would equal the area under the demand curve between A and A_1 in Figure 6.

From Figure 6, it is illustrated that the change in output is equal to $Q_1Q_2A_1A$. Thus, the change in willingness to pay becomes

$$\Delta \mathrm{WTP} = \Delta Q_1 \cdot P_2 + 1/2 \, \Delta P_1 \cdot \Delta Q_1$$

Total gain to the general welfare of society would be estimated by summating and discounting benefits (as illustrated by the relevant area under the demand curves) for each time period over the life of the project.

> In reality, however, such integrations are rarely performed since we rarely have sufficient information and the typical case is that the discounted expected market price is used as a valuation of the future stream of benefits. This generally leads to a

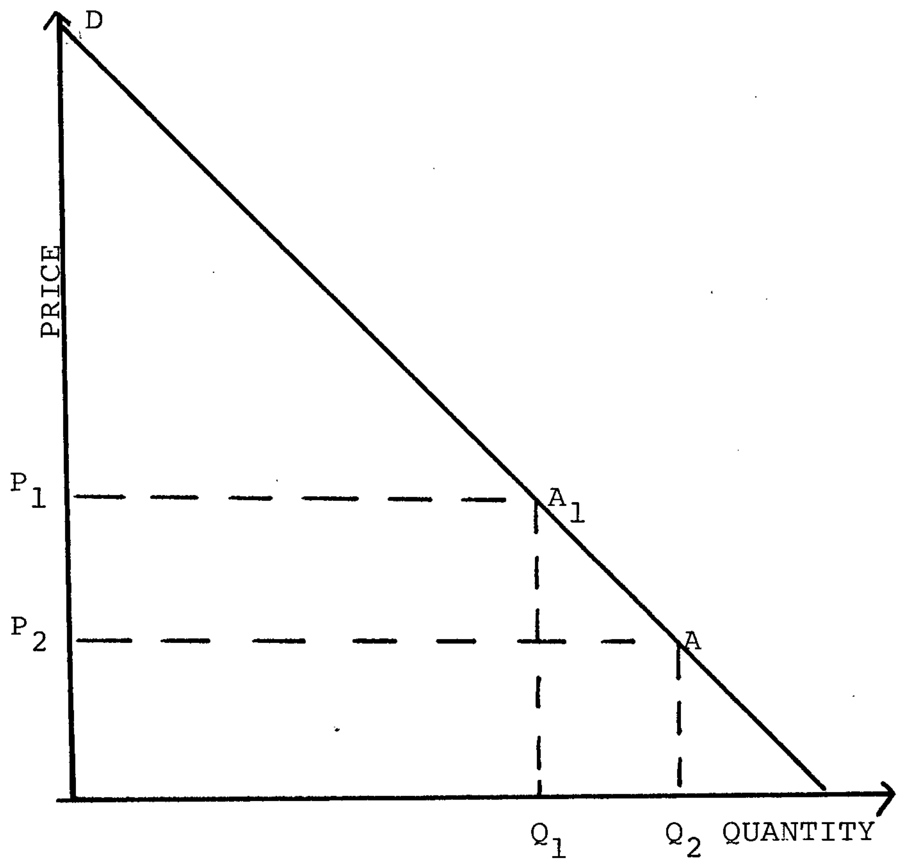


FIGURE 6

TOTAL BENEFITS FOR LARGE PROJECT

SOURCE: Davidson (1967) in Dorfman and Dorfman

> downward bias in our estimate of benefits. (Davidson, 1967; 348).

The valuation of benefits for public projects is complicated by the lack of an efficient market demand price. Since a public good is, by definition, a good that can be consumed by one individual without reducing other individuals' possibilities of consuming that good (Bohm, 1973; 32), the total demand for a public good involves a vertical addition of the individual demand curves (that is, a summation of consumer surpluses). As discussed earlier in this section, the total demand for a private good is a horizontal summation of individual demand curves, where the consumption of one individual leaves less for others at a given supply. The total demand for a public good is illustrated in Figure 7.

To compete in the political market place cost-benefit analysis has adopted the guise of simulating the market demand price -a shadow price measuring how much consumers would be willing to pay if the good was marketable -even for public goods, where the investigator knows that no efficient market price can exist (Davidson, 1967; 355). The problem of getting consumers to reveal their true willingness to pay for a public good is a serious one .

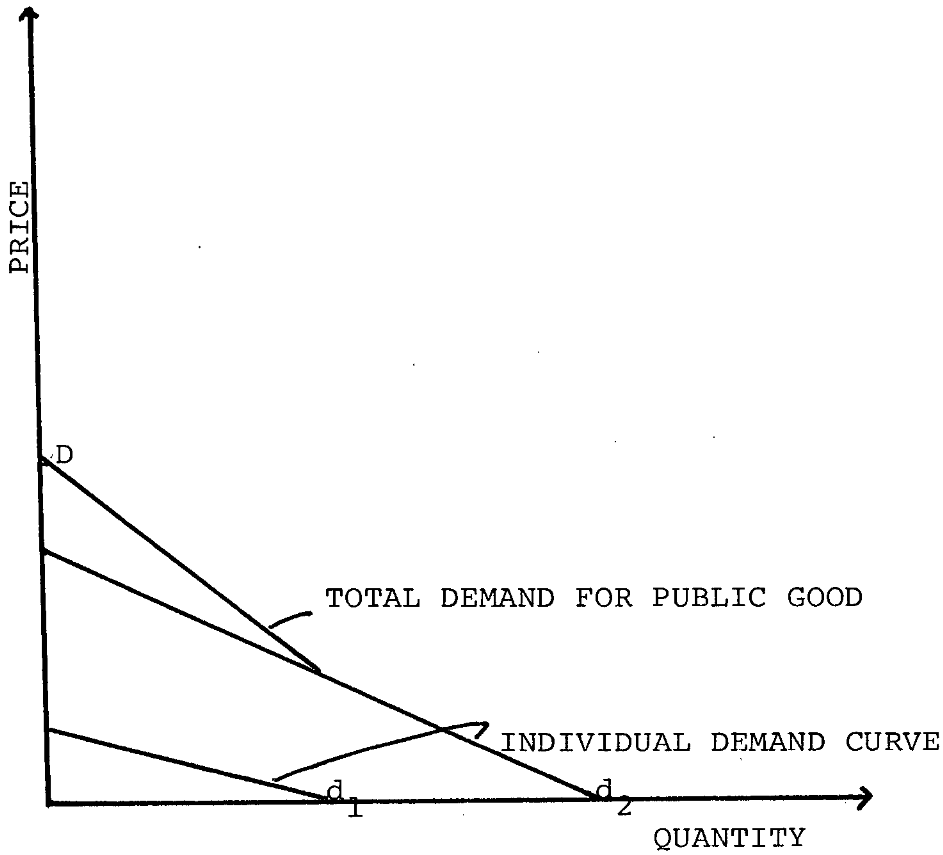


FIGURE 7

TOTAL DEMAND FOR A PUBLIC GOOD

SOURCE: Bohm (1973) and Davidson (1967)

More often than not, a consumer will underestimate willingness to pay, fearing he himself will have to pay for the good. Or conversely, a consumer could exaggerate demand in the case where he believes that an increase in production will not cause him monetary loss. In the presence of these concerns, Davidson (1967; 355) expounds "that there is no acceptable substitute for informed value judgments in the evaluation of benefits of public goods."

III. Costs

Costs are normally taken to be the opportunity costs or supply prices at full employment of inputs (Davidson, 1967; 346). Social costs can be thought of as the real opportunity costs[2] of alternative actions (McFarland, 1972; 10). The social costs include all the costs borne by firms (private costs); the costs borne by society including disposal or reclamation (transportation, reprocessing, etc.) and the costs that tend not to be reflected in markets (e.g. pollution costs) (Walter, 1976; 320). These costs include the expenditures needed to render the polluted resource fit for use, the expenditures made to avoid pollution effects, plus the

2. A opportunity cost is the value (benefits) foregone in one use because scarce resources are employed in another.

damages inflicted upon society by the wastes themselves (Auld, 1972; 8)

If a private firm decided to introduce a resource recovery facility to recycle oil, for example, concern would be to maximize profit. The costs of increased pollution due to the introduction of the facility would not be borne by the firm but rather by a third party (society) and do not enter the firm's cost functions. What the firm fails to take into account are 'external' effects - e.g. air and water pollution -which are possible by-products of the recovery process.

The establishment of social net benefit as the objective function requires that the price attached to the costs reflect society's valuation of the final goods and resource involved. The costs must include shadow prices which will reflect the social opportunity cost associated with using the resource in the proposed project. Shadow prices should relfect marginal social cost rather than marginal private cost. Divergences between private and social costs may be attributable to market failure. Instances of market failure have provided traditional justifications for the provision of public services (Canadian Treasury Board Secretariat, 1976;

13). Shadow prices simulate what users would pay for the services of these outputs if a market was present and the goods were sold in a perfectly competitive market.

Difficulty arises in the valuation of shadow prices from government projects. An example is in the valuation of collective-consumption goods, such as defense and the legal system. The political system determines the required payment in the form of taxes for the support of such services.

Clearly there is no one figure for the social cost of any item that can be proved to be correct. This is due to the fact that social costs are based on ethical judgements. In each case, it appears that a mixture of value judgements and empirical research would be needed to resolve the issue, there being no alternative but a case-by-case approach (Pearce, 1978; 29).

IV. Discount Rate

Since most projects have future costs and future revenues, the net benefits for each time period are discounted at a chosen discount rate to yield a net present value (NPV). The sum of each of these values is the NPV of the project.

The choice of the appropriate discount rate will depend upon the anticipated opportunity cost of the capital investment and value judgements (Winch, 1971; 161). The opportunity cost of the project can differ depending on whether the project is within the government sector or the private sector. If capital is to be diverted from other government projects and the interest rate of government bonds is representative of the rate of return (ROR) on marginal government expenditure, then the use of that rate will be the opportunity cost of the project. On the other hand, a private sector investment may be financed through the issuance of a bond series, then the interest rate attached to the bond will represent the opportunity cost of capital.

One conventional practice is to use a measure of the opportunity cost of capital in the private sector as a discount rate for public sector activities (Anderson and Settle, 1977; 85). However, it has been documented that the private opportunity cost is inappropriate for discounting the future effect of government projects (Canadian Treasury Board Secretariat, 1976; 25). This viewpoint is held, for individuals are considered to be "myopic" in their consumption and savings decisions. Society does not adequately take into consideration the welfare of future generations, therefore saving less and consuming more. The above reasons have been presented by Anderson and Settle (1977) for using a social discount rate that is lower than the private opportunity cost of capital.

There is much controversy over what constitutes the appropriate discount rate (Anderson and Settle, 1977; Pearce, 1971, Bohm, 1973; Canadian Treasury Board Secretariat, 1976). The literature leads to the conclusion that there is uncertainty and a lack of consensus in attempts to determine and establish a social discount rate. Accordingly, the Canadian Treasury Board Secretariat (1976) recommends that the calculation of the net present value of benefits and costs incorporate a range of social discount rates: a social discount rate of 10%, and of 5% and 15% for sensitivity analysis.[3] Hartle (1974; 30) further expounds that the inevitable subjectiveness in choice of a social discount rate provides an

3. In the light of current interest rates, the discount rate would necessarily rise to accomodate the change in rates for public and private lending and borrowing. A more appropriate discount rate would possibly be 20%, and 25% and 15% for sensitivity analysis.

instance where the use of sensitivity analysis may be advisable, to test whether the conclusions of an evaluation are affected greatly by the choice of a particular discount rate.

Figure 8 illustrates the effect of discount rate changes on the magnitude of NPV.

As the discount rate for the evaluation increases, the NPV decreases. The mathematical expression for the NPV of future income is:

$$NPV = \frac{X_1}{(1+i)} + \frac{X_2}{(1+i)^2} + \ldots \frac{X_n}{(1+i)^n} - X_o$$

NPV = net present value

X_0 = initial capital

$X_1, X_2 \ldots$ = positive cash flows in years 1, 2 ...

i = discount rate

The above formula, illustrates the relationship between the discount rate and NPV. When $i = 0$, $NPV = X_1 + X_2 + X_n - X_0$. It is presented in Figure 8 that if the X's are positive, NPV always

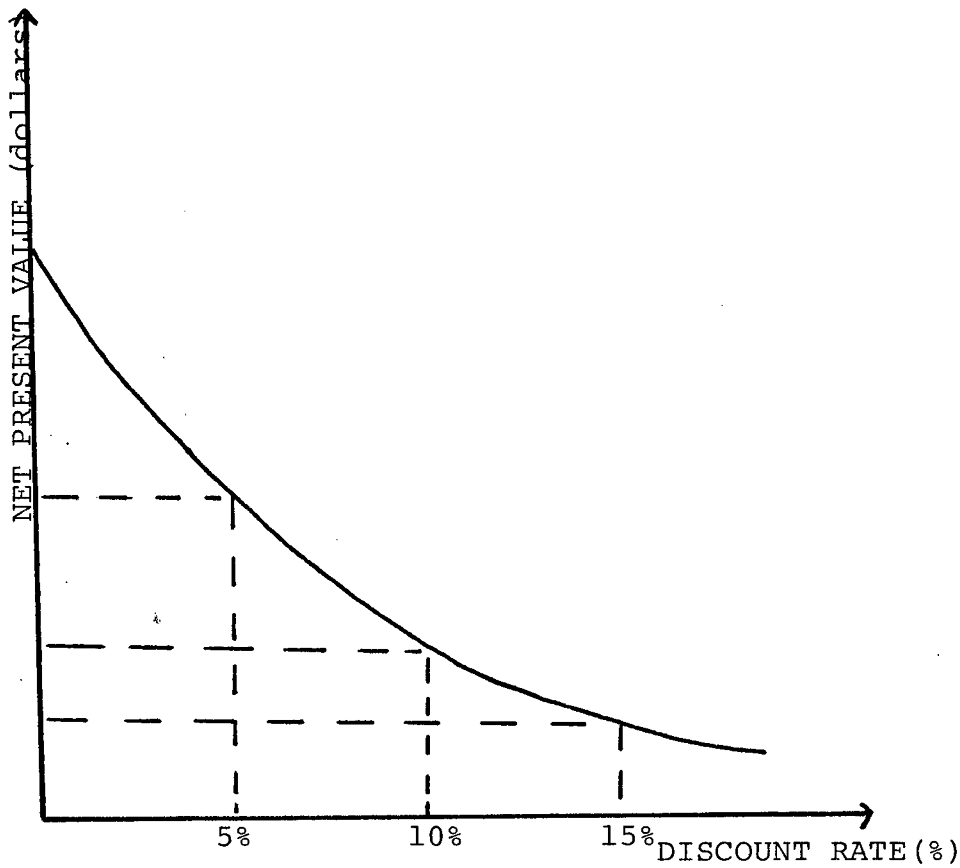


FIGURE 8

THE EFFECT OF DISCOUNT RATE CHANGES ON
THE MAGNITUDE OF NET PRESENT VALUE

falls as discount rates arise.

By estimating the net benefits of projects at different levels of discount rates, it is possible to ascertain the extent to which project outcomes are sensitive to differences in this respect (Bohm, 1973; 110). Costs will typically exceed benefits at first while benefits exceed costs later. Thus, increases in the discount rate reduces the NPV of the future costs and benefits, causing a lower benefit-cost ratio or lower NPV.

V. Uncertainty and Risk

The establishment of a project's future benefits and costs involves risk and uncertainty. Risks refer to the situations in which information about the probability of an outcome's occurrence is available, whereas uncertainty refers to situations where there is no such information (Anderson and Settle, 1977; 99).

Even the most careful estimate of benefits contain inaccuracies because of errors in the measurement of variables and errors in statistical estimation of relationships (Freeman, 1979; 30). Further, much of the data associated with the costs and benefits of a proposed resource recovery facility inherently is not quantified due to the limited knowledge of the relationships. For example, when dealing with the relationship between pollution and quality of life, estimates of benefits attributable to reduced levels of pollution from solid waste disposal are not readily available. Therefore judgment must be made on an informed interpretation of the limited literature.

> It is not always known exactly what damage a pollutant does, exactly what value to attach to it, or exactly how polluters would respond to a given change in costs. In economic terms, we are usually ignorant of the marginal damage cost curve associated with a given pollutant, and whilst individual polluters may know how they would react to change in their control costs, the central authorities of one sort or another, who need to make the decision as to the magnitude of the external costs which should be internalized, are usually ignorant of the marginal control cost curve for polluters as a whole and even for the specific pollutors in a specific polluters in a specific location (Pearce, 1974; 94)

The literature stresses the importance of making allowances for risk and uncertainty. Forecasts regarding the costs and benefits of a project are difficult, and the longer the life of the project, the greater the possibility for uncertainties attached to them. One method to handle risk and uncertainty with regard to a project is to perform sensitivity analysis. Sensitivity analysis would indicate the sensitivity of the cost/benefit model to changes in the discount rate and future estimated benefits and costs, for example. This technique aids in the evaluation of specific assumptions in the analysis.

Further, three conventional techniques have been suggested for dealing with risk and uncertainty in cost-benefit analysis

(a) adding a risk premium to the 'pure' rate of discount in calculating present value.

(b) raising those items of costs or reducing those items of benefits that appear to be uncertain, by a certain percentage.

(c) using a project life less than the formal economic life for comparable but relatively riskless projects.

A common technique for allowing for uncertainty is the use of a risk premium. A risk premium involves increasing the discount rate. The justification of this method is to reduce the importance in the analysis of data forecast for the far future (Canadian Treasury Board Secretariat, 1976). However, as Dasgupta and Pearce (1972) explain "what the risk-premium argument implies, for example, is that the extent of underestimation of costs (or overestimation of benefits) involved in a project design increases monotonically with time." In reality, most project future outcome is either better or worse than anticipated.

The second type of adjustment is that of applying a premium or a discount on estimated costs and benefits. In many cases, approximations of, or minimum/maximum limits to, the true value of project effects may be quite sufficient for reaching a decision as to whether the project should be accepted or not (Bohm, 1973; 116)

.

The third alternative is that of reducing the project's life. The method has the effect of withdrawing the later year's benefits and costs and reducing the time period within which the project is to break/even.

When cost-benefit analysis for a project is undertaken in a systematic manner with relative certainty, the above three adjustment techniques are not necessary (Pearce & Dasgupta, 1972; 196). The adjustments could unduly alter the decision-makers' choice regarding a proposed government project. Alternatively, the benefit/cost analysis could include estimates of anticipated outcomes that might arise if circumstances alter (Rivlin, 1972;

19). This information provides the analysis with data to highlight the sensitivity of the results to various decision makers, and on how and what to avoid once the project has begun.

VI. Distributional Considerations

Benefit-cost analysis focuses on the economic efficiency of government projects; that is, on the identification and quantification of real benefits and costs of such activities. The basis of the efficiency criterion states that the gains of the project allow for potential compensation to the "losers" and still leave a net increase in the value of the production to society.

Decision makers are not concerned solely with efficiency in resource allocation, but also with the equity or redistribution aspect of policies. Thus, in addition to providing information on benefits, information on who is being affected by environmental pollution and who will benefit from environmental improvements is necessary.

Some of the most familiar classifications used in the analysis of distributional considerations are income, age, region, occupation and sex. However, it is extremely difficult and costly to perform the estimation of the distributional effects of benefits and costs attributable to a project. For example, a matrix describing the distributional effects of a project affecting ten age groups, five regions and fifteen occupations would require numerous data. Further, its effects in decision making, if all the cells were filled, would be negligible for it would be difficult to interpret.

Consequently, while distributional effects may be of considerable interest, the cost of identifying and measuring such effects and the problems associated with transmitting highly detailed information suggest the analyst should normally work with relatively broad classifications (Anderson and Settle, 1977; 107). It is common for distributional assessments to be limited to simply identifying whether particular groups are gainers or losers, with no serious effort being made to measure the magnitude of a program's distributional consequences (Anderson and Settle, 1977; 108).

The integration of the distributional effects into the benefit-cost analysis can be undertaken by a change in the discount rate.

The equity aspects of the policy would mean discounting rates higher or lower than current market interest rates. A higher rate would be chosen in the case of non-market goods -social services, etc. -if the government policy was aimed at the present poor individual in society and away from future generations.

The inclusion of equity considerations in social cost/benefit analysis can be achieved by two methods: Planning Balance Sheet analysis and Goals - Achievement analysis. Lichfield, Kettle and Whitbread (1975) discuss the two approaches as they pertain to distributional considerations. Planning Balance Sheet analysis focuses mainly on the costs and benefits falling directly on those who produce and operate the project and on those who consume the goods and services it generates. The analysis organizes the costs and benefits of the affected groups of individuals into a comprehensive set of social accounts. Where a quantification of the costs and benefits is not possible, symbols are placed into the accounts to denote the level of cost or benefit associated from the activity.

In Goals - Achievement analysis, individuals are classified according to some criterion that assesses equity, i.e. income levels. Weights are assigned to the particular groups in order to represent society's preference with respect to alternative distribution of the costs and benefits which account for the net social benefit. Application of the weights is undertaken by the decision maker.

Difficulty arises when a decision maker is confronted with the issue of equity considerations versus efficiency consideration. Considerations of equity pertain to the fairness and justice of the occurrence of costs and benefits on particular groups in society, while efficiency considerations deal with the ability to produce goods and services with a minimum of expense.

VII. Limitations of Cost-Benefit Analysis

Validity of cost-benefit analysis depends largely on the ability of the welfare function to correctly specify the value of the choices to society and on our ability to correctly enumerate and evaluate, with the aid of the welfare function, the associated costs and benefits (Pearce, 1971). The social worth of a project is judged by its net contribution to raising the level of aggregate consumption of these items of value, regardless of whether or not they are bought or sold (Lichfield, Kettle, Whitbread, 1975; 59). Nevertheless, for the most part, environmental-protection programs are heavily loaded with aesthetic considerations and other intangibles (benefits that are real and important to society) but that are not automatically quantified in the market economy (Hines, 1973; 117).

Limits to the applicability of cost-benefit analysis to public policy decision making arise because of limited information and data needed to evaluate, in monetary terms, environmental improvement (Pearce, 1976; 97). A major obstacle to effective policy decision making aimed at resource conservation is the lack of understanding and quantitative data on environmental impacts (Purcell and Smith, 1976; 93).

Benefit-cost analysis is not simply a decision-making tool. Rather it should be considered as a framework with a set of procedures to aid in the organization of available information. It is a tool for organizing and expressing certain kinds of information on a range of alternative courses of action.

Ultimately, due to the many inherent difficulties in the accurate assessment of total benefits and costs, decisions regarding resource development are often made on political rather than economic bases (Coomber, 1973; 3). Because policy choices about environmental quality objectives are made in a political context, and are likely to involve comparisions and tradeoffs among variables for which there is no data or methodology to establish commensurate market-price values, monetary benefit and cost data will be only a partial determining factor of the acceptance or rejection of a particular project. This factor does not negate the importance of benefit and cost formulation as one form of data presentation.

The case for benefit/cost analysis rest on the importance of having before the decison maker information on the measurable benefits and costs of alternatives. In addition, listings of non-quantifiable benefits and costs are important so that the decision maker can make an informed decision.

CHAPTER 4

I. Introduction

Chapter 4 will present a cost/benefit case analysis as it pertains to the evaluation of the economic efficiency of resource recovery utilizing used lubrication oil.

Concern for environmental pollution has been cited as a major stimulus for the recovery of used lubrication oil (Pearce, 1975; Irwin, 1975; Barton, 1979; Weinstein, 1974). Further, the increase in petroleum product prices has stimulated the current interest in recycling. Any or all motivations are representative of the equity objective, or some indication that shadow input price diverges from market price.

II. Waste Oil Inventory

In order to discuss the costs and benefits associated with used oil recycling, specification of the system is necessary. The waste oil inventory illustrates the inventory of the oil from production through the economic sectors to the final destination of the residual -the environment.

In order to determine volumes of used oil associated with various disposal practices, a survey of used oil sources and major oil collectors was conducted in the four regions which account for 75 percent of total oil sales in British Columbia: Lower Mainland; Prince George; Okanagan; and Southern Vancouver Island (King, 1980). The survey was primarily limited to the largest cities in the four regions: Vancouver; Penticton; Kelowna; Kamloops; Prince George and Victoria. Information was gathered during personal interviews, telephone interviews and mail questionaires.

Major consumers of lubricating oil are service stations, automobile dealerships, government, transit services, transport companies, the construction industry, the mining and the forest industry. Being the major consumers of lubricating oil, the above are consequently the major sources of used lubricating oil. Additionally, the do-it-yourself oil changer amounts to 15 -20 percent of total lubrication oil sales in British Columbia (King and Oldham, 1979; 14).

Figure 9 presents the waste oil inventory for the Province of British Columbia.

In British Columbia, over 23 million Imperial gallons of

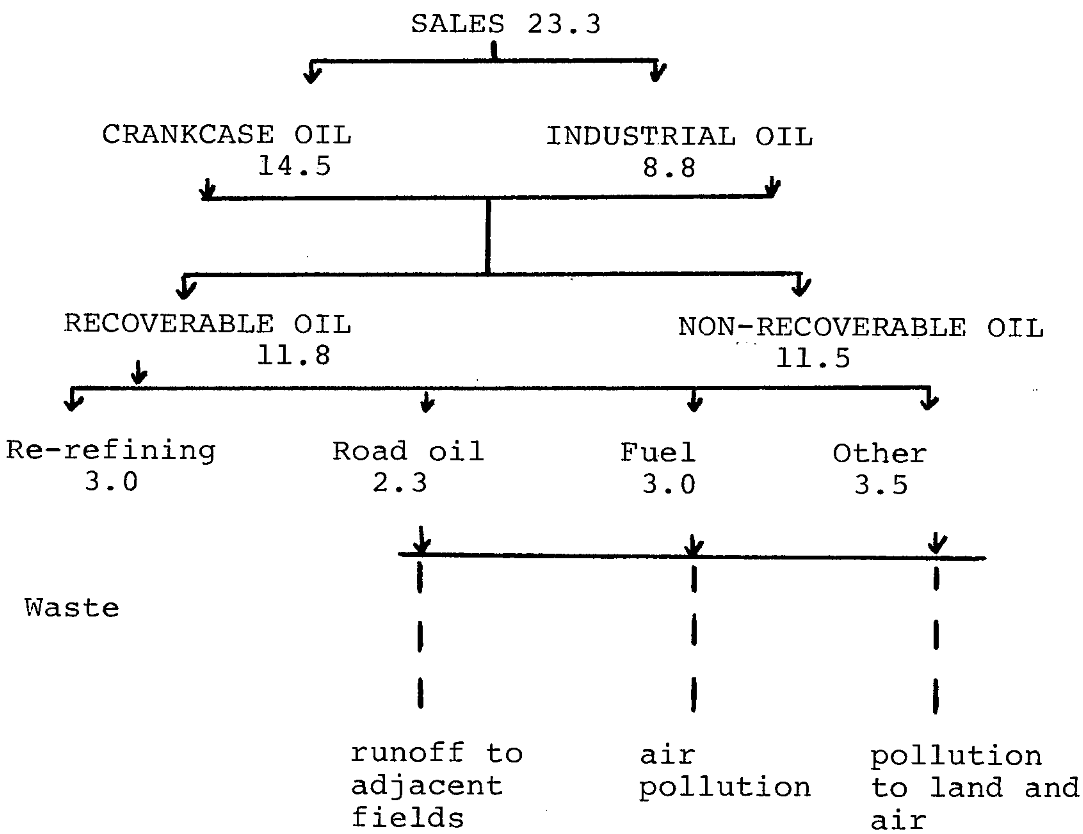


FIGURE 9

WASTE OIL INVENTORY

(millions of imperial gallons)

SOURCE: Data is taken from King, 1980

lubricating oil were purchased in 1978. Crankcase lubricants account for 14.5 million Imperial gallons or 62%, while industrial lubricants account for 8.8 million Imperial gallons or 38% of the total oil sales.

Of the 23.3 million Imperial gallons of lubricating oil sold in British Columbia, approximately 11.8 million Imperial gallons, or 50%, are potentially recoverable. For crankcase lubricants, a percentage of 63% or 9.1 million Imperial gallons should be available for recovery. On the basis of analyses conducted in both Canada and the United States (Skinner, 1974), a recovery factor of 30% is applied to industrial uses of lubricating oil. Using this figure, the recoverable volume in B. C. would be 2.6 million Imperial gallons.

As Figure 9 indicates, the current principal end uses of used oil in the province are:

1) re-refining;

2) disposal into the environment;

3) dust control agent on roadways;

4) fuel in greenhouse heating systems, boilers and asphalt plants;

5) direct re-use as a lubricant.

Of the approximately 11 million Imperial gallons of potentially recoverable used oil arising from all sources in British Columbia, 9 million Imperial gallons are concentrated in the four regions under review. The present end uses of this 9 million Imperial gallons of used oil is summarized in Figure 10. On a Province-wide basis, it is currently estimated that approximately 25%, or 3 million Imperial gallons of used oil in the Province is collected for re-refining. The remainder of the oil is disposed of as (1) fuel in greenhouse heating, (2) fuel for asphalt dryers, (3) a dust suppressant, and (4) a lubricant.

III. Environmental Effects of Used Oil

The improper disposal of used oils is a serious environmental problem for several reasons. Firstly, the disposal of oil on land tends to introduce lead and other toxic substances, some of which may be carcinogenic, into the soil and through percolation and runoff, to contaminate surface and groundwater supplies (Irwin, 1977; 702). Used oils are not readily biodegradable because of the inherent thermal and oxidation stability of the hydrocarbons, and

Disposal Method	Volume of Oil (millions of gallons)	Percentage of Total
Burning - fuel in asphalt plants and fuel in greenhouse heating	2.7 -2.45 asphalt - .25 greenhouse	30%
Road Oiling (government)	.6	7%
Re-Refining a) Acid/Clay and b) PROP (re-refining to begin 1980)	2.6	29%
Unknown End Use	3.1	34%
Total	9.0	100%

FIGURE 10
USED OIL DISPOSAL PRACTICE
(FOUR REGIONS UNDER REVIEW)

Source: King (1980)

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4. The category "unknown end uses" is expected to include private road oiling, direct re-use as a lubricant, fuel in boilers and direct disposal into the environment.

the resistance of certain oxidation-inhibitors intended to minimize oxidation during use (Walter and Maltezou, 1974; 436). Micro-organisms in the soil are not able to easily decompose these hydrocarbons. Evaporation from used oil disposed on the land i.e. road oiling, contributes hydrocarbons to atmospheric pollution (Irwin, 1977 705).

Secondly, the used oil applied as a dust suppressant to unimproved roads does not necessarily remain on the road surface. Varying degrees of used oil migration occur due to dust transportation and runoff, volatilization, adhesion to vehicles and biodegradation, depending on the rate of application and composition of road surface. The runoff pollutes surface water, adjacent fields and crops with oil, additives, and other contaminants the oil has accumulated through use in engines and machinery. Used oil applied as a dust suppressant does contain such toxic or carcinogenic chemical contaminants as 2, 3.7, 8 -tetrachlorodibenzodioxin, polychlorinated biphenyl (PCB), and 2, 4, 5 -trichlorophenol (Irwin, 1977; 703). Further, the amount of polynuclear aromatics (tetrachlorodibenzodioxin and trichlorophenol) in lubricating oil has been found to increase in used automative oil, causing used oil to be potentially more toxic than virgin oil.

The EPA (Weinstein, 1974) found that over an extended period of time:

a) 70 to 75 percent of the used oil leaves the road by dust transportation and run off;

b) 25 to 30 percent is lost by volatilization, adhesion to vehicles and biodegradation;

c) 1 percent stays on the road.

The actual percentage of the road oil that is transported from the road surface, depends on the rate of application and composition of road surface, runoff and dust migration.

Lead and other heavy residues contained in used oils migrate from the road into nearby water sources. Areas adjacent to roads treated with used oil can receive metallic contaminants, creating an environmental hazard. The EPA indicates that as much as 200 milligrams per kilogram of originally deposited lead, can be carried by wind to contaminate fields or crops adjacent to the oiled roads.

The amount of waste oil disposed of in British Columbia represents a threat to the environment as well as a waste of a potentially re-usable resource. Annual disposal of approximately 10 million Imperial gallons (11.8 million Imperial gallons of recoverable oil - 3 million Imperial gallons of oil used for re-refining + .75 million Imperial gallons of residual from the re-refining process) to the environment in British Columbia, albeit widely dispersed, may have a cumulative effect on vital life support systems. It is appropriate, therefore, at this stage of the analysis, that waste oil be re-used to conserve energy resources and to reduce environmental pollution.

IV. Identification of Benefits

Pearce (1975) outlines three social benefits stemming from resource recovery:

1) the present value of the extended resource life brought about by recycling;

2) any reduction in pollution caused by direct disposal into the environment;

3) reduced demand for land for disposal purposes releasing it for

alternative social uses.

The extension in resource life tends to be small due to the fact that the present value of the gain in resource life requires the use of a discount factor (see Chapter 3, pages 37 through 42 for a discussion of the effect of discount rates on present values).

The reduced demand for land for dumping is insignificant, for oil being a liquid, requires no specific acreage for its disposal. The waste oil is generally disposed of as a road oil, not on land specifically allocated for oil disposal as is the case for solid wastes, i.e. domestic garbage.

The benefit of pollution abatement stemming from resource recovery of used lubrication oil is the reduction in pollution damage. Thus, the primary source of benefit is the expected level of reduction in environmental damage as a result of the project being undertaken.

Oil damage can be divided into its effects on land (i.e. crops), water, air and therefore, causing effects on human health. It is difficult to quantify even the direct benefits attributable to the avoidance of pollution to the environment. There is little agreement as to the relative effect on the environment of recycling. This is due to the substantial number of variables that enter into the evaluation as well as the difficulty in weighing their relative effects. Further difficulties are encountered in evaluating the amount of economic damage. Research needs to be undertaken on the overall relationships between damages and environmental quality. No study has yet determined the economic value of the material damages suffered from different levels of air, water and land pollution specifically related to oil. It is likely that no significant relationship exists between used lubrication oil levels and damage to water, air and land in that effects of oil pollution are relatively small in comparison to pollution levels from other sources.

Lave and Seskin (1970) report the problems of measuring the effects of changes in air pollution levels.

> .....Scientists still disagree on the quantitative effect of pollution on animals, plants, and materials. Some estimates of the cost of the soiling and deterioration of property have been made, but the estimates are only a step beyond guesses. We conjecture that the major benefit of pollution abatement will be found in a general increase in human happiness or im-

> provement in the "quality of life", rather than in one of the specific, more easily measurable categories. Nonetheless, the "hard" costs are real and at least theoretically measurable.

A major concern is whether recycling technologies are more or less polluting than the disposal of "virgin" waste. According to Pearce (1975) and Irwin (1975) the pollution from direct disposal into the environment and the disposal of the by-product from the recycling process, do not constitute similar pollution concerns. Re-refining mimimizes the amount of used oil entering the environment by recycling it and concentrating the contaminants for managed disposal. The hazards created by discharge of used oil into the environment vary depending upon the quantity of used oil discharged (whether it is used oil per se or recycling wastes), the ground composition, and the type of contaminants contained in the used oil or by-product from the recycling process.

Re-refining is one means of solving the problem of used lubrication oil. Unfortunately, difficulties such as the problem with the disposal of the process residuals prevent re-refining from being the simple solution to the waste oil pollution problem.

V. Identification of Costs

The costs associated with a program of resource recovery of used lubrication oil are those of collection, residuals handling, disposal, transportation and environmental degradation (transportation and re-refining). These costs are determined by the market and, thus, are readily available in principle.

Total costs for delivery of used oil to a re-refining facility arise from the local collection and storage costs and long-haul transportation from the various regions of the Province to the re-refinery. The costs of such collection will be a function of the location of the re-refining facility and the future quantities of used oil from each source (Synergy West, 1974; 61).

Two re-refining processes are employed in the Province of British Columbia; one, the acid/clay process and two, the PROP re-refinery process. In the report "Utilization of Used Oil" by Mascetti and White (1978) information is presented on the cost factors of various re-refining processes. The acid/clay process is discussed, but no data is available on the PROP process.

The acid-clay process has high chemical costs,

> high waste disposal costs, and a low yield. These factors are sufficient to offset its low process energy requirements and result in high production costs.

The data, as found in the above-noted report, is presented below to give an indication of the range of pertinent costs associated with a resource recovery process that is presently employed in British Columbia. The costs for this Province in 1981 dollars would be significantly different than those found in this 1978 document. However, presentation of the data does illustrate potential profits of the one re-refining process. There is no mention of cost data pertaining to environmental degradation from transportation or re-refining of the of the used oil.

"A comparison of the production cost data ($.83 per gallon) for the acid/clay process to the actual market price of the re-refined ($1.18 in the Mid-West) and virgin lube oil ($1.47 -$1.85/gallon on the West Coast) indicates the potential profit of resource recovery by the acid/clay process, and the potential for further profit if the price differential between re-refining and virgin lube oils disappears." (Mascett and White, 1978; 3 -17)

Skinner (1974) prepared a cost break-down for the acid/clay process in Canada. These costs were in the following range:

	Cents/gal.
Collection costs	4 - 5
Storage costs	Ø - 1 1/2
Re-refining costs	24 - 26
TOTAL COST on re-refined base oil stock	28 - 32 1/2/gal.

By comparison, virgin base stock had a market value of \$.53/gallon (August, 1973 price) before the addition of additives.

As the two illustrations indicate, there is a substantial differentiation between the total cost of re-refined oil and that of virgin base stock (i.e. \$.83 for re-refined oil and \$1.27 -\$1.85 for virgin oil per gallon in the U. S. case, whereas, in the Canadian case, \$.28 -\$.325 for re-refined oil and \$.53 for virgin base stock per gallon). Recent virgin oil price increases have created a continued divergence between virgin oil and recycled oil stock prices.

Resource recovery of used oils is environmentally desirable because it conserves a valuable resource. However, improper disposal of the waste products can cause contamination of the environment in the same way as direct disposal of used oil can. Depending on the recycling process, several by-products are produced, the disposal of which may be potentially hazardous to society, causing a social cost.

Carcinogens, heavy metals and other toxic agents such as PCBs are in the used oil and as a consequence are concentrated in the wastes from the re-refining process. The EPA found that used oil contains polynuclear aromatics, some of which are classified as carcinogenic agents, can be found in used oils. Other toxic agents are also found within used oils and re-refining wastes, due to the concentration effect of re-refining. Table I presents a listing of these toxic agents.

The acid/clay re-refining process, used by three re-refiners in the Province, generates approximately 35 percent waste (by volume) from used oil collected. The acid sludge and spent clay from the process contain sulfuric acid and lead. Table II provides a listing of the average metal content in acid sludge. At present the re-refiners in Vancouver and Victoria dispose of the by-product in the city dumps, while the re-refinery in Winfield stores the waste product for later use as a fuel in a greenhouse operation.

TOXICITY OF SOME COMPOUNDS FOUND IN USED OIL (FROM THE TOXIC SUBSTANCES LIST, 1973 ED., U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, PUBLIC HEALTH SERVICE, NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH, ROCKVILLE, MARYLAND 20852)

<u>Naphthalene</u> (16282)

TXDS orl-rat	LD50-2200 mg/Kg
ipr-mus	LDLo-150 mg/Kg
U.S.O.S.-air	FEREAC 37,22139,82

<u>Xylene</u> (24890)

TXDS: ihl-hmn	TCLo-200 ppm TFX-IRR
orl-rat	LD50-4300 mg/Kg
U.S.O.S.-air	FEREAC 37,22139,72

<u>Toluene</u> (23487)

TXDS: ihl-hmn	TCLo-500 ppm TFX-CNS
orl-rat	LD50-3000 mg/Kg
ipr-rat	LD50-1640 mg/Kg
U.S.O.S.-air	FEREAC 37,22139,72

<u>Phenanthrene</u> (18120)

TXDS: orl-mus	LD50-700 mg/Kg
skn-mus	TDLO-2160 mg/Kg 13WI TFX-NEO

<u>Benzene</u>, Ethyl (3039)

TXDS: occ-hmn	TDLo-200 ppm TFX-IRR
orl-rat	LD50-3500 mg/Kg

<u>Benzene, Propyl</u> (3076)

TXDS: orl-rat	LD50-4830 mg/Kg

<u>Cadmium</u> as chloride (4793)

TXDS: orl-rat	LD50-88 mg/Kg
scu-rat	TDLo-2.2 mg/Kg TFX-CAR

<u>Lead</u> as chloride (14128)

TXDS: orl-gpg	LDLo - 2000 mg/Kg
U.S.O.S.-air	FEREAC 37,22139,72

<u>Zinc</u> as chloride (24994)

TXDS: ivn-rat	LDLo - 75 mg/Kg
par-ckn	TDLo - 1 mg/Kg TFX - NEO
U.S.O.S.-air	FEREAC 37,22139,72

TABLE I

SOURCE:Weinstein,1974

METAL CONTENT OF ACID SLUDGE

Element		Gasoline[1]	Diesel[1]	E.P.A.[2]
Lead	Pb	20,000	1,000	19,000
Calcium	Ca	6,400	12,000	-
Phosphorus	P	4,300	1,000	1,700
Sodium	Na	4,000	200	-
Zinc	Zh	2,100	200	2,100
Silicon	Si	1,400	800	-
Barium	Ba	1,300	400	740
Iron	Fe	1,100	500	2,200
Magnesium	Mg	1,000	70	-
Aluminum	Al	140	40	560
Chromium	Cr	50	190	28
Boron	B	50	40	18
Copper	Cu	40	40	190
Nickel	Ni	30	35	-
Tin	Sn	30	35	-
Silver	Ag	0	14	0.8
Manganese	Mn	-	-	63
Arsenic	As	-	-	45
Molybdenum	Mo	-	-	18
Vanadium	V	-	-	18
Cadmium	Cd	-	-	9
Strontium	Sr	-	-	2.7
Cobalt	Co	-	-	0.8
Beryllium	Be	-	-	0.1

Other Analysis[1]

Sulphur %	14.9	14.1
Ash SO_4	4.45	11.26
Acid % (as H_2SO_4)	47.5	40.8

Additional Information[1]

Sulphur S	13.5	-	14.5%
Titratable Acid	40	-	45%
Ash	5	-	15%
Combustibles	30	-	42%
Viscosity @ 75°F	4,000,000 centistokes		
Viscosity @105°F	475,000	"	
Viscosity @125°F	150,600	"	
pH	Oil		
Weight	12-16/gal		

SOURCE:Skinner,1974

NOTES:

(1) Analysis obtained from re-refinery - private correspondence

(2) EPA Report "Waste Oil Study Preliminary Report to the Congress, April 1973".

TABLE II

The environmental effect of the wastes from the acid/clay process are described by Weinstein (1974)

> The soluble free-acid probably leaches through the soil, and in alkaline soil is finally converted to sulfate salts, entering the groundwater or nearby streams. Some other sulfates in the sludge probably end up in the same way, but lead, barium, calcium, silver, arsenic, molybdenum, titanium, strontium, and other heavy metal salts may remain in the landfill.

The PROP plant located in North Vancouver has been designed to produce 6,000 pounds per day of a filter cake and caustic solution containing the wastes from the re-refining process. The by-products are to be distributed as an asphalt extender to be used in asphalt manufacturing; as a coating on shingles to inhibit the growth of moss; and for landfill disposal. Koch (1977) indicates that the use of oil in asphalt paving may contain phenols which could leach from the asphalt.

Although externalities can be identified, there is no quantitative data on the effects of pollution from used oil disposal and re-refining waste disposal.

VI. Summary

Some attempt has been made in this chapter to estimate the benefits and costs of used oil recovery. The estimates deal with the absolute volumes of used oil disposed into the environment. The major benefit of resource recovery is the reduction in pollution damage. Figure 9 indicates that there are 11.8 million Imperial gallons of potentially recoverable used oil in the Province of which 3 million Imperial gallons is presently re-refined. Therefore 8.8 million Imperial gallons are still available for re-refining. The benefit associated with the re-refining of these 8.8 million Imperial gallons is as follows:

> 8.8 million Imperial gallons of Oil Available for recovery x Recovery yield .8[5] = 7mIg of recovered oil
>
> 8.8 - 7 = 1.8 mIg of residual product

The costs attributable to the resource recovery process are the 1.8 million Imperial gallons of residuals produced.

The above formulation illustrates that the benefit of used oil

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5. The .8 represents an average of the yield from the acid/clay process (60 to 70%) and the PROP process (90% or more) i.e. + 70% = 160 ÷2 = 80%.

recovery is significant in absolute terms. Used oil disposal into the environment would be at a maximum of 1.8 million Imperial gallons (residual product disposal) in comparison to a present disposal of 8.8 million Imperial gallons. Thus, the net benefit is 7 million Imperial gallons of recovered oil.

A major obstacle to effective resource policy aimed at environmental protection is the lack of data on the impacts of resources in production and disposal. Given the preceding discussion on the costs and benefits of recycling used lubrication oil, it is evident that cost and damage functions are not readily available. Therefore, the benefits and costs associated with the resource recovery of used oil were only identified.

The benefits and costs identified with the use of oil residuals are primarily environmental issues. As is presented in the analysis, market prices do not include the social costs and benefits of recycling activities i.e. non-market costs and benefits such as air, water and land pollution level changes.

CHAPTER 5

I. Introduction

Increases in production and consumption of commodities have resulted in the problem of increased quantities of residuals. A direct consequence of the volumes of industrial and urban wastes is the public expenditure on solutions to handle the wastes. As the cost of maintaining wastes increases, there is a welfare loss to society. Threat to the environment is documented as a major reason to analyze the impact of resource recovery on lessening the quantities of residuals and wastes no longer utilized.

II. Economics of Resource Recovery

Historically, disposal costs have been close or equal to zero, and because of this there has been little incentive to treat waste material. One of the reasons for general disregard of land, water and air resources stems from the fact that these resources have not been regarded as economic goods - that is, goods which are relatively scarce. Our natural resources, as convenient avenues of waste disposal have been zero-priced as far as the individual manufacturing firm was concerned. Until recently, little concern has been placed on the environmental impacts of waste disposal. However, society is slowly realizing that the external costs of waste disposal are significant in terms of maintaining environmental quality. Use of wastes to produce economic goods is one method of arresting pollution.

In order to make judgements about the desirability of recycling, a consideration of the expected costs of pollution control in comparison to the anticipated benefits is required. The framework chosen herein to identify benefits and costs is benefit-cost analysis.

III. Benefit-Cost Analysis and the Case Study

The role of benefit-cost analysis in this study is to consider the economic basis for reaching decisions about pollution control through recycling. Benefit-cost analysis is not a one-step, simple decision-making tool. Rather it should be considered as a framework with a set of procedures to help organize available information.

Limits to the applicability of benefit-cost analysis to pollution problems arise because of limited information and data needed to evaluate, in monetary terms, environmental improvement. The case study of lubrication oil reveals the practical problems associated with the data input. Complexities concerning information availability have prevented the benefit-cost analysis from being entirely completed. This is due to the difficulty of calculating the benefits and costs of environmental pollution features of a project. Despite the volume of literature on the environmental effects of waste disposal, there still remains a considerable void in the research on the exact repercussions of this activity. An examination of the benefits and costs from recycling has indicated the need for more research on pollution damage and control. More specifically, with respect to pollution damage to air, water and land by oil residuals is well documented; however no study to date places an economic value on the loss.

Determination of the socially optimal re-use ratio, for example, requires the availability of hard data. Specific information required includes the following:

- methods of residual handling and disposal

- residuals re-use systems
- production processes
- residual generation associated with each production process
- externalities of both market and non-market nature associated with production, re-use and disposal.

Thus the major limitation of the case study is the absence of data on the interrelationships of pollution and recycling activities. This void in the research fails to allow a determination for each benefit and cost in monetary terms. Nevertheless, an evaluation of the net benefits of recycling used lubricating oil can be interpreted with aid of the waste oil inventory for the Province of British Columbia. That analysis allowed the examiner to calculate the absolute volumes of oil to be recovered from the project. The net benefit attributable to the recovery of used lubrication oil equals 7 million Imperial gallons for the Province of British Columbia.

As in the case study of lubrication oil, when quantification of major benefits and costs is not possible, a detailed discussion of the unquantifiable items is prepared. For example, benefit-cost appraisal of the recovery of used lubricating oil is here accompanied by a discussion of the environmental impacts of used oil on air, land and water.

Presentation of the costs and benefits is an aid for the decision-maker, not a substitute for it; due in large part to the fact that existing prices generally do not reflect all associated social costs and benefits. The information available in each case must be reviewed by the decision-maker as to the expected effect of the non-quantifiable data on the calculation of the net present value. As Dodgson (1981) emphasizes

> Despite the considerable difficulties involved in applying benefit-cost analysis in practice, the alternative may be public decision-making which is arbitrary and ill-informed, and which is more likely to be based on pressure from individuals who stand to gain financially from particular Government investment schemes, on factors such as perceived local pride and prestige... or on vague and unsubstantiated statements of the expected development or "multiplier" effects of projects.

IV. Suggestions for Further Research

The shortcomings of the research are evident. The thesis has only identified the benefits and costs attributable to lube oil re-refining. No monetary determination of the costs and benefits was attempted. In order to prepare a complete cost/benefit analysis numerous assumptions must be made. Figure 11 will illustrate some of the important areas where assumptions are required, in order to aid future research. The nature of the decision-making can be seen clearly in the diagram. Stage 1 encompasses those assumptions that must be made before any quantification of costs and benefits can be made. For example, even though a particular site may not be chosen, alternative locations can be identified and data acquired for a variety of decisions. To illustrate this point, during the course of the Synergy West (1974) study on the recovery of oil for Alberta, a number of assumptions were made in order to develop the costs of a recycling system. The assumptions included: number of re-refineries; number of collection districts; types of storage facilities; and, determined recoverability rate. The cost of collecting, transporting and processing the used oil at three alternative locations was calculated at 5-year intervals, up to 20

STAGE 1

1) number of facilities to be located in the Province

2) location of facilities

3) type of recovery process

4) size of facility i.e. capacity

STAGE 2

1) cost of collection

2) cost of transportation via rail and truck

3) cost of handling

STAGE 3

1) volume of oil that will be recycled

2) volume of residual from recycling process

3) disposal method for residual

FIGURE 11

Assumptions for Further Research

years in the future. To aid in the analysis of the data, a computer program was adopted that could store and compare the numerous data.

Further to the major decisions of Stage 1, and repercussive considerations of Stages 2 and 3, there are areas in the cost/benefit analysis that require further research. Despite the seemingly extensive knowledge on the environmental impacts of used oil disposal, the environmental effects will vary with different concentrations of impurities in the oil and different environmental conditions. For example, the extent to which oil is used as a road dust suppressent affects the environment and the extent to which the residuals from a resource recovery process pollute the environment, cannot be easily compared. It would require a study to determine the associated environmental degradation of used oil and re-refining wastes disposed of into the environment, with particular reference to British Columbia.

As indicated in the case study of lubrication oil, usually there is no market price for the benefits of pollution control or the costs of associated pollution due to pollution control i.e. environmental degradation due to disposal of re-refining residuals, because the good is a public good. Future research could entail a "simulation" of the market, to discover what people would be willing to pay for the benefit of pollution control with the knowledge that some pollution would be produced by the recycling activity, even though they will never be asked directly to pay a price. As estimation of how much people would gain in income and profit if the services were provided, can be used an an indication of how much they ought to be willing to pay, as a maximum.

Household surveys, in which individuals are asked questions concerning their willingness to pay for environmental amenities attempts to measure demand for environmental quality. An estimation of demand for environmental quality on a broad scale, is initiated by the hypothetical situations contained in household surveys. The measurement of demand as indicated by a household survey will probably indicate that there is a real demand for environmental quality, measured in terms of willingness to pay for these amenities.

The analyst can incorporate a ranking system to aid in the evaluation of environmental quality factors. The procedure of ranking is undertaken until all the factors i.e. costs and benefits, have been given an imputed range of values. The range of values would be subject to a sensitivity check in order to determine at what levels of monetary value the analysis indicates a Net Social Benefit. Maniate and Carter (1973) discuss a general method of the above approach that can aid in the evaluation of environmental quality factors in Benefit-Cost analysis.

Finally, the thesis has lead to the insight that the Government must decide to what extent they are to be concerned with the issue of used lube oil. As private industry is the only participant in the re-refining process, the level of recycling is at the point where profits are maximized. The social value of avoided waste disposal of into the environment must be investigated in order to determine the 'optimal' recycling level i.e. the point at which the extra costs of recycling outweigh the extra benefits.

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