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Urban
Solid Waste Management

ECONOMIC CASE STUDY

National Environmental Research Center
Office of Research and Monitoring
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

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NATIONAL ENVIRONMENTAL RESEARCH CENTER
OFFICE OF RESEARCH AND MONITORING
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ABSTRACT

Although about $4,500,000,000 per year is spent publicly and privately on solid waste management, little has been written about the operational and economic problems affecting specific communities. To provide some insight into local problems, a case-study approach was used to examine a sample midwestern city (approximately 500,000 population) with solid waste management problems similar to most other medium-to-large urban communities.

Changes in the productivity of solid waste collection crews brought about by substituting capital for labor are studied.

The economic effects of solid waste management costs on residents are analyzed by comparing solid waste costs with disposable income.

FOREWORD

To find, through research, the means to protect, preserve, and improve our environment, we need a focus that accents the interplay among the components of our physical environment--the air, water, and land. The missions of the National Environmental Research Centers--in Cincinnati, Ohio; Research Triangle Park, North Carolina; and Corvallis, Oregon--provide this focus. The research and monitoring activities at these Centers reflect multidisciplinary approaches to environmental problems; they provide for the study of the effects of environmental contamination on man and the ecological cycle and the search for systems that prevent contamination and recover valuable resources.

Man and the air, water, and land that surrounds him must be protected from the multiple adverse effects of pesticides, radiation, noise, and other forms of pollution as well as poor management of solid waste. These separate pollution problems can receive interrelated solutions through the framework of our research programs--programs directed to one goal, a clean livable environment.

This publication of the National Environmental Research Center, Cincinnati, reports on work related to the economic analysis of urban solid waste management systems. Substitution of capital for labor in solid waste collection and the economic effects of solid waste management costs on residents are studied.

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URBAN SOLID WASTE MANAGEMENT:
ECONOMIC CASE STUDY

By

Robert M. Clark

Introduction

Solid waste management is usually considered to be divided into two major areas: (1) collection, including storage, transfer, and transport; and (2) disposal, including any accompanying treatment. Annually, about $4,500,000,000 is spent publicly and privately on solid waste management. Of the $1,700,000,000 spent publicly for municipal solid waste management, 80% is attributed to the collection activity (1). Although these figures reflect the national effort, they reveal little about operational and economic problems that might affect a specific community. To provide some insight into local problems, a case-study approach was used to examine a medium-sized midwestern city that faces operational and fiscal problems similar to most other medium-to-large urban communities. This city is also an inner-city, part of a Standard Metropolitan Statistical Area (SMSA) of over a million people.

The Division of Waste Collection in our example administers the collection and disposal of solid waste for the entire city. The collection program includes: (1) Weekly collection of normal household and bulky waste from all residential dwellings; (2) collection of solid waste as needed from schools, hospitals, and public institutions; (3) collection of commercial solid waste; (4) collection of dead animals from streets, private property, and laboratories; and (5) emergency collection as requested. The disposal program includes: (1) Incineration of normal household wastes collected by city forces or delivered to one of the incinerators by private haulers; and (2) maintenance of dumps for disposal of incinerator residue and bulky waste collected by city forces or delivered to one of the dumps by private haulers. Both of these services are restricted to concerns located within city limits.

Migration to the suburbs has caused a net reduction in the city's 1960 population from 500,000 to its present 450,000. The traditional once-weekly, rear-of-the-house collection was changed to curbside collection in May 1969 because of a strike and a resulting wage increase; it was resumed in 1970 with passage of an increased city income tax.

Although the population decreased, generation of normal household solid waste increased during the last 10 yr; in 1960, 160,000 tons of household waste were collected and in 1969, 187,000 tons (Fig. 1). Waste characteristics have changed also. There has been a trend toward lighter and bulkier waste that results in a volume increase per ton and causes an increased workload in the disposal program. The decrease in collection of bulky waste, such as bedsprings and appliances, from 119,788 cu yd in

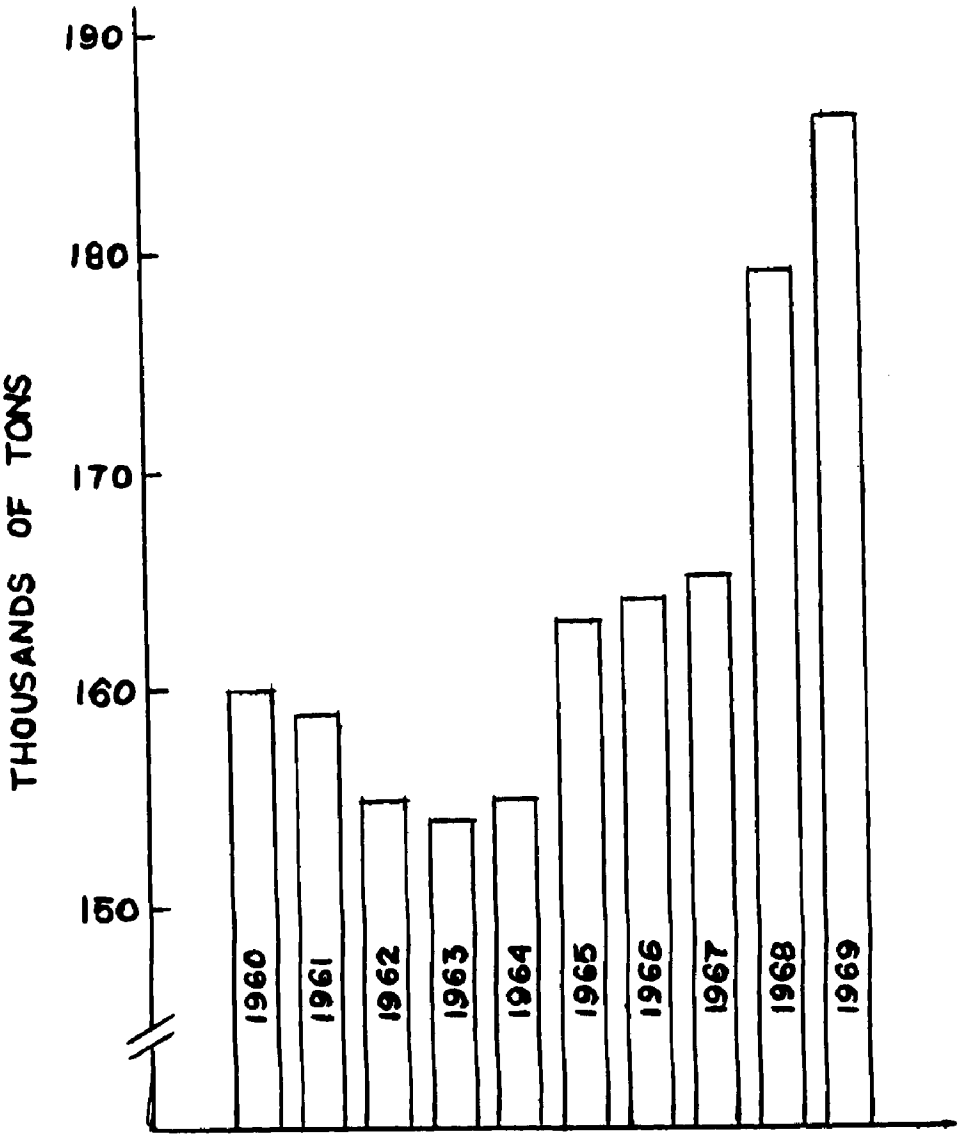

FIG. 1.--NORMAL HOUSEHOLD SOLID WASTE COLLECTED

1960 to 18,836 cu yd in 1969 results primarily from a city policy that encourages residents to handle their own bulky waste.

FINANCING OF SOLID WASTE MANAGEMENT

The city's financial problems are typical of many other municipalities (2). Each year the superintendent of the Waste Collection Division submits a new expense budget for salaries, supplies and materials, and equipment operation for the coming year based on workloads and performance over the past 5 yr. The budget committee of the city decides how much tax money various divisions will be allowed, and the superintendent of waste collection then projects his division's workload for the next year.

The city purchases all vehicular equipment from a separate budget, with each department competing for priority of need. Because the need for fire engines was believed more critical than the need for packer trucks, some waste collection load packers are 10 and 11 yr old although they supposedly operate on a 7-yr replacement cycle.

Unforeseen expenses, e.g., an incinerator chimney that must be relined or a new electric crane that must be purchased, require separate requests to city council for funds from the capital improvement fund. These are also approved on a priority of need basis.

For major capital expenditures, such as construction of an incinerator, a voter-approved bond issue is required. Because this community has regularly defeated special bond issues, the waste collection superintendent has not attempted to submit an issue for the needed $4,000,000 incinerator.

The Division of Waste Collection, then, derives its funds from an annual budget obtained from taxes, a special vehicular equipment budget, a capital improvement fund for all city departments, and special bond issues. This lack of adequate financing has led to a study of user charges for collection service and a completely new, pay-as-you-go program to make solid waste management completely self-supporting.

ECONOMIC ANALYSIS

To define some of the operational problems facing the city and to assess some of the economic effects of solid waste management, the collection services for household solid waste from 1960 to 1969 have been analyzed. The economic and operational figures used for the analysis are taken from annual reports prepared by the city's Waste Collection Division.

Solid Waste Management Costs

Between 1960 and 1969, the total quantity of normal household solid waste generated by the city's residents has increased by approximately 17% (Fig. 1) and the annual per capita solid waste collection cost has also risen continuously (Fig. 2), from $4.25 in 1960 to $5.30 by 1969. Disposal costs rose from $1.10 to approximately $1.90 per capita during the same period. Total costs for solid waste management, including overhead, increased from $5.75 to $7.50 per capita, or a total increase of over 30%.

Not included in these costs are the city's incinerators, which are paid for by property taxes. If an average cost of $3,000,000 per

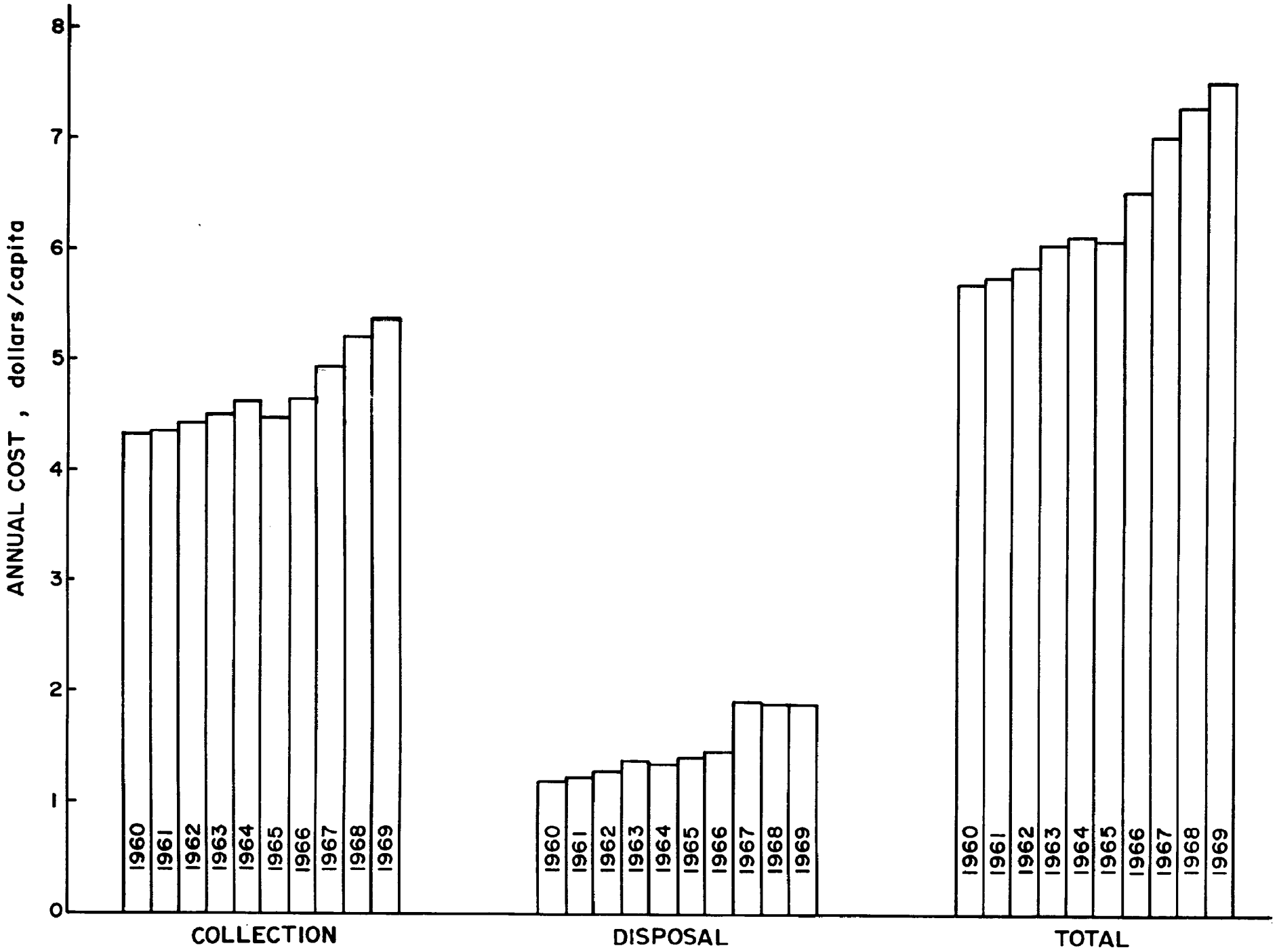

FIG. 2.--ANNUAL SOLID WASTE COSTS

incinerator, a financing and ownership cost of 6%, and a design life of 20 yr is assumed, a reasonable annual per capita cost for one incinerator would be $0.50. During the period of analysis, the number of incinerators in operation increased from three to four and the cost increased from $1.50 to $2.00 per capita. Because the current disposal system is operating over capacity, city management wishes to construct another incinerator adequate to meet current demands, at a cost of $4,000,000.

Although the cost for managing solid waste for each person increased during the study period, the cost for collecting each ton of solid waste fluctuated. The change in the direct labor and equipment costs (the two main components of the per ton costs) explains these differences. In 1960, the direct labor cost for collection was $6.75 per ton; by 1967, it had risen to $9.50 per ton (Fig. 3). For 1968 and 1969, however, this unit cost decreased to $8.75 per ton. Dollars expended per ton for equipment remained relatively constant. The different patterns followed by the per capita versus the per ton cost figures may best be explained by examining the productivity of the city's collection crews.

Collection Crew Productivity

To measure the collection crew productivity in a given year, the total combustible solid waste collected was divided by the number of man-years expended in the collection effort (Fig. 4). Productivity rose from 590 tons per man-year in 1960 to 675 tons per man-year by 1968. In 1969, because backyard collection was stopped and crew sizes were reduced correspondingly, productivity was approximately 800 tons per man-year.

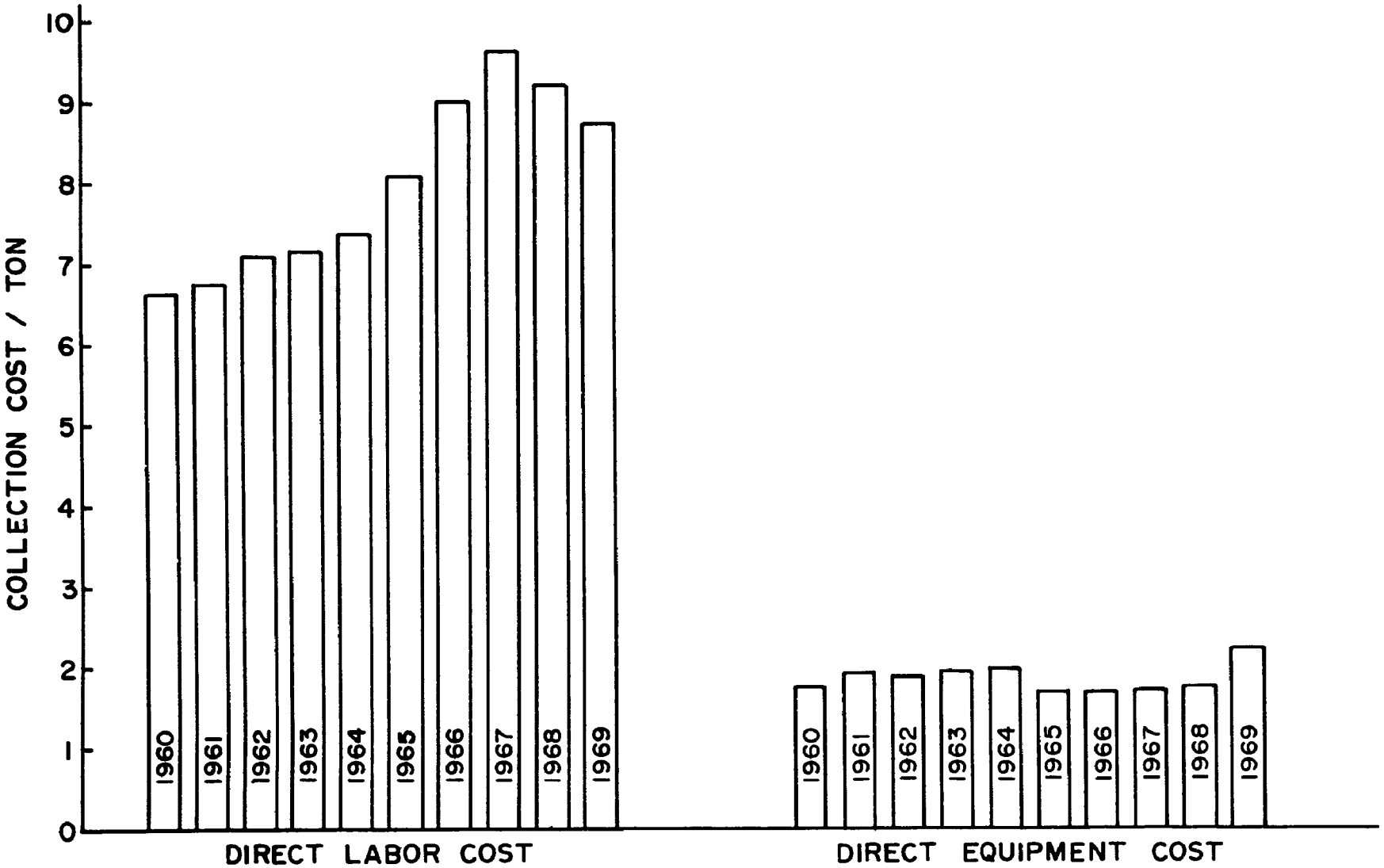

FIG. 3.--DIRECT LABOR AND EQUIPMENT COST FOR SOLID WASTE COLLECTION

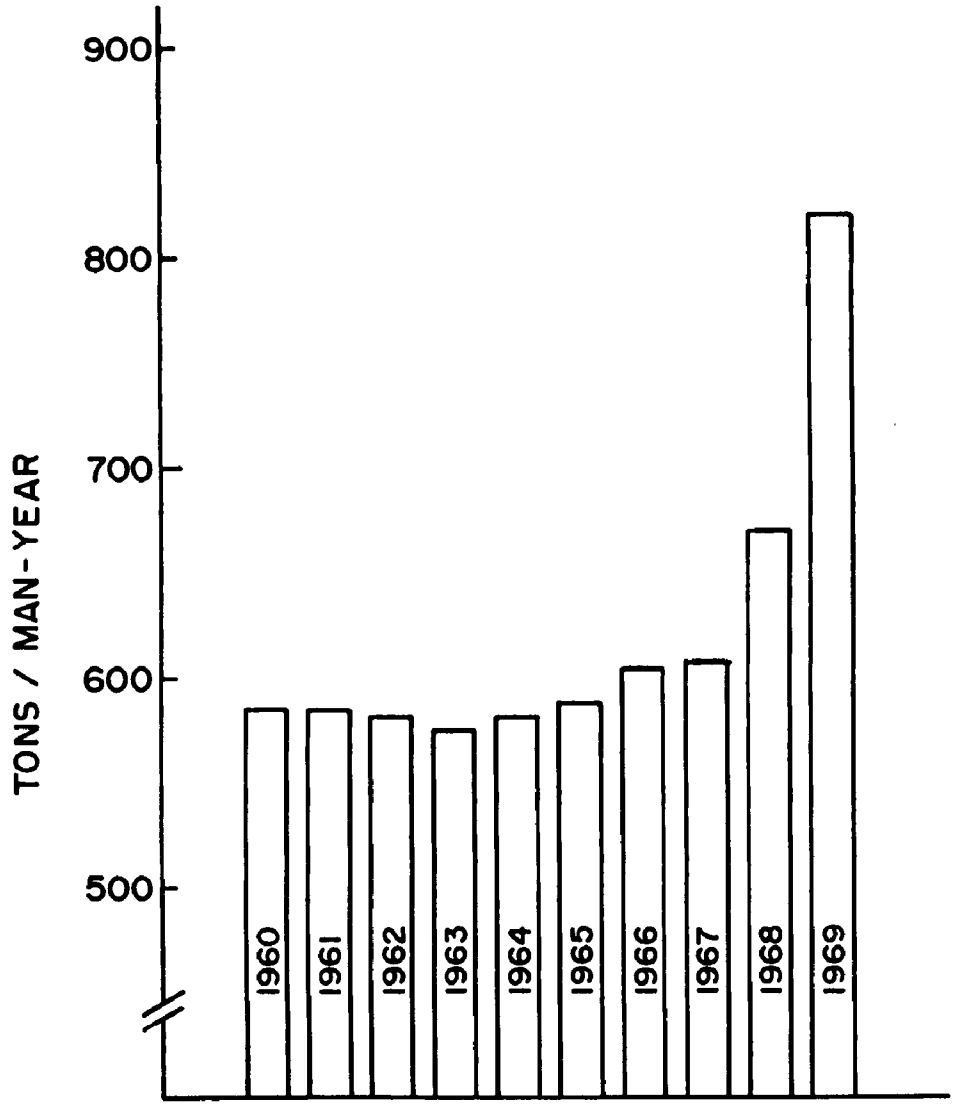

FIG. 4.--PRODUCTIVITY FOR COLLECTION CREWS

Another factor that exerted a major impact in increasing productivity was the continuing purchase of larger vehicles. In 1965, approximately 8% of the city's fleet was made up of 16-cu-yd packer vehicles and the remaining 92% was smaller than this size. By 1969, nearly 44% of the city's fleet was made up of 16-cu-yd packer vehicles. Replacing small vehicles with larger vehicles reduced the number of truckloads of solid waste collected. In 1966, when 16-cu-yd packer vehicles made up 20% of the total fleet, 65,304 truckloads of waste were collected. By 1969, when 16-cu-yd packer vehicles made up 44% of the total fleet, 60,960 truckloads of waste were collected. In a 4-yr period, even with increased waste production, over 4,000 fewer truckloads were collected because of the truck replacement schedule. According to the city's annual report, "This decrease is the result of replacement of 13- and 15-cu-yd packers with new 16-cu-yd load packers." An obvious corollary to this statement is that the increase in the number of 16-cu-yd load packers has correspondingly increased the productivity of the collection crews.

Another way to examine productivity and its effect on solid waste collection costs is to compare the change in productivity with changes in labor, equipment, and total solid waste management costs. All of these costs were calculated as dollars per man-year of effort. The percent change from 1960 in labor cost and productivity values was calculated (Fig. 5). For the years between 1960 and 1967, the slope of the productivity curve was less than the slope of the labor cost curve. Correspondingly, direct labor cost per ton rose during this same time span. After 1967, the slope of the productivity curve was greater than the slope

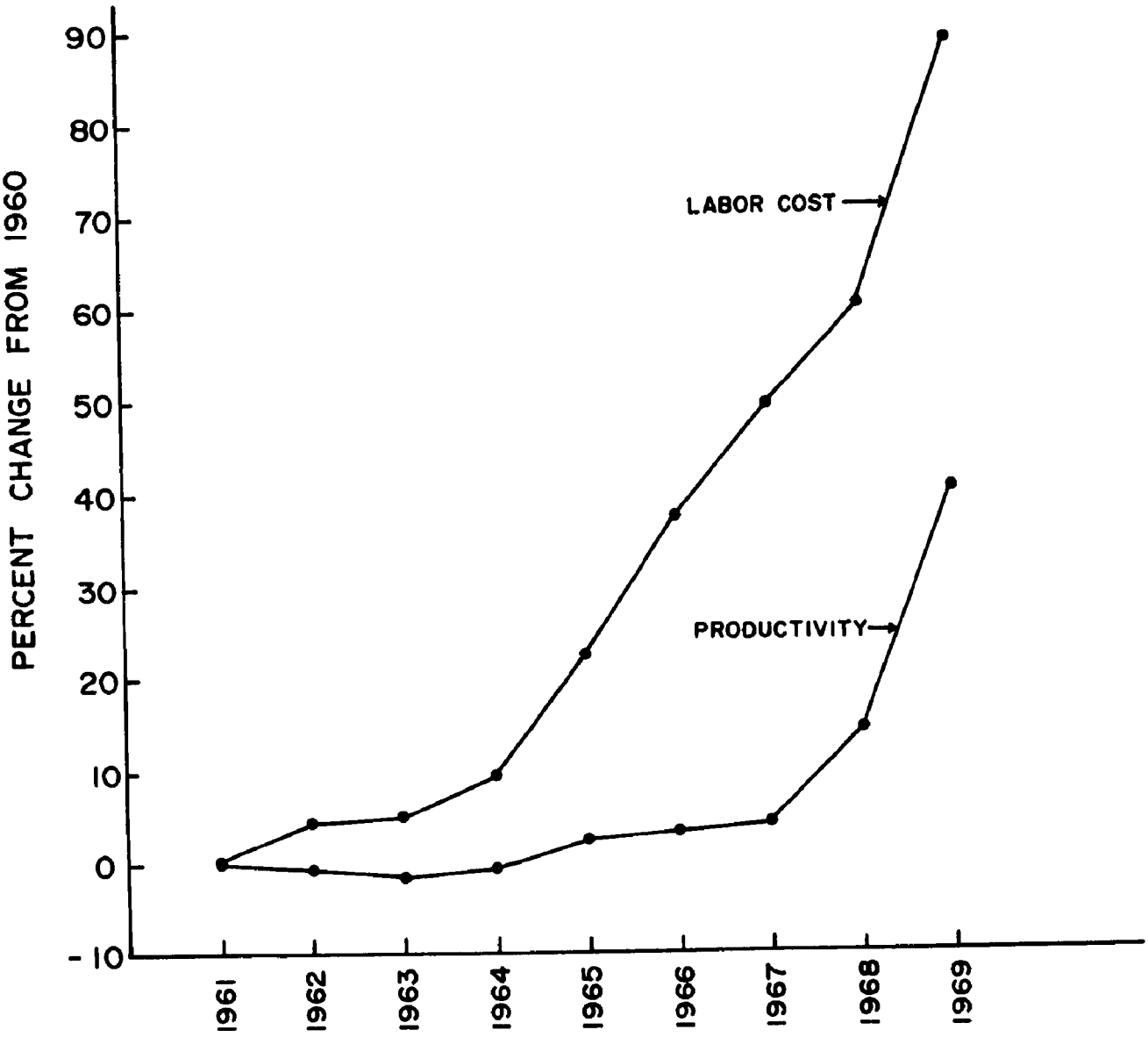

FIG. 5.--PRODUCTIVITY AND LABOR COST

of the labor curve and the direct labor cost per ton decreased. As equipment expenditures increased, productivity tended to increase (Fig. 6). For total solid waste management costs, as for labor costs, the cost per ton tends to decrease when the slope of the change in productivity curve exceeds the slope of the change in cost curve (Fig. 7). This analysis indicates that when the change in productivity exceeds the change in cost, the cost per ton for solid waste collected will decrease.

An examination of the ratio of direct labor cost to direct equipment cost reveals that, for the period of analysis, capital was substituted for labor and that when the ratio of labor to capital is decreased, productivity is increased (Fig. 8).

SOLID WASTE MANAGEMENT COST VERSUS DISPOSABLE INCOME

The economic effects of the increase in cost of solid waste management can be examined by comparing it with the corresponding increase in effective buying income (Fig. 9) (3). Disposable income for the 10-yr period of analysis increased by 39.7%. If an average household of 3.5 people is assumed, the synthesized cost per household for solid waste management, including estimated capital cost, increased from $25.38 to $32.90 per year, or 29.6%. If the estimated cost for a new incinerator was included, the cost per household would have been $34.65, or 36.6%. Between 1967 and 1969, disposable income increased by 9.3% and the actual total cost of solid waste management increased by 17.2%.

In the 10-yr analysis period, the amount of disposable income increased more than the amount expended for solid waste management. In the

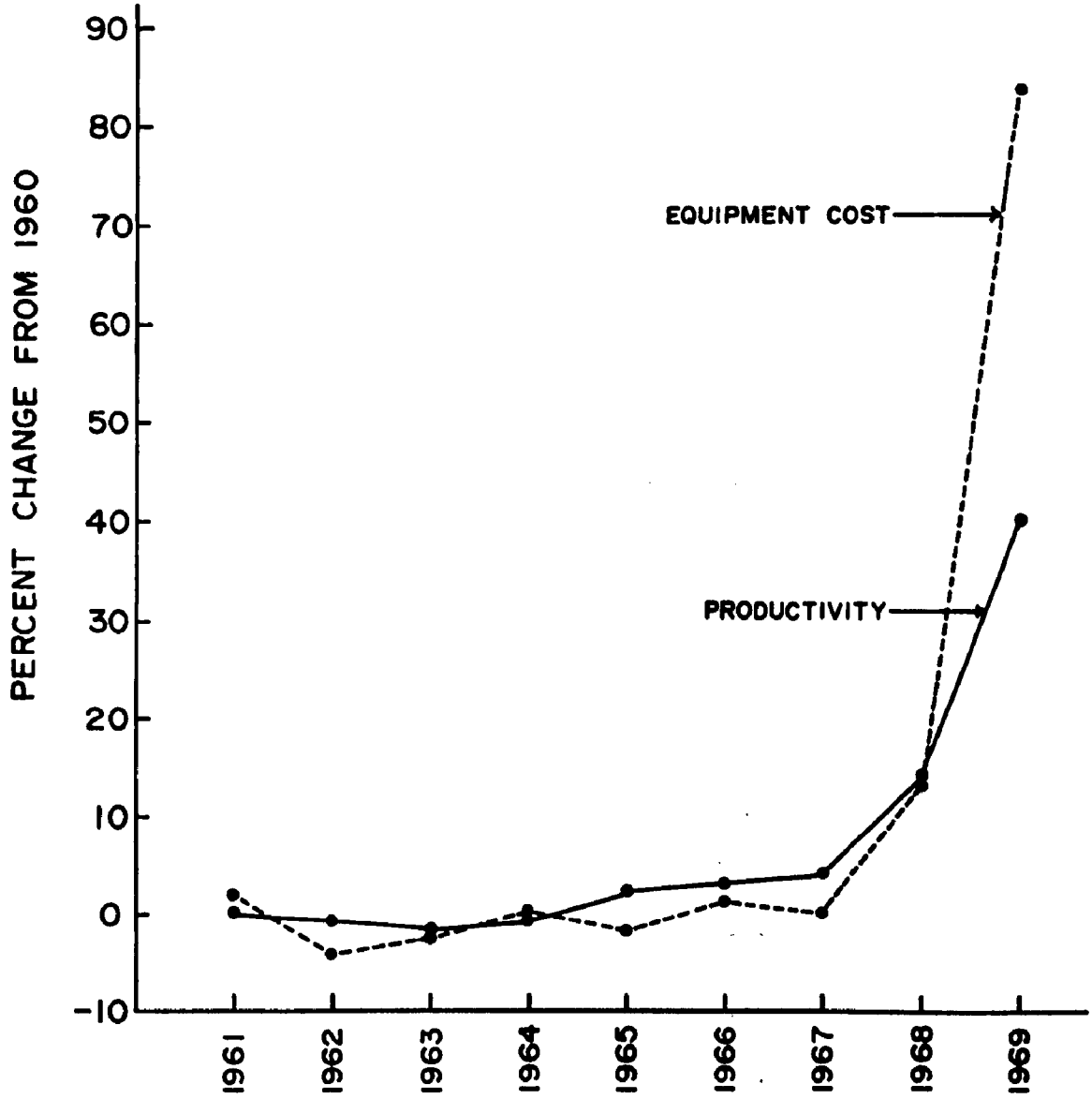

FIG. 6.--PRODUCTIVITY AND EQUIPMENT COST

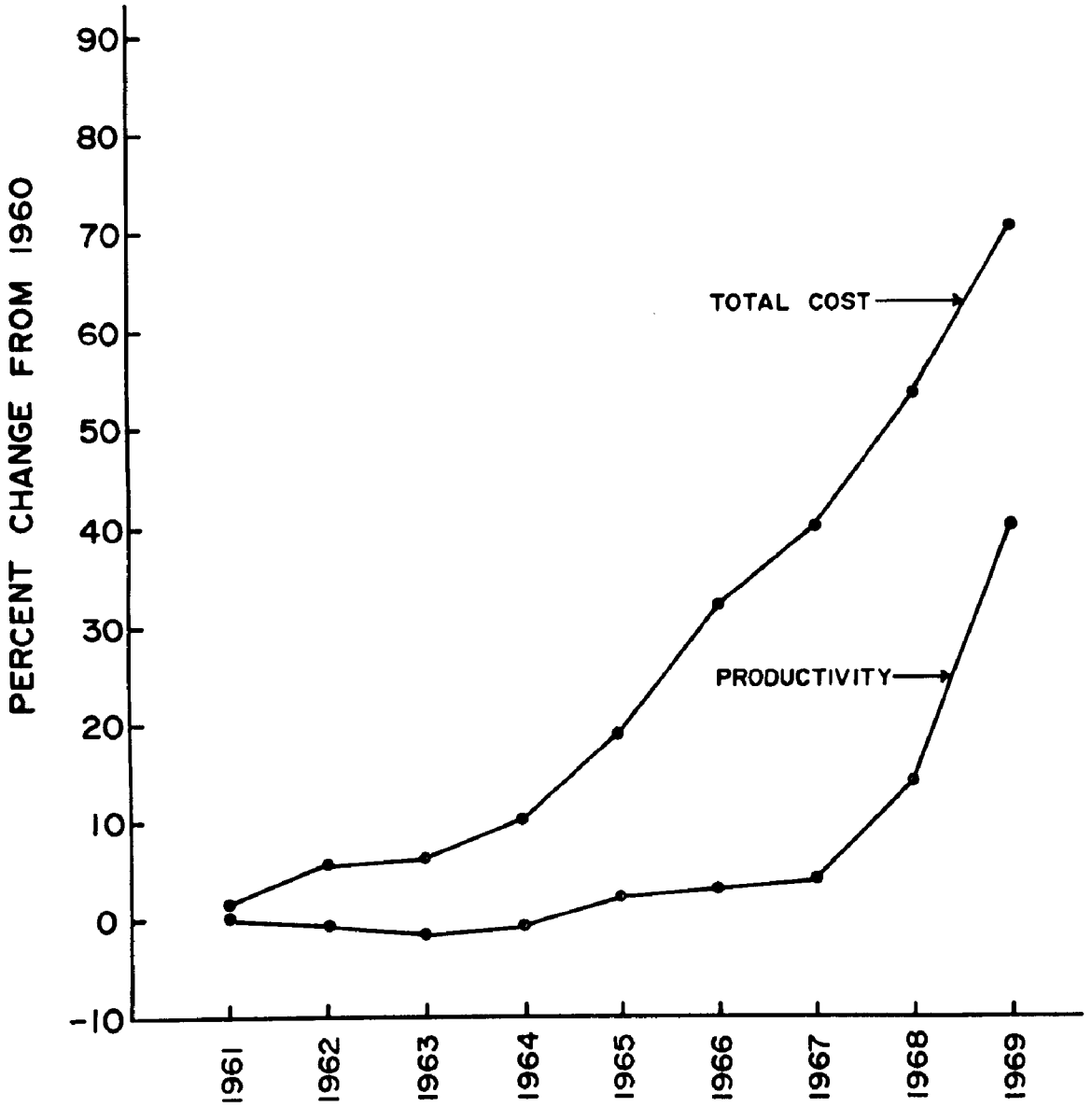

FIG. 7.--PRODUCTIVITY AND TOTAL COST

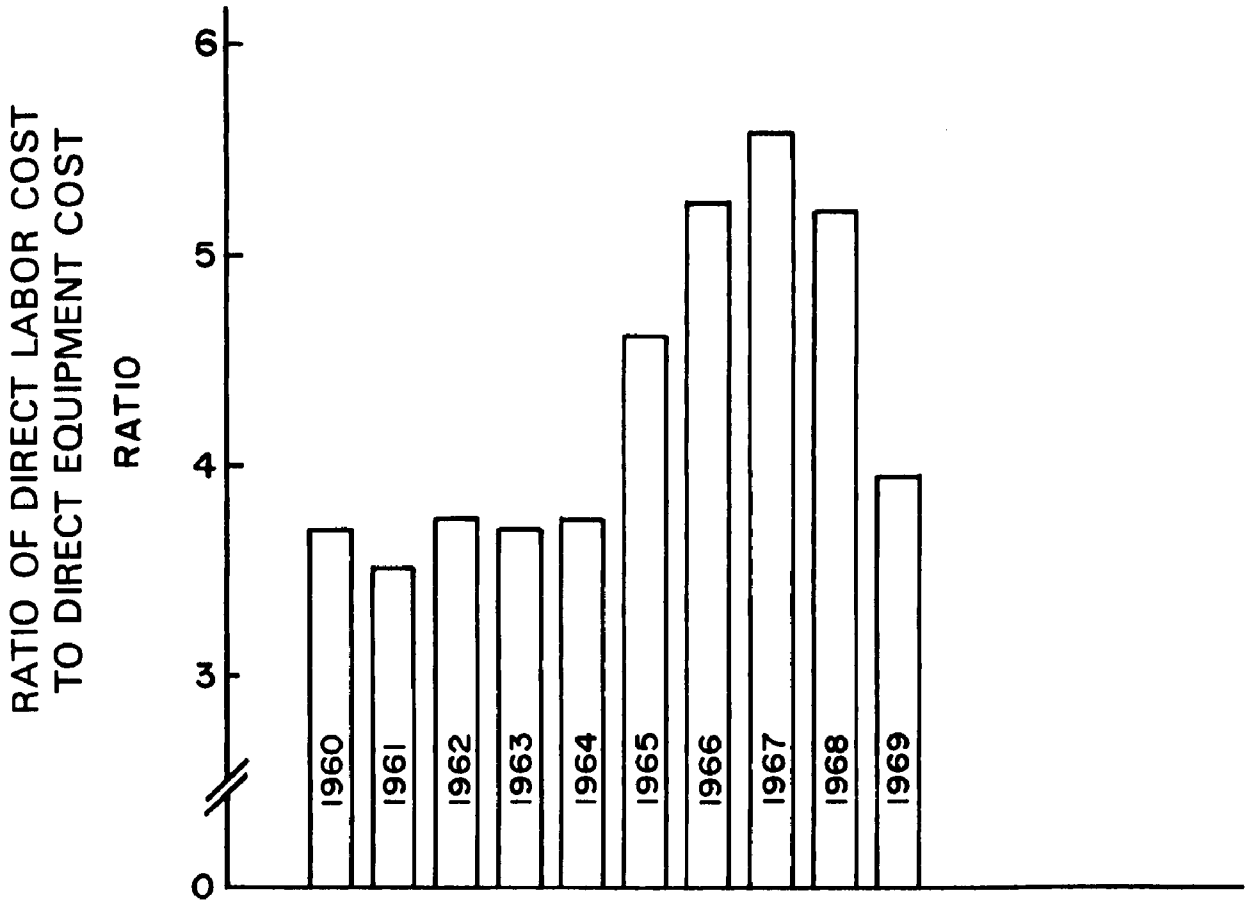

FIG. 8.--RATIO OF DIRECT LABOR COST TO DIRECT EQUIPMENT COST

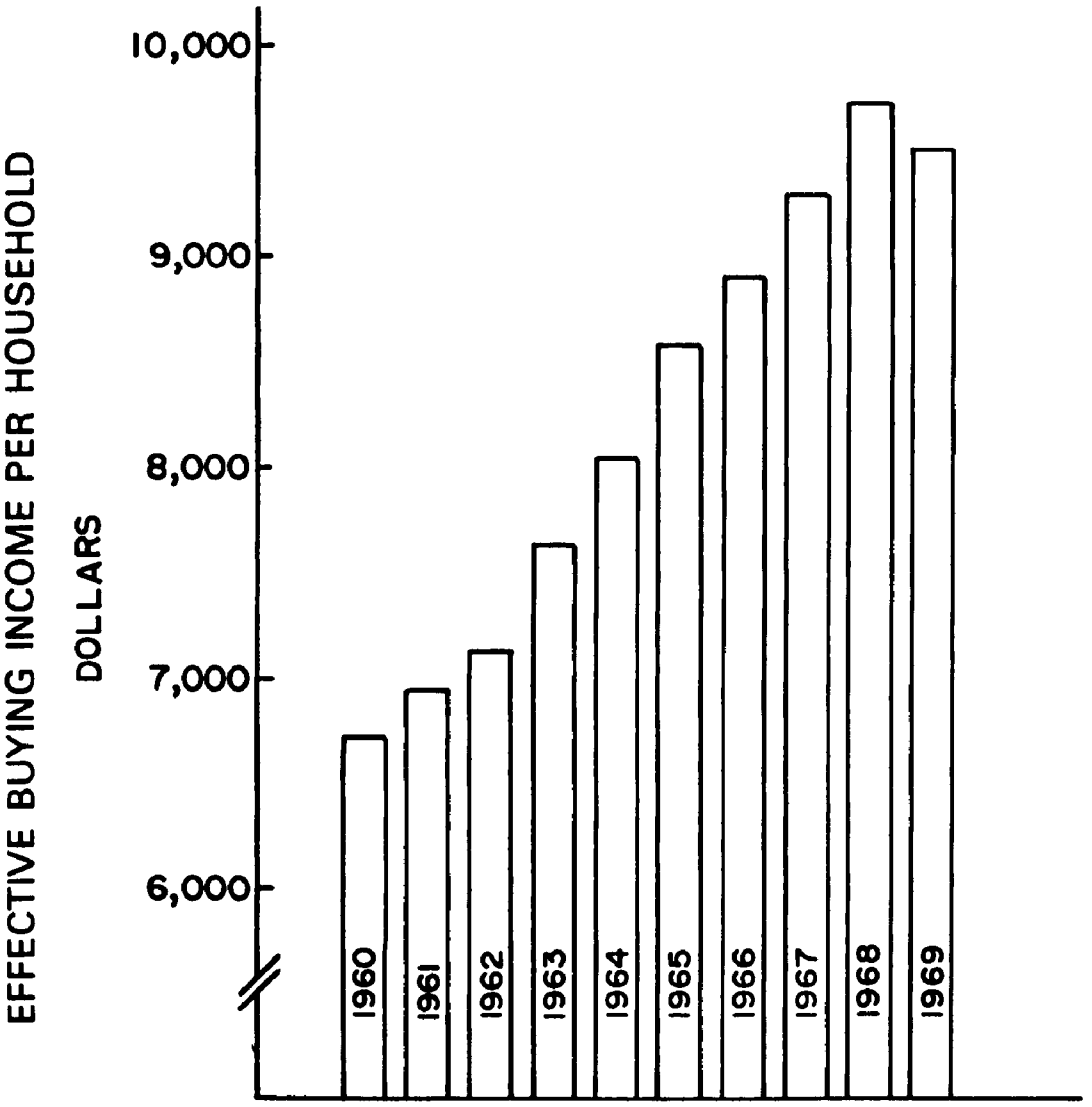

FIG. 9.--EFFECTIVE BUYING INCOME PER HOUSEHOLD

last 5 yr, however, the increase in solid waste management cost is nearly double the increase in disposable income. Part of this increase in cost is attributable to demands by municipal employees for greater wages. When higher wages are granted without increased productivity, the unit cost for service increases. Even though more money is available for city services, the cost to supply each unit of service is increasing faster than the available money supply. The citizen, having more disposable income, wants more services at an inflated rate. This forces the cost of solid waste management to increase faster than money available to pay for the service, and the result is an increase in the tax percentage assessed against the citizen.

It is interesting to compare Fig. 1, Normal Household Waste Collected, with Fig. 9, Effective Buying Income Per Household. Although there is not sufficient data for a rigorous analysis, the increases in solid waste collected appear to correspond very roughly to increases in disposable income over the same period.

SUMMARY AND CONCLUSIONS

It should be recognized that economic factors alone cannot govern the provision of adequate solid waste management. The health and welfare of the population being served are the prime considerations. It should also be recognized, however, that given the population's wellbeing as a major constraint, economic factors affecting solid waste management must be considered. Economic factors have become more important since the balance between revenues and expenditures for most large cities has become precarious.

The steadily increasing per capita costs for solid waste management during the last 10 yr have resulted primarily from an increase in per capita waste generation and in labor wage rates. Much of this increase in labor costs is reflected by the general inflationary trend in the economy. In recent years the tendency toward collective bargaining has had a substantial effect on the wage rates for individuals employed in local solid waste management functions. Both of these trends taken together no doubt explain the general increase in labor wage rates. It is interesting to note in Fig. 1 that the solid waste collected varied considerably over the period of analysis. It dropped from 160,000 tons in 1960 to 155,000 tons in 1963, approximately 3%, and increased to nearly 187,000 tons in 1969, approximately 20.6%. The sharpest increase, 9.1%, occurred from 1967 to 1968. Although these changes are difficult to explain, they seem to coincide with some of the population shifts within the example city. In the early 1960's, there was a general trend for families to move into suburban areas outside of the city limits. As these areas began to reach saturation, there was a rapid expansion of the undeveloped areas within the city boundaries. These population movements combined with an increase in per capita generation of solid waste might explain the apparent anomalies in Fig. 1.

The decrease in costs per ton for direct labor in solid waste collection in the last 3 yr has caused a general decrease in total cost per ton for solid waste management. In the first 2 yr of this 3-yr period, labor costs per ton decreased primarily because of increased productivity caused by the purchase of larger vehicles. In 1969, elimination of

backyard service coupled with a large investment in 16-cu-yd packer vehicles caused an increase in productivity from approximately 670 tons per man-year to nearly 820 tons per man-year. The bulk of this increase is attributable to the elimination of backyard service.

The author is currently working with a large midwestern city having a population of 750,000. The city is following the investment and operating pattern which this analysis points out as most desirable. Backyard service has been eliminated, larger vehicles are being purchased, and transfer stations are being built, and the city is planning on experimenting with one-man collection systems. All of the actions taken by the city management have been consistent with the goal of substituting capital for labor. The result of this effort, to date, has been to reduce the annual operating and vehicle investment budget from $14,700,000 to $10,200,000. The ultimate objective is the reduction of the annual budget by another $3,000,000.

Rising labor costs and increasing per capita solid waste generation make decreases in per capita solid waste management costs appear improbable. Increases in per ton costs for solid waste management can be minimized, however, and in some cases, reductions can be made by increasing collection crew productivity. To minimize the economic effect on the householder, the increases in per capita cost for solid waste management should be kept equal to or less than increases in disposable income.

Under the constraints of current practices in solid waste management, the possible increases in productivity are limited. Service can be reduced only to levels at which public health is not jeopardized. Substituting capital for labor can be accomplished only to the point of having

a one-man crew in a truck so large it can no longer navigate the streets efficiently.

Once the limits of service reductions and substitution of capital for labor have been achieved, effective solid waste management systems can only be maintained with basic changes--changes in technology involving heavy investments in capital to achieve partial or complete automation of solid waste collection. Otherwise, the cost of solid waste management will ultimately place an intolerable burden on the individual being served.

APPENDIX.--REFERENCES

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