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A Systems Approach to the Problems of Solid Waste and Litter

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ABSTRACT

Three principal types of proposed solution to the urban solid waste problem are critically examined: a ban on one-way beverage containers, reclamation programs, and a weight-based tax. Then legislation involving a disposal tax is designed which increases the ability of communities to handle solid waste effectively and which produces a control system that learns from its own experience and adapts to changing conditions.

Introduction

As awareness of the extensiveness and pervasiveness of our environmental problems has increased, public pressure to find simple solutions to these problems has also increased. Perhaps, in no other social problem-area are we as prone to seek panaceas as we are in the environmental area; but complex problems seldom have simple solutions.

Even simple proposals for handling environmental problems rarely generate widespread support. Few people are willing to incur any part of the cost or inconvenience that proposed solutions require. Hence, there is more interest in finding "solutions" that others pay for than in finding ones that work. Proposed solutions tend to be aimed more at punishing alleged culprits than at improving the environment.

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In May 1970, the Management and Behavioral Science Center of the University of Pennsylvania undertook an eighteen month systems study of the problems of solid waste management and litter control. Anheuser-Busch, Inc. of St. Louis sponsored the study. The company's interest in these problems stemmed from the emergence of one-way beverage containers as popular villains in the environmental debate. The objectives of the study were to investigate solid waste and litter problems from every point of view, to devise a systematic and equitable framework for addressing these problems, and to examine the implications of the framework for the future of one-way beverage containers.

We were not asked to construct a defense for the company or the brewing industry or to restrict attention to that portion of the problem which directly affected the sponsor. As a result, we were able to begin with basic principles and to construct a program that would channel corporate and governmental actions toward an ideal that could be characterized even if it could not be precisely described.

We attempted to design a program that would be both effective in addressing the problems and flexible enough to deal with a wide variety of local conditions across the country. Moreover, we noted at the outset that the technology already available for dealing with the problem was far more sophisticated than the crude dump-and-burn methods employed by the overwhelming majority of domestic solid waste processes. Hence, the principal problems we needed to address were social, economic, and political. However, we did prepare a summary of the state-of-the-art in solid waste technology, but we did not attempt to improve that technology ourselves.

The basic requirement that we imposed on any solution was that it should provide a process that is capable of 1) being improved systematically with experience, and 2) adapting to changes in the conditions under which it must operate. In other words, every solution should also be viewed as a social experiment and should be set up to conform to sound experimental principles. More precisely, a proposed solution should have at least the following properties:

1. The conditions to be corrected should be specified and measured before the proposed solution is implemented.
2. The intended effects (expressed in measurable quantities) and the times by which they are expected (the "due dates") should be specified before implementation.
3. Determination of the actual effects should be made at the "due dates" and compared with the intended effects. (Interim measurements should also be made to aid in system management.)
4. The "due date" measurements should be disseminated to facilitate

public discussion and a decision should then be made either to continue, modify, or terminate the program. Discontinuation (not continuation) should be automatic unless there is a positive intervention by the legislative or decision-making body that initiated the program.

In brief, every proposed solution should provide for learning and adaptation based on experience with it by requiring periodic, if not continuous, evaluation and feed-back controls. Proposed solutions should be flexible enough to be modified in light of such evaluation. To assure objectivity, the evaluating body should be completely independent of those who either have responsibility for implementing the program or who stand to benefit or lose by it.

Solid Waste and Beverage Containers

Environmental problems are usually divided into those of land, water, and air, although the interconnections between them are well recognized. For example, the incineration of solid waste is a major contributor to air pollution. Dumping solid waste in water or on open land pollutes water, land, or both. In our research we concentrated on the solid waste problem precisely because it can affect land, water, and air; and also because it affects visual pollution, litter, and other types of sensory pollution: noise and odors.

Our research focused on household generated solid waste, with particular attention given to beverage containers because they have been the target of more proposed environmental legislation and programs than any other product.

Beverage (soft drink and beer) containers have attracted a great deal of attention primarily because they are a very conspicuous part of a very visible problem, litter. Furthermore, unlike paper which is a much larger part of litter, bottles and cans do not degrade and disappear over time. They "stay there" almost indefinitely.

Containers that contribute to litter also contribute to solid waste. (Litter is improperly disposed of solid waste.) Solid waste disposal creates more serious but less conspicuous problems than does litter. Hence beverage containers are twice cursed. Moreover, soft drinks and beer are the only products which are still largely sold in refillable containers. Refillable milk packages were phased out in the late 1950s. Non-refillable beer and soft drink containers did not become commonplace until the early 1960s.[1] Hence the public is aware that refillable containers exist for soft drinks and beer and that they were considered to be adequate to handle all sales as recently as a decade ago. The combination of a highly visible waste product, then, with the existence of a well-known alternative (the refillable

bottle) of proven viability makes the one-way beverage container a natural target of ecologists.

The three most commonly proposed types of solution for the solid waste or beverage container problems are the following:

1. A ban on one-way containers.
2. Return and recycling of one-way containers, with return either voluntary or encouraged by the imposition of a mandatory deposit on all containers at the point of sale.
3. A tax per unit weight on all or some materials entering the solid waste stream.

We will examine each of these alternatives in turn and then propose a program which our research indicates will solve some of the problems inherent in these alternatives. We will also describe some of the research used to develop our proposed program and to investigate its possible consequences. Consider first the effects of a ban on one-way containers.

A BAN ON ONE-WAY CONTAINERS

The elimination of one-way containers, with or without higher deposits for reusable containers, is very likely to reduce consumption of soft drinks and beer. Consumption is even more likely to be reduced because a ban on one-way containers will increase the price of these products and reduce their availability. Retailers and wholesalers would incur increased handling costs with returnable bottles only. To cover these costs the price of beverages would have to be increased. Even more restrictive is the lack of storage space and handling facilities that would be required in retail stores and wholesalers' warehouses, not to mention the health hazards associated with storage of dirty containers. These factors would very likely reduce the number of outlets handling beverages as well as increase their prices.

In 1969, Federal, state, and local revenues from taxes (excise, sales, and others) and licenses relating to beer amounted to $2.062 billion. A three per cent reduction in these revenues would be slightly greater than the revenue that would have been obtained that year from a tax of a penny a pound on all beer packaging and containers. (6.091 billion pounds at 1¢/pound equals $60.91 million, and $60.91 million is just under 3% of $2.062 billion.) The elimination of one-way containers could easily reduce the sale of beer—not to mention soft drinks—by three per cent. If it did, government income would be reduced by an amount sufficient for adequately processing *all* the solid waste generated by beer packaging and containers.

In addition to the cost-benefit deficiencies of the ban approach, it also

falls short on the critical question of equity. That is, the ban approach does not treat all contributors to the problem in the same way and, because it is an approach that cannot be generalized, it cannot be made equitable by extension. Moreover, the portion of the problem that is attacked is far smaller than many people realize.

Beverage containers contribute about 3.5 per cent of the weight of domestically generated solid waste.[2,3] Since such solid waste is growing at about four per cent per year,[3] the total contribution of beverage containers to it is less than one year's current increase. Even for the ten per cent of solid waste that currently passes through incinerators, beverage containers make up at most twenty per cent of the incinerated residues and, moreover, at this point eighty-five per cent of the costs of collection and disposal have already been incurred.

Furthermore, the maximum possible reduction (3.5%) cannot be obtained because in large cities where the solid waste problem is most serious, returnable bottles used away from the place of purchase average only about five trips[4] are are about 1-1/2 times heavier than nonreturnable bottles and from five to fifteen times heavier than cans. Hence, the maximum reduction that would be obtained would be considerably less than the maximum possible. *If returnable bottles were used exclusively, and sales were unaffected, the weight of the contribution to solid waste of beverage containers would increase.* This follows from the fact that the number of trips of such bottles is less than the ratio of their weight to that of the nonreturnable can.

Some have argued that increased deposits on returnable bottles would increase the rate of their return. Such increases have been tried in a number of places including New York City, but they have had no perceptible effect on return rates. Obviously, if deposits were made "high enough," return rates would increase, but this could produce other undesirable effects. Tests already indicate that a "sufficiently high deposit" would have to be significantly higher than the cost of the bottle. If this were the case, counterfeiting of containers could become attractive or, if such deposits were imposed in less than the whole country, it could be profitable to smuggle used containers from surrounding areas into the area involved for redemption. (Some municipalities which have instituted laws on detergents with phosphates have already experienced this kind of consumer reaction.) To prevent such smuggling, containers that are now uniform across the country would have to be visibly distinguishable for each jurisdiction that had such a program. Container costs would thus increase.

Essentially the same analysis can be applied to the ban option relative to the litter problem. Beer containers account for about fifteen per cent of the littered items and soft drink containers for about five per cent.[5,6]

Therefore, the greatest decrease in litter that could be obtained by a ban on one-way containers is twenty per cent. But this assumes that no returnable containers are littered. They are and would probably continue to be. Taking into account the percentage of returnables now found in litter, one can expect only a twelve per cent reduction in litter. But this figure is probably high because current users of one-way containers appear to have a higher propensity to litter than do current users of returnable containers.

VOLUNTARY RECLAMATION PROGRAMS

These programs involve collection of containers by individuals, their return to reclamation centers, and usually, but not necessarily, the receipt of some payment for so doing.

Reclamation programs for aluminum containers have been the most successful because of the relatively high salvage value of aluminum. The most successful such programs have produced about a twenty-five per cent return rate; the average being considerably less. Even at the highest return rate yet realized solid waste is reduced by less than one per cent. In addition, there is no hard evidence that such programs significantly reduce the rate of littering or the amount of litter. A person collecting aluminum cans from litter does not usually pick up other litter that he encounters.

If the salvage value of containers was increased to make their return more likely, scavenging of trash cans would become more common and this would add to the litter problem. It is estimated that as much as fifty per cent of urban litter is currently produced by trash collection procedures.

MANDATORY RECLAMATION PROGRAMS

In such programs deposits are required on all containers, usually (but not necessarily) less for nonreturnables than returnables, and they provide for return of the deposit with return of the container to any retail establishment. Such programs are a cross between the two previously considered. They are likely to be more successful than voluntary reclamation programs because it is easier to return containers to a retail store than to a smaller number of reclamation centers. But because the deposit on nonreturnables is less than on returnables it is likely to produce lower return rates than "returnables only." If deposits are increased to increase return rates, "counterfeiting" and "smuggling" would be invited.

Deposit programs create as much, if not more, trouble for the retailer than does a ban on one-way containers because he must sort and handle more types of containers. Hence, the consequences on retailing, consumption, and tax income already considered in the discussion of "returnables only" are likely to occur with mandatory deposit programs.

TAX PER UNIT WEIGHT

By a process of elimination we would seem to be left with such a tax as the only desirable approach to the solid waste and litter problems. The basic problem to be solved in designing such a tax is that of finding an appropriate trade-off between the accuracy of the tax as an estimate of real social cost versus the cost of maintaining a very detailed and complicated cost accounting system.

Allocating social costs to each category of products in the solid waste stream is difficult because so little is known about the factors that generate costs in collection and disposal processes. Among the variables that have been suggested[3] as relevant are the weight or volume (compacted, uncompacted, or partially compacted) of the product, the weight or volume of incinerated residue, pounds of particulates produced per ton incinerated, sulfur content, time required to degrade, composition and amount of leachates, and mechanical separability.

There has been almost no research on how to break down the costs of waste handling according to material type and product size and shape. Moreover, these costs, if they could be calculated, would show that costs of handling and treating an item are sensitive to the composition of refuse around it and to the efficiency of the operation. This means that the cost of inefficiency and the costs of interactions would be substantial and would interfere with attempts to identify separate social costs for each product type. Even if direct costs could be allocated in an acceptable way, there is a question as to what characteristics truly correspond to environmental damage. There are many ways and forms in which a product may return to the earth. The items which take the longest time to degrade usually produce the fewest leachates to pollute water. It is by no means clear which product features should serve as the standard of environmental viability.

On the other hand, we can observe that most large-scale measures, like volume, show a substantial correlation with product weight across all categories of goods. In addition, product disposability does not affect the cost of collection which is the largest cost component in the handling of solid waste. Therefore, we can reasonably use product weight as the basis for a tax, making adjustments where the use of a flat product weight criterion would result in shifts in demand that are clearly not environmentally desirable.

For example, a bill introduced by Senators William Proxmire and Gaylord Nelson of Wisconsin[7] would have undesirable and avoidable consequences on beverage containers and all rigid containers, in general. Under this proposal the tax on a twelve-ounce aluminum can would be 0.044¢; on a steel can with aluminum top, 0.088¢; on a one-way glass

bottle, 0.44¢; and on a returnable glass bottle, 0.65¢. This would clearly encourage use of aluminum one-way cans to the exclusion of others. Such cans produce the worst litter problem because they are the least degradable over time and because they require a great deal of electricity in their production. Generation of electricity is currently a major source of environmental deterioration.

Our analysis indicated, however, that rigid containers are the only product category for which product weight is unsuitable as a criterion. As will be apparent in the program described below, a simple adjustment can be made for this product class.

In deciding the level at which to allocate the tax and the way in which to spend the revenues collected, we need to refine further our statement of the goals which our program is intended to serve. Such a statement is also required because a tax by itself lacks some important properties that any legislation directed at solid waste or litter should have.

Objectives of Solid Waste Programs

Such programs should seek the following objectives:

1. to minimize the amount of solid waste generated per unit time,
2. to minimize the cost and maximize the effectiveness of collection, treatment, and disposal of solid waste,
3. to maximize the percentage of solid waste that can be and is separated and reused in an economically justified way, and
4. to minimize the negative impact of solid waste disposal on all ecological systems.

To accomplish these objectives a program should provide *incentives* to *all* participants in the solid waste system which will induce them to act in ways that will promote the objectives.

Despite the great emphasis on reuse of materials, recycling is not economical in most cases at the present time. Industry should be encouraged to develop production processes with greater capabilities of using recycled materials. This can be done in several ways.

First, directed public and private purchasing of goods can provide incentives for industry to carry out the necessary research and development. For example, if otherwise desirable, the Federal Government might only purchase paper that contains at least some minimal amount of recycled paper.

Secondly, and of greater importance, the current cost to industry of virgin raw materials and their processing depends greatly on transportation costs, depletion allowances, depreciation rates on processing equipment, and taxes, all of which are controlled by the government. These can and should be

adjusted so as to make the use of recycled materials more attractive to industry where the raw material involved is in limited supply or its acquisition or processing produces damage to the environment. For example, reduced freight rates for some salvaged materials would increase their use and might benefit freight transporters (e.g., railroads). Or, to take another example, the Federal Government could permit accelerated depreciation of costs of converting to use of recycled materials or environmentally preferable types of containers. Such manipulation of costs to industry should and can be accomplished in such a way as to reflect better the social costs of environmental damage of current practices.

Although there does not appear to be any danger of resource depletion for the materials used in beverage containers—steel, aluminum, and glass—in the next century, the outlook for many secondary materials is less clear. The government might well institute an authoritative study which could serve as a basis for policy on resource utilization over the coming decades.

The technological properties of a solution to the municipal-household-generated solid waste problem are widely recognized. These involve use of a centralized system of collection, separation, treatment, and disposal. Such a system provides easily demonstrable economies of scale.

Current practices are generally far short of our capabilities. Collection can be improved by use of better trucks. The use of heavy-duty paper or disposable plastic trash bags instead of metal trash cans provides substantial reduction in the direct costs of collection and in the costs produced by litter from spillage and injuries to workers; and it provides better protection against pests and vermin.

The techniques of waste processing include incineration, shredding, milling, compaction, sanitary landfill, and a variety of lesser known techniques. Improvements of these techniques are taking place rapidly, and could be even further accelerated by enlarging the market for their output. Furthermore, with increased demand for these technologies, their costs would be greatly reduced.

Most salvagable materials can now be mechanically separated from other solid waste and thus be made available for salvaging and recycling. Modern incinerators maximize reduction of solid waste, minimize pollution of the atmosphere, and can even be used to generate power or heat. Sanitary landfill of compacted incinerator residues, as opposed to open dumping of trash, minimizes pollution of land and water and can create usable and attractive land where it did not previously exist.

There are few communities in the United States whose solid waste collection and disposal systems cannot be significantly improved by use of currently available technology. Most, however, are unable to finance such programs. *It is the cost of procuring and operating such systems that creates the solid waste problem, not the lack of technology.* Hence, a solution to this

problem must address itself explicitly to raising the necessary funds. The "trick" is to do so in a way that induces constructive behavior of all those involved in solid waste production and processing relative to the four objectives specified above.

Before considering how this might be done, one general observation should be made. Unless the costs of proper disposal of materials is made explicit to all parties involved, an effective system of incentives cannot be developed. The public and special interest groups must be made as aware of the costs of disposal as they are of the costs of production, distribution, and marketing. This, it is suggested here, can only be accomplished by fair and explicit charges for disposal of *all* manufactured nonconsumable materials whose disposal involves a cost to society.

Developing, Financing, and Administering Improvement Programs

The program proposed here is designed both to create an adaptive learning system and to meet the objectives formulated above. The details of the program are not as important as are its general methodological characteristics. For example, the program is state-based rather than Federally based. But this aspect of the program could easily be changed without altering any of its essential characteristics.

The program involves the following ten steps.

1. *Minimal national standards for solid waste disposal and reclamation equipment and procedures are set by the U.S. Environmental Protection Agency.*

Because such standards are predominantly technical and ecological, there is no need to take account of special local conditions at this point. Local conditions can be considered by allowing communities to select among alternative systems such as landfill, incineration, mechanical or manual recycling, and so forth.

2. *The state (or Federal) government solicits from each community programs of development to meet or exceed Federal standards, together with a capital budget for each program. The state (or Federal) government develops such additional programs of its own as are necessary to support local programs, and a budget for them.*

The state (or Federal) government should maintain a body of public or private consultants to assist communities in preparing these programs.

These programs will cover capital improvements and only those increases in operating costs that increase per-capita cost in the community. Full coverage of operating costs is not desirable because it would reduce the

incentive to communities to seek efficiency or cooperation with other communities in construction and use of regional facilities.

3. *A state (or Federal) Commission on Solid Waste Disposal should evaluate and adjust these proposals.*

This evaluation should provide objective professional screening of all plans for engineering and fiscal soundness by otherwise uninvolved experts. Programs with excessively high capital or operating costs should be rejected. Where these high costs are due to small scale operations, consolidation of facilities and services on a regional basis should be required.

Capital improvement programs should not run for more than six years without being reconsidered by the Commission. This should allow sufficient time for construction and operation of the new systems so that they can be evaluated before additional capital improvements are approved.

4. *The state (or Federal) government determines the total annual costs for all approved programs over the six-year period. It adds about 10-12% for recycling* (see step 8). *It then determines the average total annual overhead cost* (T) *for each of the three consecutive two-year periods in the six-year period.*

This gives the amount to be raised each year by a solid waste tax. The solid waste tax receipts (described below) should not be used for any purpose other than solid waste programs. There is a precedent for this in the gasoline tax used by state and Federal governments for highway construction and maintenance. Of these taxes an average of only 0.67 per cent has been spent on administration of the tax and five per cent on administration of the programs funded. The amount of gasoline tax directed to non-highway uses averages five per cent over all states, most of which goes to legally mandated uses such as in education.

Reclamation of salvaged materials from salvage operations is encouraged by a tax credit set forth in step 8. Because the amount to be paid out in tax credits cannot be predicted accurately in advance, a buffer must be included for this and other uncertainties.

5. *The total tax to be obtained annually from each product category* (t) *is set to equal the amount to be raised that year* (T) *multiplied by the fraction of the weight of solid waste handled publicly in the state (or nation) in the last year that was contributed by that category.*

6. *a) The tax for units in most categories is obtained by multiplying* t *for that category by the ratio of the unit's weight to the total weight of its category in the publicly handled solid waste in the state in the*

last year. b) The unit tax for rigid containers is obtained by dividing t *for this category by the estimated number of containers in the publicly handled solid waste in the state in the last year. c) Units whose materials create special problems in handling or recycling should have their tax appropriately increased.*

Tax rates for each product category should be based on a survey of the composition of publicly handled solid waste in the state (or nation) in the last year. The survey should be carried out by a private research organization with no stake in the results. Note that this base for computing the tax takes into account all materials diverted by households to voluntary reclamation programs or to other uses. Thus it provides an incentive for reclamation programs.

Since the product categories used in the survey will have to be fairly broad, any reduction in solid waste due to what one company does will provide equal tax reductions to all producers of items in its product class. Since the company has borne the cost of the reduction, its net benefit will be smaller than that of every other company so affected. The discrepancy in the size of the benefits could give each company an incentive to hold back and allow other companies to move first. However, consortiums of companies whose products fall in a single category will have a strong incentive to institute joint programs of waste reduction. This should lead to effective industry-wide programs.

Rigid packaging (metal, glass, rigid plastic, and perhaps containerboard) requires special treatment. As previously noted, if this category were taxed by weight, it would encourage use of lighter materials; for example, aluminum, and this might not be desirable. Furthermore, a unit tax such as is proposed here, will encourage use of larger containers which would reduce the amount of material entering the solid waste stream.

Some materials or products present substantial problems in separation, disposal, or collection. Plastic containers, particularly those made of polyvinyl chloride, are a case in point because of their air-polluting characteristics when incinerated. Aerosol containers, which explode when heated, can damage incinerators. Taxes for such products should be adjusted to take such factors into account.

7. Reused containers and resold products are not taxed again.

By not taxing them again their reuse is encouraged. Thus, for example, there would be an advantage to increased use of returnable beverage containers.

8. Credits against the tax are given to companies that accept salvaged material of their products from publicly funded reclamation facilities.

The credit should be equal to the net profit to the community of the transaction over the alternative of disposal. Thus the credit will be equal to the salvage value plus the disposal cost minus the total publicly-borne cost of separation, processing, and transportation. The credit per item could exceed the tax per unit. If the company's entire solid-waste tax has been credited, any further credit should be applied against other taxes.

The budget to be raised for a particular year should be equal to that year's share of the program-plus-overhead costs *after* tax credits are removed. Therefore, in setting the tax the total amount of tax credits awarded in the previous year should be added to the annual share of program-plus-overhead costs. This will be the budget for that year. Such budgeting will have the effect of shifting the tax burden from those companies which accept salvage to those companies which do not.

9. *The survey and estimates of costs should be recomputed at least every two years.*

This should be done annually if cost and time permit. Doing so is necessary to ensure responsiveness of the incentives to constructive and destructive actions of industry. It is also essential for keeping the programs on budget and on schedule.

10. *The state (or Federal) Commission on Solid Waste Disposal or some larger state or national unit of which it is a part should evaluate each community's progress annually, and discontinue support of those that do not meet Federal standards or are otherwise mismanaged.*

Conclusion

The principal function of the proposed legislation is to provide incentives which bring individual and social interests in line with each other. The effects of the proposed law are designed to change as needs change. Furthermore, the proposed charges and credits are such as to increase awareness of their systemic characteristics. Hence, the proposed legislation is also intended as an instrument of education, one that will facilitate learning by the public and by private parties about those aspects of the environment that are involved in solid waste.

Put another way, the proposed law is intended to provide controls in a social experiment. The controls derive from measurement and evaluation of effects and adjustments of incentives. The law does not constrain, restrict, or prohibit; it tries to *induce* constructive behavior in all parties involved. If, for example, the public wants a convenience package that is difficult to dispose of, and it is willing to pay for its disposal costs, it can have it.

Anti-litter legislation with characteristics similar to those proposed here for solid waste is described in the full report[8] of which this article is a digest.

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