ECONOMIES OF SCALE
IN THE
PROVISION OF URBAN PUBLIC SERVICES

by

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ABSTRACT

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Submitted to the Department of City and Regional Planning on June 19, 1967 in partial fulfillment of the requirements for the Degree of Master of City Planning

The purpose of this investigation has been to establish the presence or absence of economies of scale in the provision of urban public services. It seeks to set forth the theoretical underpinnings of the concept of economies of scale in the provision of urban public services and to relate such theoretical concepts to a survey of the empirical studies which have attempted to determine the relationship between cost, output, quality and spatial density variables inherent in providing urban public services. The need for factual data for policy and decision making is stressed and the methodology of empirical research to uncover the facts is described at length. Theoretical concepts from the theory of the firm, development economics, urban economics and public finance establish the working framework of the study. Measurement problems associated with the variables of quality, density, cost and output are considered with several approaches to the measure of the latter in terms of effort, results, performance and expenditure described. The use of a priori deductive reasoning prior to estimation of cost functions and the engineering, statistical and accounting approaches to cost curve approximations are reviewed along with their shortcomings. Lastly, a survey of the empirical findings relating to the presence or absence of economies of scale in many urban services is presented. The survey indicates neglected areas of study, strong evidence of scale economies in certain services and conflicting or inconclusive findings in other services. Further empirical investigation is strongly urged before important policies are established bearing on optimal size of local governments for the efficient provision of urban public services.

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Urban Planning is still being done too much in the dark - on the basis of inadequate facts, half-truths, hunches, impressions, guesses, and prejudices instead of carefully arrived at, tested knowledge . . . .

Coleman Woodbury

I. SETTING THE STAGE

Americans are creatures of a cold and temporate climate ancestry; they place a high value on work and derivatively a high value on productivity. So high is the value they place on work efficiently performed that almost any argument expressed as labor saving or cost reducing has such an attractive appeal that it may lead them to accept its credibility and strive to take advantage of it without a challenge to its foundation or scientific inquiry into the relevant and material facts which bear on such argument. This is particularly the case when the analysis required to challenge the argument is very complex and when the costs of acquiring the needed factual information to make the analysis are very high. Such a problem arises when arguments are forwarded concerning the economic advantages to be gained by providing certain urban public services on a larger jurisdictional scale.

For example, in support of reorganizing a local school system to a larger administrative unit, one research body presented a rather provocative argument concerning the promotion of greater economy:

> Finally the larger district offers an opportunity to obtain the maximum educational service for every dollar spent. There will be fewer teachers as every teacher will be carrying a full teaching load. In fact, over 3,000 teachers can be dispensed with. Thousands of school buildings can be closed, thus saving operating and maintenance charges. Thus savings can be used to enrich the educational program without increasing taxes.[1]

Surely, very few citizens are in favor of increasing taxes. And who isn't for enriching the educational program at no additional cost as a result of eliminating so much unnecessary waste of teacher's time and excessive school buildings. This argument strikes at us emotionally as well as rationally, playing on Protestant Ethic notions of thrift.

Or consider the arguments presented in a study which recommends a city-county consolidation for Sacramento, California:

> The immediate question that will be asked by most residents will be, "What does the new Plan cost me?". . . "What will I get?". . . "How much do we save?" Experience with metropolitan improvements in government indicates that no flat promises of cash savings can honestly be made. The reason is that inadequate governmental arrangements have left a backlog of big, necessary jobs to be done. This same experience shows, however, that the big jobs have been done, and for either the same general amounts of money or modest increases. Any increases usually have been attributable to increases in the general price structure or costs involved in meeting service backlogs and other deficiencies. . . . Improved areawide government may cost the same or a shade more than is paid for the governments it replaces, but the returns in services, area improvements, planning, and the future of the total community will represent much greater value for each tax dollar spent. . . .[2]
>
> First, research has established the fact that in the urban sections of Sacramento a large municipal unit provides the best package of services at the least cost. . . . It can be surmised that the broader municipal coverage provided by a city-county unit could effectively extend municipal-type services to new urban areas at minimum costs . . . .
>
> Second, potential savings are represented in the elimination of the dozens of small operations that cost so much in relation to the service coverage given. . . .
>
> Third, potential savings flow from the greater efficiency of a large-scale operation. Admittedly, government can become too big, although some would challenge this statement; but even at a half million or a million population Sacramento will not have passed any known size limits for maximum efficiency. Large local units generally can pay higher salaries, have adequate full-time staffs, attract top-ranking administrators, and use the best machines - because it is possible in a large operation to use the best. The large government can have a more effective merit system, legal staff, planning agency, central purchasing office, machine cost accounting, pre- and post - auditing procedures, and tax assessing and collecting practices - again because the best devices and personnel are least expensive in a government of large size. A larger operation means better utilization of each major item of equipment in such activities as road maintenance and construction. Size has its advantages, and this generalization applies in the service functions of government.[3]

Oh yes, this argument is very convincing and appealing as well. At first blush it appears to be more candid than the former. However, it remains the same emotionally pitched argument much more skillfully argued. It admits that the consolidation could cost each citizen more, but if it does, it can be blamed on price increases, large backlogs and other neglected deficiencies, or a better and higher quality of service. It is skillful in being so noncommittal; it doesn't have to eliminate 3,000 school teachers and thousands of school buildings to be a success; in fact, it will still be successful if it costs more. It is careful to include as advantages the "potential" efficiencies implied by the important symbols of progressive administration in 1957: machine cost accounting, pre- and post-auditing, planning agency and so forth. It admits some uncertainty and controversy in terms of overall savings but it holds out an impressive promise of potential savings.

The essence then is that the argument is largely rhetoric - unsubstantiated - but powerful rhetoric. In fact, this rhetoric constitutes perhaps the strongest argument available which captures the interests of citizens and motivates them to act.

Economist Charles Tiebout has chosen to forward an economic distinction in consolidation proposals:[4]

> The major economic rationale, I submit, which argues for consolidation is not economies of scale - at least as the term is ordinarily used. Rather, it is a problem of providing "adequate service", a problem likely to arise when communities act independently of each other.[5]

He uses an example of "metropolitan transportation" in which he, for simplicity, assumes there are no economies of scale. He argues that if each community in the metropolitan region provides service in its own area, transportation has been provided; but it is unlikely that the service of "metropolitan transportation" has been adequately provided "where adequacy is a measure of the quality of the product". He contends that the call for area-wide action with respect to transportation is not for rendering the same kind of service at lower cost but to provide a better quality of service.

> I would argue that this, and not economies of scale, is the issue involved when planners, civic leaders, and others, call for consolidation in order to render "efficient, adequate service."[6]

Tiebout may be correct concerning the desires of planners, civic leaders and others who have (1) studied the effects of consolidation elsewhere and realize economies of scale may not be achievable and (2) strive for adequate metropolitan service because it is their job or they have some other stake or interest in adequate metropolitan services. However, this investigator believes that the writers of the Sacramento proposal have correctly determined the question in the mind of the residents e.g. What will it cost me? How much do we save? Even if consolidation offers no economies of scale in the minds of the sponsors, which is probably too strong an assumption, they realize that the only way to sell their program to the public at large is to insist on potential savings and reduced costs of operating at a larger scale - with the hedge that if costs aren't reduced, quality has gone up and residents gain either way without increases in taxes.

Lastly, consider a proposed national policy to "modernize" local governments. Here the proposal has been forwarded by a highly respected institution, the Committee for Economic Development, to initiate sweeping changes in the jurisdictional scale of governmental units in America. The Committee for Improvement of Management in Government was established by the CED Board of Trustees in 1963. It consists of 25 CED trustees "with responsible experience in government, industry, and education, together with non-trustee members who have comparable qualifications, and is assisted by an Advisory Board of high professional competence."[7]

Their highly publicized and widely distributed policy report, Modernizing Local Government,[8] is a statement by the Research and Policy Committee, composed of 50 trustees from among the 200 businessmen and educators who comprise the Committee for Economic Development. The central concept which the CED stressed in its press releases, which has received the widest publicity, and which was the report's number one recommendation was apparently in behalf of increased administrative efficiency, considering the title of the sponsoring Committee:

> The number of local governments in the United States, now about 80,000, should be reduced by at least 80 per cent.[9]

This "reputable" body recommends a crusade to abolish 64,000 local governmental units in the name of improving government management.[10] Yet if one adopts its suggested criterion of 50,000[11] population as the minimum size for such services as police, streets and welfare, this implies that 4,000 rather than the remaining 16,000 local units might serve our 200 million population. What this investigator suggests is that a serious deficiency underlies this policy position in that this recommendation appears to be based on little more than the judgement, opinions and biases of the Committee.[12] This author was invited to disprove the value of the judgement; however, it remains a judgement for the most part unsupported by conclusive empirical evidence as to the purported efficiency gains to be derived as a result of implementing the Committee's monumentally disruptive recommendation. Perhaps the investigator asks for too much when he suggests conclusive evidence of the gains; yet, it is not too much to ask that a national policy of the type proposed here should be deferred until the weight of empirical evidence supports one. Currently, so little competently produced evidence on such issues exists that this investigator insists that now is the time for research, not policies.

It would almost appear that these prominent committee members "with responsible experience in government, industry, and education", who fully realize the value of hard facts in making decisions, did not deem that substantial evidence on the presence or absence of governmental efficiency was prerequisite to their widely publicized fanfare that 80 per cent of the existing local governments should be eliminated. After substantial research into the studies which have been made concerning economies associated with performing urban public service functions at a larger scale, this investigator has found far from complete agreement that economies exist in the provision of many functional services; and moreover, that there has been a dearth of such empiric evidence.

It is the hypothesis of this investigator that economies of the scale variety do exist in the provision of some urban public services. A survey of the relevant literature has been made in an attempt to identify some of the services in which economies of scale have been discovered.

The remainder of this thesis is devoted to establishing the economic foundation which supports the concept of economies of scale in the provision of urban public services, refining the definition of economies of scale such that a standard may be established which can be measured, discussing the methods of measuring costs and their shortcomings, and critiquing the empirical studies of economies of scale which have been performed to date.

We have elaborate, well-established theories on the economic behavior of private firms. But at present there is no generally accepted body of knowledge on the economics of public enterprises. Public agencies the world over perform economic functions on a vast scale. Just like their counterparts in the private sphere, they promote new ventures, procure capital funds, invest, plan production and marketing strategy, hire factors of production, manufacture, store, distribute, sell and render services of great variety.

Tillo E. Kuhn

II. ECONOMIC THEORY RELATED TO PRODUCTION OF URBAN SERVICES

It is important at the outset to define the concept of "economies of scale" to establish a framework for this investigation. In addressing the question of economies of scale, this investigator necessarily relies heavily on the development of related economic thought, for "economies of scale" is merely a label to describe a particular economic concept or set of conditions. This concept has evolved out of the general body of economic thought mainly through the analysis of the theory of the firm. However, confusion can result in the use of terminology for as different branches of the economic discipline encounter this concept and related concepts, they may discuss the concept from a different perspective and appear to leave the concept with a little different content. This investigator will attempt to resolve such confusion as the theories of different branches are presented.

A. THEORY FROM PUBLIC UTILITY ECONOMICS

One body of literature which yields profitable insights is that of the economic characteristics of public utilities.[13] It might be said initially that the economic and legal criteria of public utility companies are not always alike. A jurist or legislator decides what industries shall be given the status of a public utility. Public versus private is a question of the allocation of the rights to property in a given society and this issue is beyond the scope of this investigation. However, wherever the ownership may vest - privately, publicly, or jointly, the cost behavior of a public utility "type" of firm, which ordinarily is neglected in legal distinctions, is important to the economist and to this investigation. It might be noted in passing that in many instances, non-utility industries seem to display all or nearly all the economic characteristics of public utilities and that public utility economics are part of the general economic theory of the firm.

Public utility industries have large fixed investments. They have such large investments in durable equipment that, over a period of years, their most important costs are associated with the construction and maintenance of production facilities. The cost of hydroelectric service, for instance, is mainly the construction cost of the dam, power generating equipment, and transmission lines. And after a natural gas line is laid and the compressor stations are installed, a natural gas company does not incur large expenses of gas transmission. A large "plant" investment and a low rate of capital turnover also are common in other utility industries. Consequently utilities, like other firms with large plant investments, have slow rates of capital substitution. If they make unwise investments, they must make the best of their misfortunes for a long time rather than write off the old investments and start investing anew. If a utility has an excessive plant capacity, many years may pass before the excess is corrected by reinvestments in a smaller plant.

Utilities usually have sufficient plant capacity to serve all consumers who are willing to buy at the existing prices, and commonly have some unused plant capacity. Except for day-to-day storage of gas and reservoir storage of water, utility service is nonstorable. At some time of the day, year, or business cycle a utility experiences the highest demand for service; this is called the "peak demand".

If they satisfy the peak demands, as they usually do, they must plan the plant capacities in advance, making predictions about the sizes of these demands. When plant capacity plans are drawn up and investments are made, utilities build plants that meet more than the experienced, historical peak demands. Extra plant capacity is provided for unforeseeable changes in the peak demands. Building beyond immediate demand conditions, utilities often have "necessary" overinvestments in their plants. The short-run overinvestments are necessary because they are expected to serve everyone who demands service; they must serve everyone regardless of the daily, annual, or cyclical variations in consumer demands.

When a utility is expanding, cost economies can be effected by enlarging plant ahead of demand increases. Compared with a plant that merely satisfies the present demands of buyers, a large plant affords cost economies that can justify the forward-looking construction and the temporary excess of plant capacity. At least a utility does not invest in barely enough plant to meet the existing demand unless decreases in demand are expected, or unless the next minimum addition to the plant capacity is large relative to the anticipated increases in demand. When utilities constructed large natural gas lines from Southwestern and California gas fields to distant markets, they commonly anticipated increases in demand. For some time after these lines were built, they had large amounts of unused plant capacity. To use only part of the available gas plant, they sold an inferior service. An interruptible gas service, which was subject to a short or even 24-hour notice of withdrawal, was sold at nominal prices to industrial buyers.

Most economists agree on one characteristic of utility operations: utility services commonly are produced under decreasing cost conditions. When the output of utility service increases, the average unit cost of production decreases. Those who speak of utility industries as decreasing cost operations usually do not explain the sense in which they use the idea of decreasing cost. Apparently they think of average cost changes when the plant capacity is fixed. If a short view of costs is taken and the existing plant is examined, it is easy to show a decreasing cost condition over a considerable range of output. This is true because some of the total costs of service, such as plant depreciation and investor returns which are familiarly known as fixed costs, do not vary with output changes. Starting with a small output from the established plant, the utility has a high average cost of production because the so-called "fixed" costs are divided among only a few units of service. As the output increases, the same or nearly the same total of fixed costs is spread over more units of output and the average cost decreases. This is obvious when the off-peak service expands; this kind of service requires no additional investments in the basic plant capacity. Likewise, as the regular output expands toward the optimum output of the plant, the fixed costs become a smaller part of total costs and the average cost declines. Using a simple illustration such as Figure 1, we can see that, as the demand increases from D_1, to D_2, and even to D_3, the average cost decreases; until the output is extended beyond OQ_3, the average unit cost decreases.

FIGURE 1

Short-run Average Cost Curve

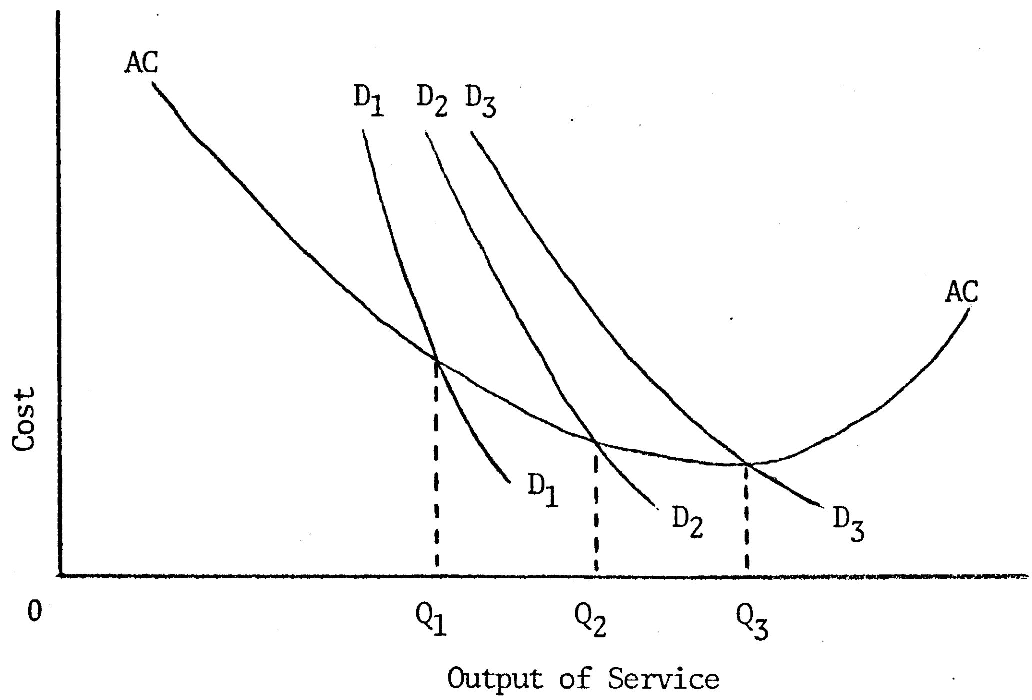
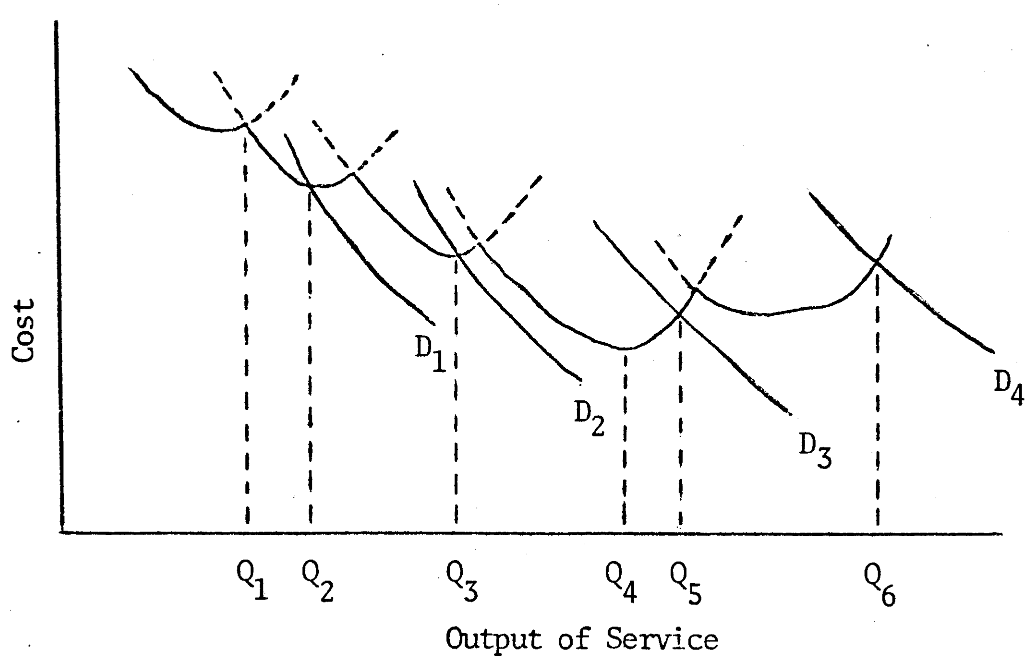


FIGURE 2

Long-run Average Cost Curve



When the plant capacity is fixed and the total costs are divided by small as well as large amounts of actual output to determine the average costs of production, a condition of decreasing cost is bound to be measured. Indeed, when a durable plant is taken for granted and average costs are measured in this manner, any kind of productive activity, either utility or nonutility, experiences decreasing costs of operation. Yet, even if these conditions of cost measurement are accepted, the average costs do not always decrease. If the utilization of an existing plant is pushed far enough, a condition of increasing cost rather than decreasing cost prevails. Such a condition is shown in Figure 1 when the average cost curve slopes upward beyond output OQ_3. A production operation can experience decreasing, constant, and increasing costs if the range of output variation is unrestricted.

Another measure of the average-cost variations gives a different view of the decreasing and increasing costs of utility services. In this case a long-run instead of short-run view is taken of the cost behavior. The existing plant is no longer assumed fixed; the average costs of production vary with the scales of plant - with the alternative choices of plant capacity. The average costs of production decrease or increase as the plant scales (plant capacity) are changed. It is as though a utility, looking over the various sizes of plants, is computing an average cost for each distinctive choice of plant. Before the point of optimum production is reached, the average costs decrease; beyond this optimum the average costs increase. In Figure 2, these distinctions are illustrated with different cost curves for several plants.

Each of the average unit cost curves in Figure 2 represent a different technical condition of operation. And the solid, scalloped line shows the minimum average costs of producing different amounts of service. Further technical innovations may lower the position of one or more of these average unit cost curves, but the difference in the plant-cost curves is likely to persist. If, for instance, a larger output than OQ_1 is planned, the company does not invest in a plant with an AC_1 curve; the second scale of production is used as long as the AC_2 curve is below any other cost curve; the third scale of operations is used when the AC_3 curve is less than any other cost curve, and so on. Given these cost conditions, the average costs of production - the solid line - generally are decreasing through the first four scales of production. When the demand increases from D_1 to D_2, the average unit cost of service (measured by the intersection of the several D and AC curves) decreases; the average unit cost of an OQ_2 output is higher than that of an OQ_3 output. But the average cost of production can increase too. When the demand increases to D_3, the D_3 curve intersects the AC_4 curve at a point that is above the optimum output of OQ_4, and a condition of increasing cost is encountered. If output is extended by a D_4 demand to OQ_6, a still greater increase in the average unit cost of production is incurred.

If the scale of production is extended far enough in any productive activity, the average costs probably increase. Although the literature usually overlook the possibility of increasing production costs in the electric and gas industries, writers on public utility subjects have observed an increasing cost condition in telephone service as the state of telephone technology then existed. Since the maximum number of telephone connections increases geometrically as the number of subscribers increases, they say that telephone utilities, expanding their scales of production, operate under a condition of increasing costs. This explanation puts emphasis on the increasing costs of switching calls, and does not allow for a decreasing cost condition for small telephone plants. Telephone utilities may experience both decreasing and increasing costs as they expand from small to large production scales. One study, which was made for Minnesota and Iowa companies, showed decreasing costs per station (subscriber) for small plants.[14] The average total costs decreased up to 1,000 stations, were approximately constant between 1,000 and 4,000 stations, and started to increase after the telephone plants had about 4,000 stations - after the communities had about 15,000 to 20,000 inhabitants. Other costs of telephone service may increase also. Installing underground conduits instead of overhead lines, paying higher wage rates for maintenance work, and building a wide expanse of lines and plant, a local telephone utility incurs increasing unit costs as the output expands.

In summary, this view of public utility economics presents the concept of "economies of scale" in the long-run cost behavior pattern in which the capital invested in plant capacity is no longer assumed fixed and the average costs of production vary with the scales of plant - with alternative choices of plant capacity. It should be remembered that the economist's definition of "short-run" permits the quantities of labor and material devoted to production to vary but fixed capital investment in plant and equipment must remain constant, while the definition of "long-run" permits changes in the capital base as well. Also the literature on public utility economics suggests that: (1) the output produced displays the characteristic of being non-storable, i.e. if the unit of service is not consumed as it is produced it may be lost, to some degree, forever; and (2) public utilities have large fixed investments in the form of durable plant and equipment capital goods relative to the amount of labor needed for production. A closer examination of this latter characteristic is worthwhile and is treated in another body of literature.

B. THEORY FROM DEVELOPMENT ECONOMICS

Development economics yields some useful concepts concerning the capital versus labor characteristics of the production operation. It suggests that some short-hand terms may be used to describe particular relationships. When, as in the case of public utilities, the production operation calls for very large capital investments in plant and equipment relative to the amount of labor needed, the production operation can be termed "capital intensive". And the converse: when the production operation calls for large amounts of labor relative to the capital investments needed in plant and equipment, the production operation can be termed "labor intensive". It might be noted at this time that the production of some urban public services might be described as capital intensive production whereas others might be described as labor intensive.

More can be said about the production operation than to merely define descriptive categories. Figure 3 depicts the curve of a "production function". The curve represents the production of only one good or service. However, it points up the fact that the good or service can be produced by a combination of different amounts of alternative resources -

FIGURE 3

The Production Function

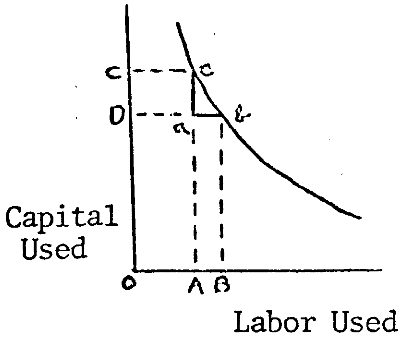


FIGURE 4

Incremental Production Function

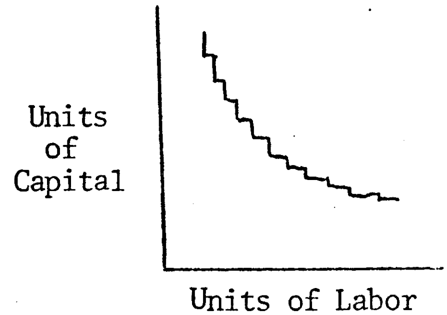


FIGURE 5

Economical Production Combination: Exchange Ratio and Production Function

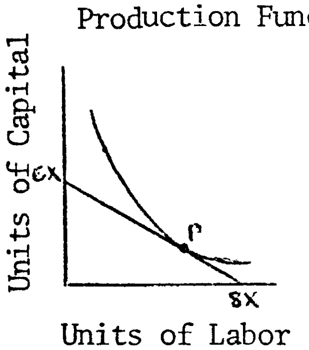


FIGURE 6

Capital Intensive Production Function

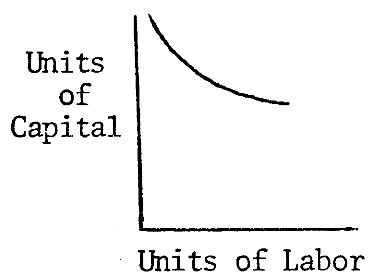


FIGURE 7

Labor Intensive Production Function

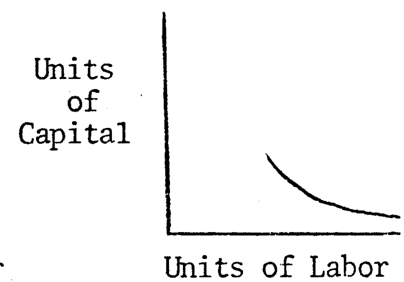


FIGURE 8

Non-Continuous Production Function

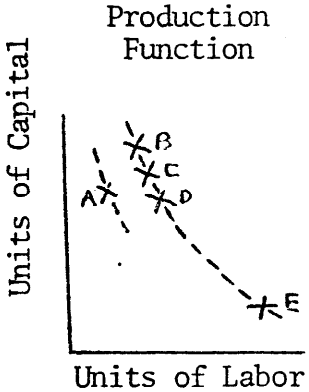


FIGURE 9

Effect of Labor Saving Innovations on a Production Function

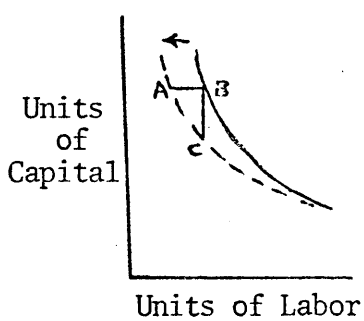
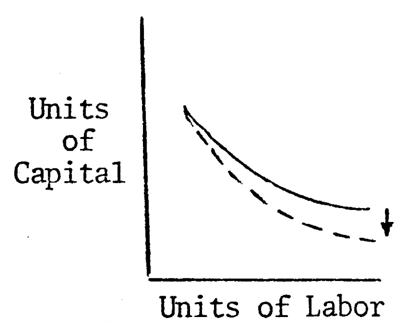


FIGURE 10

Effect of Capital Saving Innovations on a Production Function



capital and labor. It might be argued that land should be considered as one of the resources. It will not be considered as such here for the reasons that: (1) considering only two resources makes for ease of analysis and (2) very little land represents a resource which has not been produced by a substantial amount of capital investment such as railroads, roads, trucks, nearby villages and the like. The production function is convex to the origin because in substituting units of capital for units of labor, the characteristic of requiring more units of capital to be substituted to reduce one unit of labor is theoretically assumed after a given level of capital has been invested in the production operation. For example, in Figure 3, to reduce the labor used from OB to OA a more than proportional investment of units of capital must be made - from OD to OC ($\Delta C > \Delta L$). The converse also is assumed to hold near the lower end of the production function. The substitution possibilities may be visualized in a step-like curve presented in Figure 4.

What the production function represents, then, is that theoretically, there are many different alternative designs or production possibilities for producing a good or service, each requiring a different combination or allocation of resources. In the selection of the most economical production possibility it is necessary to consider the costs of the use of capital versus the costs of the use of labor over a given time period. The cheapest production possibility is the alternative combination of resources on the production function which is tangent to the exchange ratio between capital and labor in the market. For example, the exchange ratio might be that six units of capital are equivalent to eight units of labor. This concept of the most economical mix of productive resources to combine in the production operation is represented by point P in Figure 5.

Figure 6 represents a capital intensive production function in which the number of units of capital at any "technologically possible" point on the production function is greater than the equivalent number of units of labor required for the operation. Similarly, Figure 7 represents a labor intensive production function. What is meant by "technologically possible"? In considering the production function thus far, it has been assumed that it is continuous - all combinations of capital and labor could equally well produce the good or service. Such is not the case in the real world. In actuality, there may only be a few combinations which have been designed by engineers which will operate technically, i.e. there is an engineering limitation or restriction on the number of possibilities. Thus, instead of a near infinite combination of production possibilities, a true-to-life production function may appear more like Figure 8 with each X representing the known plant designs technologically feasible for production of the good or service and the dotted lines representing the engineer's rough locus of probable plant designs feasible.

In the United States there has been a long trend downward in the cost of capital relative to the cost of labor. Thus there has been an incentive to substitute more units of capital into production possibilities with a reduction in the units of labor. The attempt to infuse more capital into the productive process has been the basis of new technological innovations throughout our "industrial revolution". It has led from inventions in the early days, to mechanization, and to automation today. Technological innovation in the United States has become an expressed objective and large sums of money are expended each year on the development of new production techniques. Production technique A on Figure 8 represents a "labor saving" innovation with respect to the other alternative production technique B, C, D, and E, and most of all of the innovations of American technology have been "labor saving". Figures 9 and 10 represent shifts in the production function resulting from innovations tending to be "labor saving" or "capital saving" respectively. The dashed curves in Figure 9 and 10 are said to be relatively labor saving and relatively capital saving. To determine whether the new production possibility is actually labor or capital saving, one must take the old production technology, as point B in Figure 9, and calculate the percentages saved of both labor and capital. For example, assume that the new production technique lies along the arc between points A and C: the new technology would use less of both capital and labor. If the new technology saves 5 per cent capital and 40 per cent labor over the technology applied in the production technique employed at point B, then the innovation is "labor saving".

One more point should be emphasized: the production function, non-continuous as it may be, as illustrated in Figure 8, is a purely technical matter. The actual production possibilities in real life are limited by physical and engineering considerations. However, the choice between the alternative production technologies available along one or more production curves is a concern for an economist. As suggested in Figure 5, it is the economist's determination of the exchange ratio between capital and labor which should be used to select the most economical production technology along the production function.

1. Sample Application to an Urban Service

The following is an illustration of how the production function concept may be applied to the provision of an urban public service. Refuse accumulates at about three pounds per capita per day. This amounts to at least 1,000 pounds per capita a year or a sanitary landfill of about 2.25 cubic yards of space. Thus, there is a need for the production of an urban service - refuse disposal. Over the years several different production technologies have been developed and offer alternative production choices. Several of the production technologies to be considered as an illustration are incineration, composting, sanitary landfills, open dump and on-site disposal.[15]

The disadvantages of an incineration are that it requires sizable capital investment and is expensive to operate and maintain. However, an incinerator can be operated without being a nuisance. For every ton of refuse that is burned in an incinerator, 15 to 20 pounds of fly ash are produced. This fly ash must be removed before it escapes into the atmosphere. It is not difficult to remove the first 50 to 70 per cent of the ash; however, the remaining 30 per cent presents quite a problem. Thus, air pollution, and in some locations truck traffic, can present problems. There are many scales of incineration plants and costs range from $4.00 a ton to $8.00 a ton.

A second production possibility is composting, which attempts to produce something useful out of refuse. There are a number of alternative production techniques of composting. The plants in Israel do it out in the open. However, in American metropolitan areas it would more likely be done in enclosed buildings. The high-rate, mechanized composting performed in an enclosed building consists of four basic operations. Mixed garbage is brought into the plant building. Next it is taken by conveyer belts through a series of picking tables and magnets which remove the metals. Paper and cardboard are not removed for they are really cellulose and cellulose composts very easily along with the garbage. It then goes into a grinder which can reduce glass to sand. Lastly, it is fed into vats which are moisture-controlled and heat-controlled. The materials digest by means of low temperature burning for a period of five to seven days. The pulpy sort of material which emerges can be used as a supplement to fertilizers and exhibits the desirable property of retaining a volume of water from three to five times its weight. One local government recently contracted to have its refuse composted for $4.35 per ton.[16]

A third production possibility is the use of a sanitary landfill. This technique of disposal requires a relatively large parcel of land and a bulldozer in the way of capital resources. The bulldozer digs a trench and the refuse is filled into the trench. Each day the refuse is covered with the dirt extracted to make the trench. If this productive technique is carefully performed, it will neither become an eyesore nor attract rodents. It can be operated in a manner that will safeguard the quality of the surface and ground water. The major disadvantage of the sanitary landfill technique is that it consumes large quantities of land to dispose of the refuse. The cost of this technique ranges from $1.25 a ton up to $3.00 a ton.

Another production possibility is the operation of an open dump. Here refuse is dumped on the surface of the land and remains exposed to the elements and rodents, as well as the sight and smell of residents. Sometimes modifications can be made to reduce their undesirability; however, most would agree that this technology should no longer be tolerated even though it is widely in use.

On-site disposal, the last disposal technique considered here, requires each resident to dispose of his own refuse. This could mean that a household would need an incinerator for combustible materials and a garbage grinder for garbage. There remains a problem of what to do with tin cans, ash, and big bones which won't go through the grinder. It is believed that a pick-up once a month instead of several times a week would suffice. This method has been tried in a number of small communities. Only one large city has attempted this disposal technique. Detroit passed an ordinance which required on-site disposal. The initial problem was the serious amount of air pollution created from the available home incinerators. The city worked with a gas company in developing an incinerator which satisfied its air pollution code requirements; but, after the incinerator was developed, it was found that the local housewives couldn't be trained to operate the incinerator properly. Apparently different sizes and types of materials introduced into the incinerator created problems.

Although there exist other techniques to produce refuse disposal service, these five will suffice. It might have been noted that each technique called for different combinations of capital and labor, strictly from the engineering standpoint. Another observation is that the first technique required that the local government incur large capital expenditures and high operating and maintenance expenditures whereas the last technique required significant capital investment and labor contributed privately by each resident.

It is not uncommon to find such a range of productive technologies as well as differences in the incidences of who will bear the capital and labor costs, although the argument could be made that in the final analysis private residents pay one way or the other. For example, electricity is frequently produced privately through a home generator. Techniques for producing water service range from private springs and wells to very large water treatment plants. Techniques for producing sewage disposal range from privately operated cesspools and septic tanks to gigantic public sewage treatment plants.

Another observation to be made from the examination of the refuse disposal techniques is that there may be more costs to be attributed to a productive technique than merely the production costs expressed in units of capital input and units of labor input. Some undesirable by-products result from different techniques: fly ash, air pollution, rodents, odors, eyesores, and underground water pollution. These are costs which are borne by the community external to the productive operation of refuse disposal. They have been called external diseconomies. Economic development literature has offered some helpful concepts to structure the thinking and terminology of this area of production costs.[17]

2. The Issue of Externalities

The first distinction is between external and internal economies; the second, between pecuniary and technological. See the matrix below.

	Internal	External
Pecuniary	1	2
Technological	3	4

Internal economies are those within the production operation; external economies are external to the productive operation but available to other productive operations. Pecuniary economies arise from a change in the price of capital or labor, or an intermediate good or service which combines these factors, or a cost of distribution. Technological economies are realized when a higher scale of output permits a lower input per unit of output to be realized in physical terms.

1. Internal pecuniary economies are those accruing within the production operation as a result of changes in the factor prices of capital and labor or an intermediate good or service. This is a case in which a productive operation can buy factor inputs more cheaply as its scale of operation increases. This situation is probably rare; while quantity discounts may be achieved on larger material purchases, larger labor inputs may lead to higher costs due to unionization and collective bargaining. Perhaps internal pecuniary diseconomies are more frequently encountered.

2. External pecuniary economies are those accruing to all other production operations as a result of changes in the price of factor inputs, or an intermediate good or service, usually resulting from internal economies achieved by a supplier with the increased efficiency passed along in the form of lower prices, or a lowering of the cost of

marketing (distribution). When the markets to which the service is distributed are small and fragmented, it is necessary to incur marketing costs to move production. The external economy is realized through reducing marketing costs. The organization of formal or informal markets can play an important role in the achievement of scale.

3. Internal technological economies are those accruing within the production operation resulting from the division of labor, the use of specialized machinery and other capital equipment with considerable capacity. Offsetting technological economies, in some part, are technological diseconomies. These are largely a function of the increased difficulty of organizing, administering, and supervising work as its scale increases. The net result of the set off between internal technological economies and diseconomies is the presence or absence of "economies of scale" for each given productive capacity - the concern of this investigation.

4. External technological economies according to Kindleberger are those accruing to other production operations as a result of two productive operations providing external economies for each other. The classic example usually cited is that of beekeeping. A farmer's bees previously had to fly about a mile to acquire pollen. If a neighboring farmer grows an orchard, the bees can produce more honey at no additional cost. The beekeeper would experience an external technological economy.

Another body of economic literature has discussed the same issues using different terminology and perhaps has made more significant contributions.[18] The literature of public finance discusses the concept of "spillover" costs and benefits and "spillin" costs and benefits with respect to small jurisdictions within a metropolitan area. The categories defined do not face the issue of technological versus pecuniary economies; however, the terminology does stress "internal versus external" to the jurisdiction being examined and it properly points up the negative aspect as well as the positive side i.e. diseconomies as well as economies.

	Internal	External
Economies	Benefit Spillins	Benefit Spillovers.
Diseconomies	Cost Spillins	Cost Spillovers

The four descriptive classifications are not tainted with a connotation of "production" of services but instead with a connotation of "financing" services. The question of financing the production of urban public services is not within the scope of this investigation and in a federal system which successfully channels considerable sums through tax sharing and grants-in-aid from higher governmental levels to local governments to finance the production of urban services, a convenient separation may be made for the purposes of analysis between financing and production.

Yet, because legal jurisdictions and governments do not coincide with economic boundaries, the former generally being many in number for each of the latter, public finance economist Otto Eckstein properly points up the problem of physical interdependence:

> In the economist's jargon, the typical area is a nest of spill-overs, of physical interdependence, and of economies and diseconomies external to individual communities.[19]

Emphasizing that the question of improved planning and potential cost savings versus increased governmental centralization is one of value, Eckstein illustrates some of the problems of ignoring physical interdependence - in large part problems of scale:

> The division of the metropolitan area into many legal communities makes it particularly difficult to provide those public services for which the metropolitan area has to be considered a unit for physical reasons. It makes no sense to plan transportation on other than an area-wide basis because of the typically long distances separating people's homes from their places of work. A rational road network must be able to move cars freely within the area. Mass-transit systems, subways or buses, also should be laid out on an area-wide basis. Yet, it is usually only the core city which feels it has sufficient stake in such a system to give it active support; the commuter suburbs are happy to have residents drive into the city and then let the city worry about the congestion of streets and downtown parking.
>
> Water supply is a similar problem. To obtain a supply of high quality water at low cost frequently requires the construction of a large reservoir at some distance up in the mountains. In the absence of unified area planning, localities improvise their own supplies, out of wells and other sources. The ground water level may gradually fall as supplies are depleted. The pumping process slowly raises pumping costs to the town and neighboring communities. Having made the investment in the pumping facilities, they are slow to abandon them, and are reluctant to participate in building a cheaper, better common system.
>
> These cases illustrate the point that the scope of particular governments must match the physical contours of the problems. . . . When physical interdependence is ignored, decentralized decision-making does not lead to efficient results. The costs which localities consider in their choices are not the full social costs to the area.[20]

While Eckstein's examples yield less theory than fact and opinion and while he exhibits a strong normative bias for area-wide decision making, this professor of public finance presents a viewpoint on "physical interdependencies" which is valuable, and his examples illustrate many instances of external and internal economies and diseconomies.

3. Indivisibilities and Other Issues in Economies of Scale

More may be said of internal technological economies which result in economies of scale. Economies of scale are said to exist if when the inputs are doubled into the productive operation, the output produced will be more than doubled. This result corresponds to a "decreasing cost operation" and is often called an "increasing returns to scale" condition. If the output exactly doubles, it is a constant cost operation and a constant returns to scale condition has been achieved; however, the latter is the limiting condition for the concept of economies of scale. There must exist some increasing returns to scale (i.e. decreasing costs with increased scale) before the productive technique is said to exhibit "economies of scale".

Again, economic theory usually assumes that there is an infinite divisibility of capital and labor. Actually, frequently indivisibilities exist. Earlier it was stressed that engineers had not designed and built plants to operate at every capacity along the production function. Thus, it may not be possible to take a plant which now experiences economies of scale, cut its inputs in half, and expect it to experience economies of scale afterward.

Perhaps the most pervasive source of indivisibility is the labor input. Employing less than one individual (i.e. using part-time labor) usually involves rather substantial increases in costs as compared with what they would normally be if an individual's full-time services were utilized. On the other hand, the advantages of division of labor and specialization as described by Adam Smith lead to substantial economies through the use of several individuals in specialized tasks rather than a smaller number of Jacks-of-all-trades. It may be so that certain pieces of equipment are indivisible, e.g. a half an ambulance or garbage truck may not be purchasable. If the individual equipment in the productive operation has reached the optimum size, further expansion of the production operation is possible by increasing the number of production units operating in parallel.

If a doubling of output is attempted by running two or more duplicate production operations under a single management, the character of this management is likely to experience a change and this change is likely to be in the direction of increasing costs. With additional layers of managerial supervision, minimum ratios or differentials between salaries are often higher than what would be required by a perfectly competitive market. And at some stage in the growth of the production operation an increased volume of paper work and communications, a dilution of incentives, and an increase in auditing and performance measurement may outweigh the advantages of specialization. Economist William Vickery has made the following observation of business firms:

> Thus it is at least admissible to suppose that at some point, as the size of a firm increases, the possibilities for further economies of scale on the technological side diminish to the point that they are outweighed by diseconomies of large-scale management. A point of diminishing returns to scale may be reached in this way. . . .
>
> However, these diseconomies of scale in the field of management are at best not nearly so striking as the technological economies of scale, particularly as we pass from medium to large-sized firms. While these diseconomies may be fairly substantial as we pass from the one-man business to the small establishment in which the entrepreneur is in close and direct contact with all of his employees, and as we pass from such a scale to the next in which this direct contact is largely lost or at least greatly impaired, and perhaps even somewhat beyond this, it appears on the whole likely that once the stage has been reached where a fairly elaborate managerial hierarchy is required, further expansion produces few if any diseconomies of this sort.[21]

The question must be raised: at what scale in the provision of each individual urban public services and its subservices do the diseconomies incurred in larger management level off such that technological economies of scale may truly be felt? Australian economist, G. M. Neutze,[22] has crudely tested the assertion that large local governments become top-heavy and that their administration is inefficient and expensive. He has examined the administrative fraction of total expenses for all the municipalities in New South Wales. The results are presented below.

TABLE 1

PROPORTION OF ADMINISTRATIVE TO TOTAL EXPENDITURE, N.S.W., 1957

Population of Municipality	Administrative expenditure as a % of total expenditure (mean)
Less than 25,000	9.9%
25,000 - 50,000	7.8
50,000 - 75,000	7.4
75,000 - 100,000	6.5
100,000- 125,000	6.5
125,000- 150,000	6.0
150,000+(Sydney city)	8.6

He comments on his findings: "This table includes individual L.G.A.s within Sydney. It supports the idea that there are economies with growth but the high cost in the special case of the City of Sydney is not very convincing evidence of diseconomies."[23] Besides certain indivisibilities in both labor inputs and plant capacities designed by engineers, there exist other limitations to achievement of economies of scale. The consumption area for the urban service produced may be so small that it cannot support a productive technique which experiences an economy of scale, unless there is a market for the service created by surrounding communities.

In relation to the size of market for the service, the cost of acquainting a given body of consumer residents with the properties of a service may be virtually independent of the output level of production. If anything, this cost is likely to diminish as output increases: as the volume of use of a given service increases within a given area a certain amount of word-of-mouth advertising (i.e. awareness) will take place at no cost to the producer; thus there may also be economies of scale in publicity as the potential distribution area is enlarged, since some forms of advertising media are prohibitively expensive unless the product has a wide distribution. The provision of public health services normally requires an active education program in health. Not only does a larger scale of production of this service justify a media form which may more successfully publicize the availability of the service, but without knowledge of the free services available, the public will not consume this service in sufficient quantities such that technological economies of scale may be achieved i.e. that the high fixed costs of producing the service will be spread over an increasing output of service.

Lastly, there may be an absence of some social overhead investment or infrastructure, a large "lumpy" capital investment such as a road network, sewer "distribution" system, dam, water reservoir or catchment basin, which stands in the path of adopting the productive technique offering scale economies.

C. THE ROTHENBERG MODEL

Urban economics, as well, provides some theories relating to economies of scale. Jerome Rothenberg has addressed the question of how economies of scale are related to the size of political jurisdictions and although he has developed a much more elaborate positive and normative treatment of problems associated with local governments, this investigator is hopeful that the following abstraction will not interject misinterpretation.[24]

Rothenberg views the task of local government as twofold: (1) to provide the right mix of public services in the right amount and (2) to produce this mix of services efficiently. The first task deals with the smooth workings of a political representation process which is all too frequently assumed to adequately fulfill the first task. The second task must be tackled from two quite distinct approaches: (1) What are the resource costs of producing the mix of services at the desired level most efficiently?, and (2) What is the size and importance of the "political" externalities in the exhaustive set of local governments.? By the latter, he refers to the dollar costs and dollar benefits of spillovers and spillins among "political" jurisdictions.

On the first task he argues that the "right" mix and amount of services to be provided rests upon the preferences of the residents in each political jurisdiction, which residents are highly sensitive to not only the content of the mix and the quality/amount of the service but also how they are charged for the mix of services. He suggests that an individual enjoys the choice of many close substitute jurisdictions within a metropolitan area in which he may continue to experience relatively the same environmental conditions (cultural activities, newspapers, social community, work community, law, and so forth) yet, be subject to quite a range of service mixes and levels and therefore costs. The individual may register his satisfaction or dissatisfaction with the service mixes offered through his mobility, by moving to or moving away, and that moving costs appear to be presenting less of an obstacle to satisfying his preferences. Local governments operate under severe constraints in providing attractive service mixes when individuals can economically afford such sensitivity. Actually, commercial and industrial residents may not be able to enjoy such sensitivity. They are constrained by sources of raw materials, sources of labor, location of markets, available land, adequate transportation facilities, and after located - heavy fixed investment and high moving costs. Thus, local governments actually have more leeway in confronting these present or potential residents than they do with individuals.

The degree to which the "right" mix and level of services is achieved would appear from the resident's viewpoint to depend on the number of residents dissatisfied with the mix. The ultimate, in political efficiency would appear to be to adopt policies on which every resident's preferences coincided on mix and amount. In essence, this means a population homogeneous in its preferences within the jurisdiction. As a practical matter - to achieve such "efficient" political processes wherein enough people share like preferences - there is a decided bias for the establishment of small political jurisdictions. Indeed, the small political jurisdiction bias for the reason of satisfying economic preferences is bolstered in American tradition by an historic fear of large governments and a desire for local political participation.

On the second task of local governments, the issue of political externalities is the most relevant to the above discussion, which suggests that the first task might come closer to being accomplished by governmental "fragmentation" - not a bad word per se. The line of economic argument on political externalities, or benefit and cost spillovers and spillins, is that the reason they exist is due to the fragmentation of the economic region by political jurisdictions. The best way to eliminate the undesirable effects of externalities is to internalize them, which would suggest making the political jurisdiction coterminous with the economic region. Of course, the question of where one economic region ends and another begins is too esoteric for this discussion. However, what is suggested and what is very important is that the elimination of severe externalities is competitive and incompatible with the first task of achieving the mix and amount of services satisfying the residents.

It is often assumed that by introducing more externalities a less efficient, sub-optimal solution would result, with respect to the initial conditions. However, if the initial condition is not optimal, a decision which introduces more externalities may indeed make the result more optimal. The same sort of logic applies to a tangential albeit related issue:would it be appropriate for a local government to adopt the objective "minimization of costs" in the fashion that business firms seek to "maximize profits". The answer is: it all depends. . . . If the decision to minimize costs is undertaken when the first task of local government has been achieved, i.e. the "optimal" mix and amounts have been determined, then by minimizing costs a more satisfactory economic optimization may be obtained than would be achieved without it. But if the first task remains sub-optimal, then adopting the objective of cost minimization may do more harm than good.

Now, consider the next issue in the second task of government: the efficient use of resources. Is the local government most efficiently producing the mix and amount of services? The Rothenberg model provides a very strategic role for the answer to this question, which is essentially the question of economies of scale. If a continuum can be visualized with one end labeled "right mix and right amount of services" and the other end labeled "complete absence of political externalities", then the role for economies of scale in the provision of services is to help determine the tradeoff, the location on the continuum between these conflicting and competing objectives. Unfortunately, one of the serious complications happens to be that economies of scale may exist for several services but that the scale for each may be different.

A solution to this dilemma does not follow from establishment of one or more single function special districts to take advantage of economies of scale. It is true that economies of scale may be achieved but it is only one of three criteria which local governments must balance. By maximizing the returns from economies of scale, the local government not only does not solve the two issues of "mix and amount" and "political externalities" but it may seriously impair its ability to do so. Such an approach assumes that service functions are separate and discrete - that they are not interrelated. It is pragmatically experienced that they are often highly interrelated and efficient production costs is likely not the key criterion to handle the interrelationships and the problems of coordinated operation. Another disadvantage is that residents prefer to make decisions on the basis of whole packages or mixes of services where the tradeoffs are apparent.

Rothenberg suggests that a search for an optimal city size may be as futile as the search for the Holy Grail. Rather, as the two parts of the second task of local government are subject to quantification and objective standards while the first task remains in the realm of value judgements, efforts should be devoted to develop good information on externalities (spillovers and spillins) and efficiency (economies of scale) such that better decisions can be made in tradeoffs with local autonomy.

D. MUSGRAVE'S EXPANSION OF VARIABLES

Having set so many theories in motion as a foundation to thinking in economic terms about economies of scale, it is now appropriate to introduce complexities. Earlier in this theoretical discussion, economies of scale were suggested to be represented by a long-run decreasing cost curve presented in the economic theory of the firm. It will be recalled that in the long-run, the amount of capital invested in plant could be varied and a potential producer could be faced with a choice of many alternative plant capacities, each promising a different average unit cost of its output at its optimum production volume. If he would forecast the output needed to serve his market, he could then select the plant capacity offering the lowest average unit cost over his expected range of output. By building this plant capacity and operating it as an economist would, he would experience the economies of producing "optimally", for he had selected the most efficient scale. The curves presented in Figure 1 and 2 depicted two variables: units of output and average unit cost. However, an implicit assumption was made about the output produced. Each unit of output was assumed to be homogeneous. In mathematical terms: cost and output could vary but quality was held constant.

Actually the producer of urban service, local government, is much more complex than a business firm, and urban services tend to be more complex than the traditional text book product of the firm - "widgets". Therefore, there is, and there should be some hesitation to apply theories about profit motivated business firms to local governments. In many areas they do display strong similarities, but strong distinctions usually accompany each case of similarity. In considering the cost curve for the production of an urban service, there are in fact more variables to be contended with than the basic two underlying the curves in Figures 1 and 2 (cost and output). The number of variables need to be expanded when it is admitted that the economies of scale for urban public services may be "spatial" economies of scale and when variations in quality not only blatantly exist but are desired. Public finance theorist Richard A. Musgrave, to this investigator's knowledge, has been among the first to tackle this expansion of variables.[25] The following is a statement of Musgrave explaining his view of "spatial" economies of scale.

Actually, the supply of any one service may be organized such as to cover a smaller or wider region. A block may be lit by one large light in the middle of the block, or by several smaller lights spaced along the street, and so forth. The choice of the benefit area thus becomes a variable in the policy decision and has important bearing on the cost at which the service is rendered. The supply of public services is subject to economies of scale, and the appropriate service region is one of the dimensions of this problem.

Among the variables are the service region R, the population density D, and the level of services L that is to be provided. Holding constant D and L, the cost of rendering the public service will vary with R. As R is increased, more people participate in the service benefits, which (for any given total cost) reduces cost <u>per person</u>. But the total cost (to the group) of rendering a given service level may vary as well. It may fall as the region to be serviced is increased up to a certain size, and rise if the region is expanded beyond this point. Sooner or later, the latter factor may come to offset the gain from increased numbers, and per person cost begins to rise. If so, there is an obvious advantage in choosing the low-cost region and in adapting the number of service regions accordingly, depending on the size of the entire area to be covered. This consideration is of major importance in urban finance, where traditional districts may be too small for efficient supply of certain services and a metropolitan area-wide unit is called for.

Another aspect of the scale problem appears if R and D are held constant while L is varied. The average unit cost of services may now decline as the service level L is increased, and rise if raised beyond this. Finally, holding constant R and L, the cost per person may be found to vary with D. As D is increased, the cost to any particular individual tends to fall because any given total cost is shared among more people. But as density increases, the <u>total</u> cost of rendering the service may again fall up to a point and then rise. The net effect on cost <u>per person</u> will again be declining up to a certain level of density and may rise thereafter. Moreover, density if carried too far becomes a disutility which must be weighed against possible reduction in per-individual cost of public services.

The determinants of the regional structuring of public services are thus two-fold. Not only should the supply of particular services be organized such that costs are allocated to and policy determination is made by those residing

> within the benefit region, the size of the benefit region should also be determined so as to comply with least cost considerations.[26]

Note how Musgrave weaves back and forth in the labeling of variables from regional size versus per capita cost, to service level versus average unit cost, back to density versus per capita cost. Per capita measures are very useful in public finance for it is convenient to aggregate per capita expenditures for different services and have a feel for the average revenue per capita which must be raised from all sources to cover governmental expenditures. Per capita measures are also convenient for purposes of comparison with other communities. However, per capita measures are of questionable value when the issue is that of lowering the production cost of a unit of service.

This investigator believes that this expansion of variables yields new insights into the complexities of efficiently providing urban public services. Theoretically, before the question of measurement is addressed, it is necessary to establish the relevant variables for the cost functions dealing with urban services. It is suggested that at least the following variables are essential:

1. Cost of a unit of service (average unit cost)
2. Number of units of service produced (output)
3. Quality of the service
4. Density of the service area

Variables 1 and 2 are in the judgement of the investigator required to maintain the "efficiency of plant production" concept.

Variable 3, quality of the service, may on occasion be somewhat interchangeable with Variable 2, the number of units of service produced. For example, on the quality scale, "poor" refuse collection service may be equivalent to one pick up a week, "fair" service - two pickups a week, and "good" service - three pickups a week. If the unit of service produced (Variable 2) is a pickup at a dwelling unit, then care must be taken to account for the similarity in measuring Variable 2 and Variable 3 and its effects upon analysis.

Variable 4, density of the service area, is much more complex. Normally, one thinks in terms of the number of people per unit of area. Actually, why couldn't there be one variable, "number of people" and another "number of area units?" Indeed, this could be done. A curve of average unit cost for service "X" could be plotted against increasing numbers of people. But, from the standpoint of usefulness, the cost curve may only be meaningful if the area being served is held constant throughout the measurement. The converse is likewise true: cost versus area just might be useful only if the number of people served is held constant. Although it may not be possible to proceed with measurement unless some control over either population or area is introduced, it may be more convenient to approach this problem through the concept of density for other reasons to be mentioned later.

Assuming the two variables of population and area, with density being the ratio between the two, it is possible to visualize the variable of density versus the variable of cost but only permit one portion of the density ratio to vary. For example, if a constraint is placed on the denominator, i.e. <u>any</u> given quantity of area is held constant for the experiment, the numerator (population) may be completely free to vary, and thereby variable 4, "density", will likewise vary over the "fixed" area. Similarly, the constraint may be placed on the numerator of the ratio, such that any given population may be held constant for the experiment while the units of area and, a fortiori, the density be permitted to vary versus cost. Leastways, it does not appear that harm will be done by working with the concept of density in this fashion.

Not only does this approach lend itself to emphasize the consideration of alternatives because it is necessary to consider the effect between average unit cost for service "X" versus density when population is 10,000, 20,000 or 100,000 or when service area is 10 sq. mi., 20 sq. mi. or 50 sq. mi., but it lends itself to thinking in terms of other relevant densities. The cost of providing some urban public services may not be highly related to population at all. In fact, some statistical studies made to isolate the determinants of per capita expenditures for different urban services have discovered that neither size of population or population density contribute significantly to the explanation of why per capita expenditures differ for a particular service from one city to another of different population size or average density.[27]

What may be more relevant than population density in the provision of certain urban services may be dwelling unit density or capital investment density, or income density or school-age density or commercial use density. The investigator knows of no serious efforts to examine such densities versus the costs of units of service. Seymour Sacks has presented findings for the cities in New York state that indicate that assessed industrial property valuation per square mile is positively correlated with city expenditures on general operations, sanitation, and fire protection.[28]

With the above contributions of different branches of economics, a model describing the role of economies of scale in determining tradeoffs between local autonomy and the lessening of externalities, and an introduction to the complexities of defining economies of scale when the variables of quality and density are introduced, the pragmatic considerations of measurement may now be addressed.

The problem in social science is performing controlled experiments on social phenomena. In the absence of such experiments, scientists must use data generated in a single, complex, uncontrolled experiment that is the history of society.

Herbert A. Simon

III. MEASUREMENT CONSIDERATIONS

Shortly after the Advisory Commission on Intergovernmental Relations published its report on Performance of Urban Functions: Local and Areawide,[29] Norman Beckman of the Commission's staff revealed some of the difficulties encountered in the undertaking:[30]

> Like everything else connected with urban life, we quickly become aware of the complexities involved in such a deceptively simple and straightforward question, "How is an urban function best provided?" Two complicating factors should be kept especially in mind in carrying on such a study in a local community. First, each of the 15 functions studied is not homogeneous and discrete. Rather, each such function, be it education, libraries, or air pollution, consists of a number of subfunctions or specializations, each of which must be examined individually. Thus, police administration includes such aspects as foot and car patrol, traffic regulation, and fingerprint identification, all of which may be performed on differing geographic and jurisdictional bases.
>
> Second, each function has to be looked at from at least four different time phases of administration: planning, decision-making, actual administration or execution, and evaluation. Each time phase might call for a different optimal performance area. For example, there could be area-wide planning and agreement on minimum air pollution standards for the entire area, but each municipality might retain responsibility for financing and administering an enforcement program with discretion to enforce a higher standard at its own option.[31]

The investigator is in agreement with Beckman up to this point. But in his illustration of the many subfunctions of police protection he goes out on a limb:

> Many police services are amenable to substantial economies of scale and increased effectiveness, if performed areawide. Specialized services of all kinds, including laboratories, communication systems, homicide, vice control, detective, and other specialized squads, impose prohibitive unit costs unless they serve a population large enough fully to utilize their capacity. A central metropolitan records file can utilize most effectively all the services provided by the national files of the FBI and the state.

> Jails and penal institutions can usually be operated more efficiently on a larger scale. Likewise, traffic control on intercity expressways, as distinguished from local and neighborhood streets, can be handled more efficiently on an area-wide basis. (Emphasis added.)[32]

The above declaration suffers from the same infirmity as the proposals presented in the introduction, too much rhetoric and too few facts. Each word emphasized above is subject to "measurement", but there is a lack of evidence that such measurements have been performed. However, Beckman's comments do serve as an introduction to the complexities of measurement.

A. MEASUREMENT OF QUALITY, QUANTITY AND COST

1. What is the Ultimate Output?

Urban economist Rothenberg has said that the measure of at least some urban services is the measure of probability. He argues that the only service that the public is interested in when it pays taxes for fire protection is a reduction in the probability of injury to life and property by fire; or of police protection: a reduction in the probability of injury to life and property by "persons" under the law; or public health: the reduction in the probability of poor health as a result of pollution, poor sanitation, communicable diseases and so forth. In other words, he would measure functional output from the viewpoint of the public, which is neither interested in the factor inputs of labor, materials and capital into the public health production technique, nor the number of children immunized by public school nurses, the number of milk and food processing operations inspected, the number of restaurants certified as sanitary, the number of plumbing plans for new homes approved, and so forth. In effect, to Rothenberg, all of the factor inputs and all of the sub services produced are merely "inputs" to the service of reducing the probability of poor health or increasing the probability of good health. Of course, in a very real sense he is correct; however, it dodges the issue of measuring economies of scale. It is admittedly more satisfying for an econometrician to work with outputs measured in probabilities than in an abundant number of rather mundane sub-service outputs and their variety of unit dimensions.

2. Are the Tools of Public Finance Applicable?

What have the students of public finance, a branch of "applied" economics had to offer? Dr. David C. Ranney, a recent graduate of the Maxwell School at Syracuse, makes the following admission of "heroic" assumptions:

> [N] o useful measures of the actual outputs of municipal services have been developed by public finance specialists. For this reason, the inputs or per capita expenditures have been used as an index of service demands on the assumption that local government officials are responding the best way they can to the demands of their constituents.[33]

How have students of public finance handled the variable of quality i.e. level of service? Again Dr. Ranney candidly reveals:

> [N] o precise measure of service "levels" has been determined. To remedy this situation, students of public finance have generally taken the unit service inputs (per capita expenditures) as a rough index of relative service levels.[34]

It must be concluded that literature concerning the subject of economies of scale written by those whose unit of measure is per capita expenditures of any given service must be studied with appropriate caution. Other reporters may not be as careful as Dr. Ranney in spelling out the assumptions concerning the measure used.

The dangers of the per capita expenditure measures are the following:

1. Per capita expenditures for a particular functional service (usually the public finance investigator goes no lower than the department or bureau level, ignoring the variety of sub-services produced) is calculated using the actual total expenditures for the service over a given time and the population of the local government. However, actual total expenditure figures for a service disguise differences in the level of service or quality. Ignoring the effects of variation in the density measures discussed earlier, a local government may spend X dollars to provide function Y to its population Z, and achieve an "excellent" quality of service by some objective standard; however, its metropolitan neighbor, which also has population Z, may likewise spend X dollars to provide function Y, but achieve a "poor" quality of service by the same standard. Thus, the per capita expenditures measure leaves the variable of quality uncontrolled, and its use would give an incomplete and inaccurate measure of possible economies or diseconomies of scale.

2. Some investigators of city size versus per capita expenditures have used per capita <u>total</u> expenditures of each local government rather than per capita expenditures by function. Obviously the use of total expenditures, besides suffering the maladies mentioned above, obscures the relationship between <u>specific</u> <u>services</u> and city population. However,

another danger is present here. Total operating expenditures of local governments include expenditures for annual debt service. Debt service is the payment of principal and interest for capital investments purchased over time. In other words, the total expenditures figure reflects a given amount of expenditures for capital items over the given time period. But payments of principal (redemption of municipal bonds for capital improvements) are in no way comparable to the item of "fixed costs" in the economies of scale concept and should not be included. Fixed costs represent wear and tear or consumption of the capital investment through production over the given time, i.e. depreciation, as well as other fixed and semi-fixed costs. The same problem would arise if the debt repayment of principal were distributed or allocated to each function when per capita expenditures by function was under study.

3. Per capita expenditures or actual total expenditures by function represent "inputs" to the production operation, and the economies of scale concept is concerned with "outputs". One is forced to stretch one's imagination and make monumental assumptions to substitute dollar per capita inputs to the production of a service as a proxy for units of output produced in many dimensions by sub-service. Yet, there have been studies labeled "economies of scale" which have done just this.[35]

3. The Ridley and Simon Contribution: Various Measurement Units

Perhaps, the most comprehensive viewpoint developed on approaches to measuring urban services was presented by Clarence E. Ridley and Herbert A. Simon in 1938. In their study, Measuring Municipal Activities, published by the International City Managers' Association, they present a survey of suggested criteria for appraising functional administration.

It appears that shortly after the first World War, some students and practitioners of public administration sought to apply some of the principles of Frederick Taylor's scientific management movement to an objective appraisal of the urban management function. Ridley and Simon made the pioneering effort to establish a general methodology in the above-mentioned classic monograph. Simon has long since turned his efforts to making industrial administration a science and the follow-up of their lead has been largely confined to articles in public administration journals. Ridley and Simon first point to the need for measurement:

> The corporation manager makes decisions on the basis of information furnished him by his cost accountants. But public business is not operated for a profit; and the techniques of cost accounting have only limited applicability. It is necessary, therefore, that other criteria be devised for the appraisal of governmental activities if the citizen, the legislator, and the administrator are to make intelligent decisions.[36]

Next they proceed through the public services of fire, police, public works, public health, recreation, public welfare, public education, public libraries and city planning, establishing a methodology to approach the measurement task. As a quick example of their approach, observe how they go about breaking down the overall objective of fire protection:

It is generally agreed that the final objective of fire protection is to minimize both the fire loss and the fire cost. The total fire loss includes: (1) the value of the property destroyed, (2) losses due to the disruption of business by fire, (3) insurance premiums in excess of losses paid, and (4) personal injury and loss of life. The fire cost comprehends: (1) the cost of municipal fire protection, which is chiefly the cost of operating and maintaining the fire department, (2) the installation and maintenance cost of private fire protection, and (3) the cost of compliance with fire prevention laws.[37]

One can easily identify the "total system approach" advocated by Ridley and Simon as early as 1938. Simon has since referred to this effort as "proto-operations research," and suggested that the state of operations research and management science today "is so remarkably advanced beyond its position before World War II that the difference of degree becomes one of kind."[38] Unfortunately, its advance hasn't kept pace in the local government sector.

However, it is the issue of "possible units of measurement" which Ridley and Simon set forth that are of immediate concern. They suggest that the "need" for a particular service may be established by the physical and social characteristics of an area - its areal size, population, street mileage, economic status and property characteristics; but the question remains: how will the "amount" of service in relation to a given need be measured? They present four alternatives: measurement in terms of results, performance, effort and cost.

They suggest that urban public services are directed at the accomplishment of certain aims or objectives. A measurement of results determines the degree to which a particular objective has been reached - for example, a fire department's results are measured (negatively) in terms of fire losses; a police department's results in terms of numbers of crimes. Note the close similarity of using results as a measure with Rothenberg's measurement of probability. There is an easy transition from the functional service administration viewpoint of results to the public viewpoint of results measured in terms of increases or reductions of risks.

On the other hand, measurement of performance records the amount of a particular governmental activity which has been carried out in pursuance of service objectives. Performance in a police department may be measured by patrol-miles covered, number and thoroughness of investigations, and so forth; performance in refuse collection may be measured by the number of collections and miles of travel.

A measurement of effort records the number of equipment-miles and man-hours involved in the performance of a particular activity. A measurement of cost records the expense (preferably on an accrual basis) incurred in carrying out a particular activity.

Each of these service measurements has a distinctive significance, but which is the most appropriate for use?

As alluded to earlier, from many standpoints it would appear desirable to measure service levels in terms of results, or more precisely, the ratio of results to needs; for citizens are interested primarily in repression of crime, reduction of fire loss, street cleanliness, and the frequency of refuse collection, and only secondarily in the activities which government must undertake to provide them this protection and service. Yet to use results as the measure, they suggest, would necessitate knowledge on how large a fire loss could be expected in a particular area if a given amount were spent on fire protection; how "educated" the children of the area would be if a given amount were spent for schools; and so forth for each governmental service. Definite information on these points continues to remain, for all practical purposes, nonexistent.

With respect to the use of expenditure as the unit of measure: to evaluate the results obtainable from a given expenditure would necessitate knowledge on not only the amount of expenditure, but also the degree of efficiency with which funds were disbursed. Ridley and Simon present the following quip to illustrate their point:

> Suppose someone said to you, "I'm a very efficient shopper. I spent only five dollars today." Your reply would be, "That's all very well and good, but what did you get for the five dollars?"[39]

In view of the difficulties with results and expenditures, focus can be turned to units of measurement which will provide a definite basis for estimates of expenditure, and which will remove from consideration questions of administrative efficiency. They suggest that measurements of performance and effort are best suited to this purpose.

Effort in the provision of an urban service refers to the number of units of resources or "resource-use", which have been acquired by the expenditures on a function and used in its operation. Units of resource may be expressed in terms of "number of patrolmen", "number of pieces of equipment", and so forth, and units of resource-use in terms of "total man-hours", "total equipment-miles", and so forth.

The measure of performance is a refinement of effort, for it is the effect of the application of effort. Performance could be defined more precisely as the number of work units performed, or the amount of work accomplished, in a given time period by a given service unit, including sub-service units. The performance could be that of an individual man or machine, or a crew, or an entire function; it could be given in terms of "number of inoculations", "number of refuse collections", and "miles of street patrolled", among others. The performance of a function can be quantified. For sub-functions such as "fire-fighting" in which performance are sporadic in timing and irregular in intensity, the measurement of performance becomes difficult and there are wide fluctuations in the production of output, usually tending to keep average unit costs high.

The basic measure of efficiency in any form of production is cost-per-unit-produced. Ridley's and Simon's four alternatives are not exhaustive and other students of service outputs have gone beyond the measures above to create new ones.[40] However, not every measure devised or set forth above is the appropriate tool to measure economies of scale. There may be more than one motive in measuring functional activities; depending upon the hypothesis tested, differing measurement tools yield differing degrees of success. At the present state of art of measurement techniques, it would be foolhardy to insist that only one tool yields the true measures. But as the literature and thought out of which the economies of scale concept developed consistently used cost-per unit-of-output as the measure of efficiency, this investigator holds that until extensive testing with this tool has proven to be fruitless, or until some justification for departure from this measurement tool is presented - and well it may be for the variety of urban public services is great and complex - then investigators logically should attempt to postulate, measure and evaluate in terms of cost of unit produced if they choose to label their investigation as research in economies in scale.

4. Hirsch's Measurement of "Need"

Economist Werner Z. Hirsch has made significant contributions to measurement techniques as well as to the overall theme of providing urban public services. In his summary of the St. Louis metropolitan studies he accounts the following:

> A general inventory of each government produced data on its number of services and employees and its expenditures. Meaningful analysis of these data required some kind of measuring device to enable the making of significant comparisons among various governments. Without such a device, the only comparison possible was a numerical count of the services being provided by each. Although information about quantity is of some significance, comparisons that take adequacy or quality of service into account are much more meaningful. Consequently, a tool is needed to express services rendered by each government in terms of a common denominator. Only then can comparisons be made about the quality or level of service supplied by various governmental units.
>
> A unit of measure is also essential in order to make comparisons of service expenditures. It would be fallacious to conclude that it costs more to perform a specific public service in a large city than in a small community unless the quality of service performed by each city can be compared against a common standard. Once a unit is devised for measuring such quality or level of service, costs per unit can be computed for all municipalities and significant comparisons can be made.[41]

Ridley's and Simon's suggestions were considered for their appropriateness. The measures selected were neither arbitrary nor totally objective as Hirsch reveals:

> The Survey staff kept constantly in mind that its study was <u>oriented toward an action program</u>. The kind of

measures used to compare services performed by the various governments therefore had to be understandable and meaningful to residents of the City-County area, and had to reveal significant differences in either the nature of the services or their expenditures. (Emphasis added.)

A decision was reached to use measures that would indicate the effort expended to perform a service in terms of the need for the service. Effort could be measured simply by number of persons employed. The need for service was to be ascertained by the use of factors that were quantifiable and generally recognized as indicative of service needs. Population and area thus were assumed to be determinants of the number of policemen needed by a city.

A standard of adequacy for fire and police services was established by averaging the present service level in eight and nine, respectively of the most populous cities in St. Louis County. This kind of standard can be readily understood by citizens living in the area since it is based on actual performance in communities with which they have some familiarity. The Survey did not propose that its specific suggested standards be necessarily adopted; it was more interested in providing a methodology that responsible authorities could readily use. (Emphasis added.)[42]

It would appear that the measurement tools adopted in St. Louis were tailored to be compatible with an action program which among other things sought to enhance the differences among local governments for some purpose other than the measurement of economies of scale. The technique of averaging to develop a standard of adequacy was applied by Simon in 1943 in his study of the Fiscal Aspects of Metropolitan Consolidation[43] of San Francisco Bay Area governments. Yet, it is useful to examine in some detail the Hirsch approach. Using the example of measurement of police protection, he asserts that it was based on the assumption that a number of factors for which information was available demonstrated the "need" for the level of service. Recall as Ridley and Simon pointed out earlier: "need" for a particular service may be determined by the physical and social characteristics of an area, - its area, population, street mileage, retail sales and so forth; Hirsch's measurement technique does not actually measure the "amount of service rendered".[44]

The first factor he included was "area, expressed in square miles". Consultations with police chiefs had revealed that a substantial part of police work demanded the maintenance of motorized patrols. The number of patrol vehicles and policemen required for regular patrol duty was statistically determined in part by the total area covered; and the costs such as motor fuel, tires, and vehicle repair and maintenance are directly affected by territorial size.

A second factor that showed the extent of required police service was "population". In municipalities with approximately equal areas, the level of police service needed was assumed to be greater in the one with the larger population. His premises stated that the number of police calls is affected by the number of people requiring police protection, and similarly, the number of private cars on the streets is closely associated with population and the magnitude of the traffic problem. "Using both area and population to determine a measure of police protection takes into account whatever effect density may have".

"Assessed valuation of property" was used as a third criterion. It was used to furnish an indication of the amount of property requiring police protection. Since high property valuations usually signify commercial rather than residential development, he proceeds on the premise that when high property values are present a higher concentration of policemen is generally required.

"Number of miles of streets" was also considered influential. This factor influences regular patrol assignments and serves as an indicator of traffic control requirements.

The fifth and final factor used in the measurement was "total annual receipts from retail sales and services" in the municipality. If the figure is high in any city, the number of people in the community at certain times is larger than the total resident population. A business population requires the assignment of police to the business area. This factor is also related to the amount of commercial property for which police protection is required.

To establish a base against which police service in any particular community could be compared, an average was computed for nine of the most populous and well-established cities in St. Louis County. The norm for police service was ascertained by obtaining the average number of policemen employed in these nine municipalities in terms of the foregoing five factors, which were given equal weight. The average number of policemen were:

6.33 per square mile
1.22 per 1,000 population
.64 per $1,000,000 assessed valuation
.42 per mile of streets
.60 per $1,000,000 annual receipts from retail sales and services

The following examples show the computations made to compare two cities against the established norm.

First city:

Area	2.18 sq. miles	X 6.33 =	13.80
Population (in thousands)	12.13	X 1.22 =	14.80
Assessed valuation (in millions)	22.22	X .64 =	14.22
Miles of streets	22.0	X .42 =	9.24
Annual receipts (in millions)	22.4	X .60 =	13.44
Number of policemen required to meet norm (averaged)			13.10

In order to meet the proposed norm, this city needs to employ 13.1 policemen. Hirsch reports that this city actually had 13.2 policemen. The fraction was accounted for by the use of some part-time policemen. Second city:

Area	5.25 sq. miles	X 6.33	=	33.23
Population (in thousands)	16.00	X 1.22	=	19.52
Assessed valuation (in millions)	20.05	X .64	=	12.83
Miles of streets	50	X .42	=	21.00
Annual receipts (in millions)	23.1	X .60	=	13.86
Number of policemen required to meet norm				20.09

The actual number of police employed by this city was 9.5. This community, which was new and rapidly growing, was substantially below the norm (20.09) established for police service by the Study. Application of the norm to each municipality in St. Louis County revealed that the actual number of policemen employed in cities with populations of 5,000 or more compared favorably with the norm. The deficiencies, outside of some rapid growing communities where all public services lagged, were concentrated in local governments with populations below 5,000: He found that only a few municipalities under 4,000 maintained any full-time police officers. Thus he reports:

> It became apparent from these comparisons that no serious indictment could be made against the larger municipalities of the County regarding local police service. This certainly was an important determinant in the Survey's decision not to recommend the consolidation of all municipalities in the County, or the creation of a single County-wide police force and the abolition of all municipal police operations.[45]

This is a case, as Tiebout suggested earlier, where recommendations to consolidate were based on "adequacy of service" or "need" rather than "economies of scale". Hirsch reports further:

> The Survey was aware that the standards on education, police, and fire measured indirectly rather than directly the results achieved by a governmental unit in the performance of services. . . The measures appear to have several features that make them useful in action-oriented research. They are readily adaptable to other local government services. They are based upon actual performance levels in communities well known to most residents of the particular areas. Moreover, the information required for computation of standards and for comparisons is available in most instances, and the computation is readily understandable by the public. (Emphasis added.)[46]

This investigator cannot justifiably find fault with Hirsch's approach, recognizing that it measures "need" rather than "output". He carefully sets forth the limitations of the methods and the action-oriented purpose of the measurements; and as emphasized above, results were measured only indirectly through his direct measurement of effort expended to perform a service in terms of the need for the service(as expressed in his standards, made up of "causal" indicies for which data was available). This approach is useful for it distinguishes the measurement of "need" as opposed to the measurements of quantity and quality. The following study attempts the measurement of output directly.

5. Schmandt's and Stephen's Measurement of Municipal Output

Henry Schmandt and Ross Stephens expressed dissatisfaction in 1960 with the shortcomings of previous studies which had used per capita expenditures:[47]

> The three studies mentioned analyzed expenditures only, not quality or units of service. They made no attempt to determine to what extent the variable of "service level" contributes to variations in municipal outlays.[48]

In commenting on Hirsch's St. Louis efforts to introduce service level into equations to generate the cost curves of various services statistically, they refer to a second technique which Hirsch developed to deal with service level.

> Using multiple correlation techniques, Hirsch analyzed expenditures among local governments in the St. Louis area for three municipal services: police, fire protection, and garbage collection; and for one non-municipal function: public education. Population, density, area, growth, per capita property valuation, and service level were used as independent variables. The service level index was constructed from items that presumably reflect the quality or level of the service rendered, such as training and experience of personnel, ratio of personnel to population, amount and kind of equipment, and subjective ratings of the various municipal departments by experts in the field.
>
> Hirsch's findings, while differing in some respects from the others, generally support the conclusion that population size has little effect on per capita municipal expenditures. This result apparently holds true even when the element of quality or service level, as roughly measured by the indicies which Hirsch employs, is introduced as an independent variable.[49]

Schmandt and Stephens conducted a study of the local governments in Milwaukee County to test the assumption that population size is unrelated to per capita expenditures even when service levels are considered. They develop a "service output index" as a substitute for Hirsch's service variable which they deemed too costly to construct. The following represents the thesis of their argument.

One of the major problems in comparing service levels among municipalities is the lack of a satisfactory measure of output. It is relatively easy to determine this factor in the case of municipal utilities - water, sewers, electric power - by using gallons, or cubic feet, or kilowatt hours. However, it is a far different task when functions such as police and fire protection are considered. Hirsch's index of these services consists largely of inputs (personnel, equipment, salaries, and similar items) which a municipality purchases in order to provide a given service. While these items influence output, they are the ingredients and not the measure of production. Many of them, moreover, directly reflect per capita spending rather than output. This is particularly noticeable in services where personnel costs constitute a large proportion of total expenditures.

The measurement which Schmandt and Stephens employed was essentially one relating to output. It was based on a breakdown of each municipal service into subfunctions or activities. Thus police protection was broken down into 65 categories including foot and motorcycle patrol, criminal investigation, youth aid bureau, ambulance and Pulmotor service, school crossing guards, radio communication, radar speed units, and manual traffic control. The service index or level for each function was determined by adding the number of activities performed by the municipality. The list of municipal subfunctions used for this purpose totaled 550.

They acknowledge that construction of a service index on this basis is admittedly open to criticism. In the first place, it gives only a crude quantitative measure of output without telling how well or efficiently the activities are being performed. Secondly, it assigns equal weight to each activity so that the maintenance of a detective squad is equated with the furnishing of emergency ambulance service. Yet, they admit the fact that the subfunctional listing is so detailed that a qualitative element is indirectly introduced into the index. Note that although they seek a measure of "output", presumably a proxy for quantity, that this dimension of quality in the measure or "service output index" does not make for a suitable proxy of either output quantity or quality. Rather it only creates a new variable with high or low correlation to other frequently analyzed variables such as population, density, and so forth. As to the first objection, they assume that the more activities a department performs, the greater is the degree of specialization of personnel, equipment, and facilities within it. As to the second objection they believe that the question of weighting becomes less important when the detailed listing is applied across the board to a substantial number of municipalities for comparative purposes. Efforts could be made to work out a system of weights for the various subfunctions but, they suggest, whether such weighting would add much to the usefulness or accuracy of the index is problematical. Certain basic activities are generally performed by all local units that provide a given service. The chief advantage of employing an activities listing as a measurement of service output they contend is the simplicity and relative ease with which the necessary data can be assembled.

The results of their testing are interesting. Applying simple, multiple and partial correlation analysis to police protection in Milwaukee County municipalities, using 1959 sub-function listings, police expenditures and population, they indeed present evidence to confirm their hypothesis that "population size is unrelated to per capita municipal expenditures even when service levels are considered". They determined that their hybird "output index" (both quantity and quality in its crudest state) exhibits unusually high correlation with population, age of municipality, total current expenditures and density (.80, .86, .84, and .73) while there is no correlation with per capita expenditures (-.07). Also, they express an opinion that their correlation results relating to several individual functions present some indicators that economies of scale may be present in police and school services. This evidence will be referred to later. It might be mentioned that Harvey Shapiro applied the above "service output index" to eight functional activities performed by 66 of Wisconsin's 71 counties. His weak results would not tend to encourage the continued use of the "service output index" method.[50]

6. The Problems of Measuring Quality, Quantity and Cost

It is obvious that neither of the above described measures, that of "need" (i.e. adequacy) by Hirsch or "counting the number of sub-services" of Schmandt and Stephens, are adequate measures of output to measure "efficiency". This investigator did not wish to belabor such inapplicable methods but only to forward (1) several examples of what is not appropriate and (2) several examples of the makeshift tools experimenters are forced to adopt because of constraints of time, available data, purpose, money and other reasons, knowing full well the shortcomings of their measurement constructs. However, it is not altogether clear to this investigator, who is not directly struggling to measure the presence or absence of economies of scale of a particular function, whether an appropriate method of measurement can be outlined for the reader or indeed if the method of measuring output for one particular service or subservice is generally applicable to the measurement of other services. The guideposts that are set forth below reflect the wisdom of others who have previously found it necessary to "bloody their hands" with the thorny problems of quality, quantity and cost measurement.

a. Quality

The basic measures of economies of scale in any form of production are unit output and average cost-per-unit produced. Since efficiency is relative rather than absolute, cost-per-unit becomes meaningful when it is compared with the cost of the same service at some other time or place. These comparisons are justified only when the services provided are very nearly identical. In manufacturing a product, modern quality control techniques insure a relatively homogeneous product; however, examples of homogeneous services are difficult to find. Even a kilowatt-hour of electricity is not a standardized product under all circumstances. For example, an auxiliary generator may be maintained in one city to reduce the frequency of power failures and not in another city. Not only is the cost per kilowatt-hour likely to be higher for the first city, but the electrical service of the two cities differ in quality. The closer one looks, the harder it is to find a standardized service.

Werner Hirsch has pointed out that where the urban service is both produced and delivered, the quality dimensions of both the product and the delivery service must be considered.

> For example, a cubic foot of water has important inherent quality characteristics in terms of its physical, chemical, and biological attributes, including hardness, turbidity, temperature, color, taste, odor, mineral content, bacterial count, etc. Quality characteristics of the delivery process include water pressure, reliable supply, rapid repair, courteous and correct metering, etc. . . .
>
> While quality specification is important in defining physical output, quality evaluation is needed to add up different qualities and types of output; quality evaluations must be made on decisions regarding how much of a certain public service, of a given quality, to produce (as well as what quality to produce). (Emphasis added.)[51]

He stresses the number of quality dimensions which a basic service unit tends to have. If one considers "a person served by a library" as the basic library service unit, there are many quality dimensions - some of which include: the library's selection, the physical condition of the books, the availability of books, the reading room facilities, the help given to children in selecting books, the reference service and many others. All of these dimensions determine the quality of the service, although proxies may be substituted which may simplify the measurement process.[52]

b. Quantity

If satisfied that the quality of service is the same, there is a problem of determining output. The basic service unit must be defined and a time dimension added. For example, an estimate of the number of units produced per year may be appropriate. Some outputs will seem to have conventional or natural units of measurement. A basic unit for water is usually a cubic foot or a foot acre delivered to the place of use. For refuse: a ton, a cubic yard or foot, or sometimes a container of refuse collected and disposed of may be the basic physical service unit. Hirsch points out that at times it may be necessary to fall back on the next best information, which may be the number of households or city blocks served. He suggests that if the nature of the production process is kept in mind:

> the basic service unit of street cleaning can be a mile or square yard of street cleaned; street lighting, a mile of street lit; police protection, a city block protected from crimes; fire protection, a city block protected from fire; urban transportation; the number of cars moved per minute in rush hour; hospital service, patient days in the hospital; and schools, the number of pupils completing a specified grade.[53]

There is no argument that defining the basic physical service unit is plagued with conceptual difficulties, and its measurement, with empirical difficulties. However, this problem is not unique to urban public services. It is characteristic of measurement of services of all varieties and frequently industrial products as well.

c. Cost

If the problems of "quality" and "physical output units" can be mastered sufficiently, economist A. J. Vandermeulen warns that there still remains a question of computing costs, particularly if comparisons between governments are contemplated.[54] She stresses that governments are notoriously lax about the allocation of overhead cost, e.g. interest on debt for capital construction is often omitted; frequently no depreciation is charged; and capital outlays tend to be included as a lump sum in the year in which it is made. The allocation of overhead cost may be further obscured when one functional department provides more than one service - for example, 65 police sub-services. Few multi-service departments bother to allocate direct cost accurately, much less overhead expenses. She has observed that when they are forced to make some kind of division of their expenses in reports, they are likely to resort to hindsighted guesswork. It's a fact that among skilled industrial accountants, there is no single generally accepted method for distributing overhead.

Private producers are better able to use cost per unit as a measure of efficiency than governmental producers. There is greater likelihood in business that products are identical and that some standard accounting methods, albeit not perfect, have been used. Also in business, the optimum standard for private producers is clearly set by the minimum-cost producer, regardless of size of plant or geographic location. To the contrary, there is no single minimum cost for an urban public service. Private producers are free, at least in the long run, to make decisions about the size of plant which will be most efficient. This opportunity is not open to urban service agencies, except occasionally through contracting with other jurisdictions for specific services. However, urban public service production is subject to the same economies (and diseconomies) of scale as private production. Therefore, in comparing unit costs, one must make sure that urban service plants of the same capacity are contrasted.

Since governments are not free to operate their plants in the most advantageous locations, allowance must also be made for differences in the costs of materials and labor among geographic areas. One private producer may be more efficient than another because it produces where labor is cheap or the climate is favorable, but governmental producers have little control over the higher costs caused by locale.

Similarly, comparisons of unit costs for one governmental service operation over a series of years must be adjusted for price changes. Adjustment is difficult. The reasons are legion but a few may be presented. Years ago, the movement of prices for the factor inputs (labor and materials) to urban production operations tended to lag behind the movement of the general price level. The lag was caused partly by the custom of governments to purchase under long-term contract and partly by the inertia of the wages and salaries of public employees. At times, labor expense tended to be more sluggish than the cost of materials. Also variations in the lag were present, with the lag likely to be longer for smaller governments than larger ones, and longer or shorter with swings in the price cycle. The situation of today is significantly different and yields no prospects of returning to the above state. Many urban services are labor intensive and in cases when an urban service requires individuals with specialized skills which are in short supply, labor costs of governments may cease to lag for certain functional services, and if competition with other governments and private concerns presses, may even lead general price increases. A few examples are worthy of consideration.

The Council of Economic Advisors using the Department of Labor information, reported that the general consumer price index had risen by 1965 from a 1957-59 base of 100 to 109.9 for <u>all</u> commodities and services, but from 100 to 120 for services alone.[55] Also, as to medical care and transportation services, which are partly provided by governments, the indicies had risen over the same period to 122.3 and 111.1 respectively, both higher than the general price index. This consumer index reflects the price increases facing consumers made up of "city wage earners and clerical workers". More detailed studies have been made to analyze the rising "costs" facing local governments. One such report analyzes the rising costs of public education and another the trends in the supply and demand of medical care. The former analyzes average annual salaries of public school teachers from 1900 to 1958. It indicates that the index of average annual earnings of full-time public school teachers in state and local governments rose from a 1954 base of 100 to 123.7 by 1958. While the two indicies are not actually comparable, the general consumer price index rose roughly from 100 to 108 over the same period.

The medical care price index may be compared to the rise in the consumer price index from the base of 1947-49 = 100 to 1959. While the consumer price index rose from 100 to 124.5, the price index for medical care rose to 150.6.[56] The latter includes rises in hospital rates to 209.6 over the same time period. The investigator reports:

> As newly developed diagnostic and treatment equipment is added to hospitals, more - not fewer - people are required to operate it. Hospital equipment is expensive, its cost is impressive, but the enduring element of cost of these new services is the new trained personnel who must accompany it.
>
> In addition to the rising expense of professional and other highly trained workers, hospitals are faced with payroll pressures from the general wage level on costs of lower

> paid, unskilled workers. Although there have been significant increases in hospital wage scales and reduction of hours worked, there is still a considerable lag behind the general wage level of industry. Wages averaging $1,330 a year in 1946 for a 48-hour week rose to $2,873 in 1957 for a 42-hour week, an increase of 11.6 per cent in pay and a decrease of about 14 per cent in hours.[57]

Thus it remains somewhat of a "bane" to local government administrators and a "mixed blessing" to taxpaying citizens that salaries for many public jobs continue to lag general wage increases. Yet, the caveat remains, that in measuring the cost of a particular urban sub service over a period of years, considerable caution must be exercised when adjusting for price level increases (or decreases).

Lastly, consider the effect on the cost of production by producing at varying volumes. Earlier, it was pointed out that the units of service produced by a public utility may only be stored to a limited degree. For example, if more electricity is generated than the quantity consumed, the over supply may be wasted. Or if more water is available than the reservoirs will hold in storage, the excess water must be released even though shortages may be anticipated at a later time. Such "over supply" characteristics affect the cost of the unit produced. Or consider "under utilized capacity" of a large telephone exchange which is equipped to handle 10X calls simultaneously but the number of calls placed throughout many hours of the day is only X.

The local government may provide free public health services at local health centers, but unless the public is aware of the service and goes to the health center for services, the staff and equipment which may represent high costs are not producing units of service. In other words, in many urban public services, unless the service is solicited, the unit of service is not rendered. Thus, the number of units produced may fluctuate widely from day to day, week to week, year to year depending on the fluctuations in the solicitation. For example, if there is a tight credit situation in the economy, this may ultimately appear to raise the unit costs of many governmental sub-services. An abbreviated oversimplification of what may result follows:

1. Fewer new construction starts will be initiated by private citizens.
2. Fewer building permits will be issued.
3. Fewer zoning checks will be made.
4. Fewer plumbing plans will be approved.
5. Fewer electrical inspections will be made.
6. Fewer fire inspections will be made.
7. Fewer building inspections will be made and so forth.

The staffs of the many service operations cannot be expanded and contracted easily with fluctuations in public solicitation. Similar to business firms, they would incur high hiring and firing costs, high training costs, severance pay and so forth as well as prohibitive "political" costs. From the economic standpoint alone, in the long run, it is usually more economical to stabilize the production operation including personnel rather than respond to fluctuating demand. What does this mean if the unit of measurements is cost per building permit, cost per plumbing plan approved or cost per building inspected? It means that the costs of operation remain high but the output of units of service is low and corresponds to point Q_1 in Figure 1 (where in the short-run with plant fixed, production is not at an optimum, and average unit costs are higher than the planned optimal costs). Thus, influences completely external to the production of the urban service can determine the ultimate cost per unit and destroy its usefulness as a measure of productive efficiency. The plant may continue to be the appropriate size to take advantage of economies of scale if the "average" demand or some output volume close to it is solicited; but for some urban service plants the demand for the sub-service may display high standard deviations from the average demand and in such cases, production will take place at non-optimal output levels much of the time.

Or consider the case of adopting the number of venereal disease cases treated or the number of crimes solved by the detective division as the unit of output. Here is the peculiar but not uncommon case in local government when the "effectiveness" of the sub-service tends to reduce the output of units produced. If the detective department is successful in solving crimes, this may in turn reduce the incidence of crimes committed, which in turn leaves less crimes for the detective department to solve in the next time period (so called "second order" effects). Thus, although the detective staff logically should not be reduced or the crime rate may go up, the costs of operation are spread over a fewer number of cases solved and the cost per unit of service rises. The same may be true if the public health department is successful in preventing the spread of venereal disease.

Many of the foregoing type of considerations should be balanced in the selection of the appropriate units to measure quality, quantity and cost. But there is another variable in the local government equation: density.

7. A Brief Comment on Density Considerations

In comparing the costs per unit of subservice produced between different local government plant scales, what is the effect of density? As density measures the intensity of land activities or characteristics, density may be expressed in virtually as many variations as there are activities or characteristics, e.g. dwelling unit density, population density, household wealth density, school age children density, commercial density, industrial density, fire hazard density, poverty family density, capital invested density, etc., and even on the basis of political influence, such as labor union member resident density, local government employee density, and so forth. When two service plants are compared, if they service two residential areas, are the residential areas of about the same economic status with comparable street patterns? Service is harder to define when it is necessary to compare the services provided to a central business district with those provided to a residential district or a wholesale district with a manufacturing district. Shall it be said that two areas have equivalent fire protection if the average fire loss per thousand dollars of property at risk is the same in the two areas? The probability of occurrence of fire might be much less in one type of district than in another, and the task of reducing fire losses to the desired quality correspondingly less difficult.

Local governments are composed of several different basic land uses e.g. residential, commercial, industrial, streets, etc.; however, local governments vary widely in the proportions of each of these basic uses within their jurisdictions. For example, Table 2 shows some striking contrasts between selected characteristics of seven local governments in

TABLE 2

SELECTED INDICATORS TO CLASSIFY MUNICIPALITIES AND PER CAPITA CURRENT OPERATING EXPENDITURES BY FUNCTION

CLEVELAND METROPOLITAN AREA, 1956

Governmental Unit	Assessed valuation per sq.mi.	Indus. & commercial estimated tangibles per sq. mi.	Personal intangible valuation per sq. mi.	Density persons per sq. mi.	Residential property as percent of all real property	Per Capita Current Operating EXP: General Govt.	Police	Fire	Streets & Highways
	(thousands of dollars)					(in dollars)			
Industrial Suburbs:									
Cuyahoga Heights	28,644	18,273	3	234	4.3%	79.40	117.60	175.30	35.30
Brook Park	9,829	6,155	-*	335	19.5	17.50	42.60	35.60	21.70
Walton Hills	5,318	3,169	-*	210	28.4	5.40	14.50	1.10	10.20
Wealthy Dormitory Suburbs:									
Shaker Heights	22,627	588	268	5,317	79.6	7.30	10.60	9.90	10.20
Bratenahl	5,110	72	123	1,214	95.2	10.70	55.50	6.50	26.60
Gates Mills	899	13	23	131	97.1	17.40	30.70	2.00	33.20
Hunting Valley	724	4	22	64	99.1	28.20	69.40	2.40	59.20

*less than $500

Source: Table II-8 and Table IV-2, Seymour Sacks and William Hellmuth, Financing Government in a Metropolitan Area (New York: Free Press of Glencoe, Inc, 1961) pp. 30-32 and 76-78.

the Cleveland Metropolitan Area. Although the first three local governments are predominantly "industrial" and the latter four "wealthy dormitory" suburbs, there are extremely wide variations in the indicies within each group. Such data illustrates problems of comparison of urban service production among such local governments.

Likewise, comparison of a metropolitan suburb with the more complete spectrum of socio-economic characteristics and activities found in an isolated town of equal population and population density may be risky. Again, comparisons between California oranges and Florida oranges, although both oranges, can be a difference in kind, not degree.

Consider the effect of topographical conditions on the performance of urban functions. Pittsburgh, Pennsylvania is spread over very rugged topography while Miami, Florida is spread over a flat coral rock formation averaging probably no more than a few feet above sea level. The rugged topography of the Pittsburgh area makes the planning and construction of transportation facilities very difficult. The pattern of transportation networks can be very influential in the cost of providing different urban services. Miami is laid out in a grid network, whereas main arteries in Pittsburgh follow every river and stream valley. Many hillsides within the central city limits are undeveloped because of construction difficulties on steep slopes. Boston's transportation network consists of highway, railroad and subway nets which converge on its central business districts like the spokes of a bicycle wheel converge to its hub. Yet transportation arteries in directions perpendicular to the spokes is severely limited. The effects of varying socio-economic and activity densities as well as topography and climate, mentioned earlier, add to the complexities in the process of measuring "spatial" economies of scale.

B. EMPIRICAL ESTIMATION OF THE LONG AND SHORT RUN COST FUNCTIONS

1. Empirical Estimation Approaches

The short run cost function presented in Figure 1 is the appropriate curve to estimate to determine the volume of units which will be the optimum production level (lowest average unit cost) for the given plant (the staff and facilities) of an urban public service or sub-service. The long run cost function is the appropriate curve to construct to compare costs for various plant capacities. Economists have long speculated about the shape of the relationship of cost to output. The accepted economic doctrine has been that the average unit cost curve has a U-shaped relation to output. In the short run, some of the input factors i.e. buildings, equipment, and supervisory personnel, are assumed to be held constant and not capable of immediate adaptation to changes in output rate. The basic proposition is that there exists in the short run a functional relation between cost and a set of independent variables, which may include: (1) generally - the volume of production, the prices of input services and the variety of output among others; or (2) specifically, in the example of police service, some of the following - night-time population, total miles of streets, night-time population density per square mile, combined receipts of wholesale, retail, and service establishments, per cent of night-time population under twenty-five years of age, and so on. The independent variables will be different for each type of productive operation, although in general the most important variable is volume of output. The independent variables are considered to be the determinants of cost behavior.

The rate or volume of output is usually the most important to study because it is subject to faster and more frequent changes. In fact, economic analysis of the cost function usually refers to the relationship alone between cost and output, and thus assumes that all other independent variables are kept constant.

There are several approaches to an empirical approximation of a cost function:

1. Classification of accounts into fixed, variable, semi-variable on the basis of judgment and inspection.

2. Estimating the relationships of cost-output on the basis of engineering conjectures.

3. Determination of the cost function and the degree of output variation by statistical analysis.

The method of statistical analysis of past behavior of costs is the most thorough and "scientific", since it deals with each major problem of determining empirical cost relationships explicitly. The other two methods must cope with each of these problems, but they do so less consciously and usually less successfully.

The three approaches, accounting, engineering, and statistical, are not mutually exclusive. Often it is desirable to use two or more approaches to supplement each other. Nevertheless, it is usually desirable to try to determine at the outset which of the three should receive the greatest emphasis.

a. Accounting approach

The accounting approach involves classification of expenses as (1) fixed, (2) variable, and (3) semi-variable, on the basis of inspection and experience. This approach is the simplest and least expensive of the three. Hence, it should normally be used whenever feasible as a supplement to the other methods if it is not used as the principle method. To be most successful the requisite methods are

(1). Experience with a wide range of fluctuation in output rate.

(2). A detailed breakdown of accounts kept on the same basis for a period of years.

(3). Relative constancy in wage rates, material prices, plant size, technology, and so forth.

Since the accounting approach provides no way to correct data explicitly for changes in cost prices or for changes in other conditions that affect cost behavior, a constancy of these cost conditions is essential if accurate results are to be obtained. The statistical method can tolerate more variation in underlying conditions because it possesses a means of dealing with these variations. Uniform coverage of the output range is not essential for success of the accounting method. A group of observations at each extreme of the range is sufficient. The accounting method isolates constant cost easily by inspection. It identifies variable cost easily, but determines less accurately the pattern of variation of these and of semi-variable costs. This approach needs to be supplemented by graphic analysis to separate the variable and fixed components of semi-variable cost and to determine the linearity of output relationship for semi-variable and for variable costs.

b. Engineering Approach

The engineering approach relies on technical information supplied by engineers. In essence, it consists of systematic conjectures about what the cost behavior ought to be in the future on the basis of what is known about the capacity of the plant or equipment, modified by experience of labor requirements, labor efficiency, and past cost behavior. Thus, this approach depends mainly on knowledge of physical relationships supplemented by the judgements of practical operators. Typically, the engineering estimate is built up in terms of physical units, i.e. man hours, pounds of material, and so forth, and converted into dollars at current or prospective cost prices. The cost estimates are usually made for a series of output volumes that cover the contemplated or potential output range. Functions so constructed benefit from the fact that a range of applicability is known and can be estimated over a wider range than statistical data permit.[58]

Engineering cost functions, however, do not incorporate the managerial or supervisory costs into the function as part of the plant capacity. Thus, in the urban service area, they have a narrower application, e.g. a refuse collection crew, the operation of a fire fighting unit or refuse incinerator - where the managerial capacity of the production operation is minimal. Although very useful in deriving cost functions to estimate labor, capital and material requirements, they are not useful in the measurement of the off-setting diseconomies of scale in administration. Walter Isard and Robert Coughlin[59] made use of engineering data to estimate school, land, sewer, and so forth, requirements and their carrying capacity. However, not many attempts[60] to use this approach have been made.

c. Statistical Approach

The statistical approach, when conditions are appropriate for its use, is likely to produce more reliable results than the other methods. However, it is more time-consuming and expensive if applied in a thorough manner. In essence, it uses multiple correlation analysis to find a functional relation between changes in costs and the important cost determinants, such as output rate (volume), output fluctuations, and so forth. Although ideally it should have an algebraic form fitted by least-squares analysis, much can be learned by graphic analysis.

The power of statistical analysis lies in its ability to pick out the fixed cost elements in each cost component, such as direct labor or fuel consumption, and to show whether marginal cost is constant or variable with changes in cost determinants. These relations are derived from the shape of the cost function statistically.

2. Theoretical Cost Function Guides for Estimation

Perhaps it may be helpful to digress temporarily to review the theoretical model of the cost function and how a priori deductive reasoning may aid estimation. First, there are three main cost functions: total cost, average cost and marginal cost. The average cost function can be further subdivided, if desired, into average fixed cost and average variable cost, and the total cost function can be subdivided into total fixed cost and total variable cost. The short run total cost function for a theoretical production operation is presented in Figure 11.

TFC and TVC depict the total fixed cost curve and total variable cost curve and represent how fixed and variable costs theoretically may vary over a range of output when plant, management, and quality of output are held constant. Summing the TFC and TVC curves, the TC or total cost curve is derived. TC represents the shape of the total cost function assuming a diminishing and rising marginal cost condition. The MC or marginal cost curve is shown in Figure 12, and represents the increment in total cost associated with a small change in the rate of output, or alternatively, it shows the additional cost that must be incurred if output is increased by one unit. Figure 11 and 12 assume that in the lower range of output, marginal costs fall and at a higher rate of output, they begin to rise. The average cost is measured by the tangent of the angle Z with the rays drawn from the origin in Figure 11 to points along the TC curve. To reach points along the curve for successively higher output levels, it is evident that the angle Z must first decline and then rise. (See rays OA, OB, OC, and OD and their respective angles). It is this property of the total cost function that makes the average cost curve U-shaped.

The average cost curve, AC, represents total costs divided by units of output for each level of output. Thus, it is really the average unit cost curve. Angle Z in Figure 11 is the smallest when the output level is OP; therefore, the low point of the AC curve in Figure 12 is at output OP also. AC is the summation of the average fixed costs, AFC, which tend to fall over the complete output range, and average variable costs, AVC, which are influenced by the marginal cost of each additional unit produced.

At the inflection point, B, on the TC curve in Figure 11, the marginal cost curve hits its lowest value and begins to rise. The fall and rise of the MC curve at output OR is shown in Figure 12.

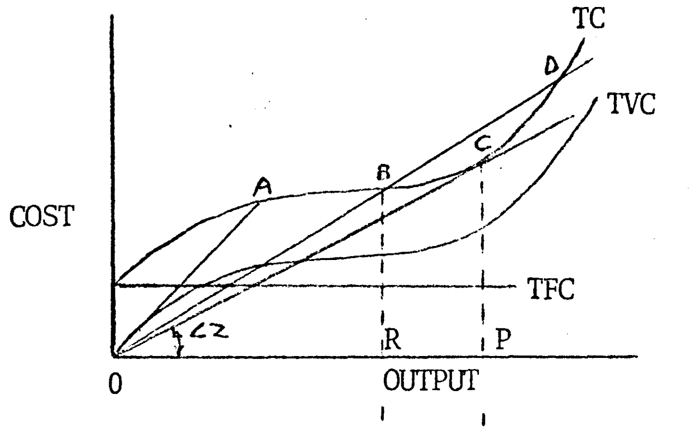


FIGURE 11

Short-run Total Cost Functions

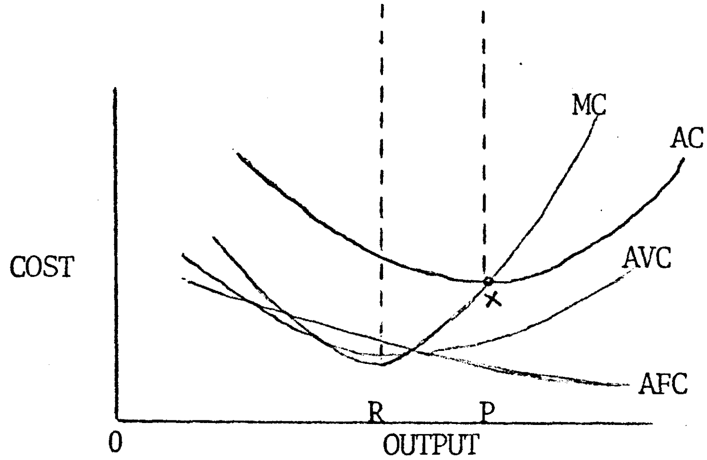


FIGURE 12

Short-run Variable Marginal Cost and Average Cost Functions

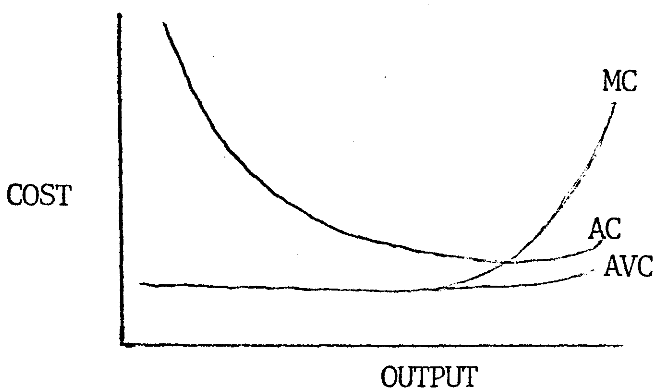


FIGURE 13

Short-run Constant Marginal Cost and Average Cost Functions

Thus, the marginal cost curve begins to rise while the average cost curve continues to fall; however, when average cost per unit equals marginal cost per unit (point X on Figure 12), the low point on the AC curve has been reached and the AC curve turns upward. An easy way to remember the location of the MC and AC curves is to use the rule that when the AC curve is falling, the MC curve is below it, but when the AC curve is rising, the MC curve is above it.

Of what value is this model? It helps to visualize the relationships behind the curve which the investigator of economies of scale is empirically attempting to construct. For example, when the marginal cost is known to be variable, as above, a U-shaped average cost curve may be anticipated. Suppose, it is assumed that marginal costs are constant over the greatest part of the output range. Actually, businessmen commonly do this. On a priori grounds, what is the anticipated shape of the average cost curve? Figure 13 shows the effect on the average cost curve of a constant marginal cost over a wide range of production.

Also, overhead or fixed costs are significant in determining the shape of the average cost function. If a production operation required no fixed costs, then the average cost curve would be continually rising. There would be no falling portion because there would be no overhead to spread over increasing output levels.

Econometrician Lawrence Klein offers some comments to those who estimate cost functions:

> Much of the research in the statistical analysis of cost has been concerned with the shape of the total cost function, particularly its departure from pure linearity. Conventionally,

economic theory is based on curved cost functions. . . which are associated with U-shaped average cost curves and either U-shaped or rising marginal cost curves. These same curves are the type that fill the textbooks of economics. If the total cost function is, however, strictly linear, marginal cost will be constant because a straight line total cost function will have a constant slope. The marginal cost curve simply becomes a horizontal straight line in a diagram with the usual axes of cost and output. The curve of average cost will be either hyperbolic (continuously falling in a curve) or constant (a horizontal line identical with the marginal cost line) depending on whether there are fixed costs or not. . . .

Short-run average cost functions are drawn on the assumption of the existence of limitational factors, such as size of plant. In the longer run, this factor is not limited and can be generally varied. Although the short-run curves are drawn, logically, so that they have a U-shape, it is debatable whether the long-run curve ever turns up. If the long-run total cost function is linear with nonzero fixed costs, the long-run average cost will not turn up. With this distinction in mind, the econometrician must settle clearly in advance whether he is going to extract cost data for his sample values from short-run cost items alone or from both short and long-run costs.

In a firm's income statement there are both operating and non-operating costs. Presumably, financial and other non-operating costs are fixed costs. They may, however, be long-run costs such as interest or mortgage and bonded indebtedness, or they may be short-run costs such as interest on 90-day notes. Among operating costs there are costs of materials, costs of labor, and depreciation. Some labor and depreciation costs must vary with output levels and some may be fixed. If output is measured as "value added", material costs may not be taken into account in estimating the cost function.[61]

What a priori deductions can be drawn by the empirical investigator from such theoretical constructs depends to a great degree on the characteristics of the urban public service he studies. For example, law enforcement service produced by the town sheriff in the "early days of the West" required little in the way of fixed investment - a sheriff's badge. Any "man" in those days provided his own horse and pistol(s). If he later added a few deputies to produce more units of law and order and provided each with badges, then the cost function for law enforcement may not show the typical U-shaped average cost curve. This service tended to be highly labor intensive, requiring little in the way of managerial and other fixed costs or material costs. The production function and cost functions may have been discontinuous because of indivisibilities (no "part-time" deputies). The cost functions may have taken on a different appearance due to the low fixed investments to be spread over output. Also, as more units of law and order were demanded, the sheriff probably produced more law and order at roughly constant marginal costs. The total and average cost curves may have appeared similar to those in Figure 14 and 15 below.

Discontinuous Short-Run Total Cost Function with Little Fixed Cost

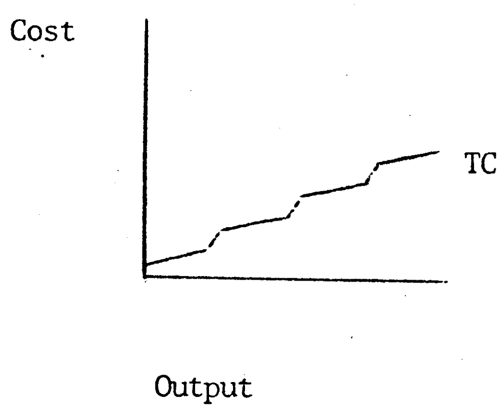


Figure 14

Discontinuous Short-Run Average Cost Function of a Labor Intensive Service

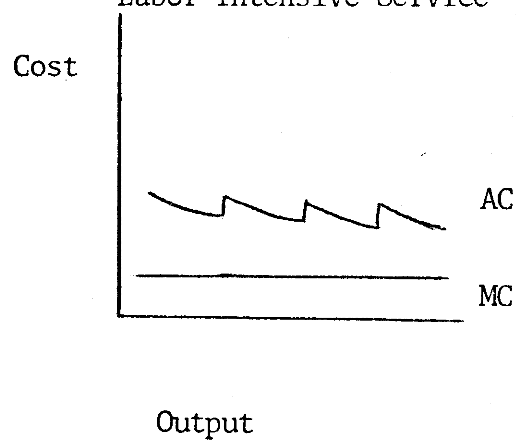


Figure 15

Thus, the investigator may deduce, to some degree, the shape of the cost curve he is likely to develop empirically, a priori.

The actual rigorous steps necessary to empirically construct a cost curve using the engineering approach or statistical approach are too detailed to present here and are also beyond the scope of this investigation. The work of economists, Alan R. Ferguson[62] and Hollis B. Chenery[63] may serve as good guides for the engineering approach while the work of Joel Dean[64] and Werner Z. Hirsh[65] provide sound sample applications of the statistical approach.

3. Some Limitations to the Estimation Approaches

Statistical data show costs in relation to scale for the many different technologies actually used by producers (and the mix used within any one service function e.g. the mix of refuse disposal techniques applied in one jurisdiction). If the technologies used by different service plants varied only because different sizes of plant require different technology, the data might be appropriate. But technology varies from plant to plant for other reasons. For example, some plants are old and others newly built. Technological improvements are incorporated from year to year. Further, technologies tend to be selected at various times because of different relative factor prices, or because of different demand expectations. Statistical studies may have limited significance if they regarded all or most of the service plants from government to government as sufficiently homogeneous in technology to warrant grouping them together to derive a long-run cost function.

Another difficulty with the statistical approach is that it assumes that each cost-size observation used represents a point on the long-run cost function; that is, that every output studied is the optimal output for that plant or firm. This is truly an unwarranted assumption, but most studies make no attempt to eliminate any observations because they represent obviously nonoptimal outputs. There is, perhaps, a taut assumption that at any one time all plants are operating in the same relation to optimal output and that their nonoptimal function is similar to the optimal cost function. Simply to state these assumptions reveals their inherent dangers.

In the engineering approach, each element of the production technique is studied to discover the relation between inputs and outputs at different scales. The input-output relations are then combined to give the over-all input-output relations. The introduction of prices for the inputs transforms these relations into cost-output relations. Studies made on the basis of observations by engineers avoid the problem which arises from the fact that the existing plant was built when different production technologies existed, but they may have similar limitations. They may be over-oriented toward the study of input-output relations in the elements of the presently utilized productive techniques because these relations are the only ones thoroughly investigated by the engineers. Both Ferguson and Chenery recognized explicitly the fact that this narrowed the economic significance of their studies. The importance of this limitation is greatest if a change in scale or factor price makes it more economical to adopt techniques whose input-output relations have not been studied. Engineering studies tend to show ideal rather than actual relations of size and cost. This can be good or bad; it depends on what the cost function is intended to reveal. Finally, the relation of factor cost to scale, if not explicitly studied, can further limit the usefulness of engineering studies.

Finally the reader of reports prepared by empirical investigators may read too much into the investigator's results. Although this is not a limitation of one of the estimation approaches, it is frequently the case that once an investigator discovers data which might be used for an empirical study, he is strongly inclined to use them, and to present the study "for whatever it is worth". Readers, less familiar with the problems posed by the data, are likely to overrate the significance of the study. This may serve as a caveat to the studies which follow.

Simplifying assumptions are essential to the development of theoretical concepts. Inevitably, however, each simplifying assumption blocks the path toward an empirical investigation of the relationship which the theory states. In empirical investigation the complexities cannot be removed by a simple declarative sentence; nor can the empirical economist - like his empirical brethren in the laboratory sciences - remove complicating factors by carefully regulated experiments in which the factors are held constant.

Caleb A. Smith

IV. SURVEY OF EMPIRICAL RESEARCH ON THE PROVISION OF URBAN PUBLIC SERVICES

There exist any number of classification systems to categorize the empirical research which has been done. There would be advantages and disadvantages of each system. The Advisory Commission on Intergovernmental Relations in Performance of Urban Functions: Local and Areawide appears to have no organization in the presentation order of its findings on the fifteen urban functions which it studied. Each function is considered individually, not in alphabetical order or any other order. Only after the findings are set forth and the summary prepared is there a one paragraph attempt to rank the findings on a scale of "most local" through "most areawide" in character (fire protection, public education, refuse collection and disposal, libraries, police, health, urban renewal, housing, parks and recreation, welfare, hospitals and medical care facilities, transportation, planning, water supply and sewage disposal, and air pollution control). Although the report states, "These functions represent 85 per cent of total local government expenditures", the findings were not even arranged in terms of highest to lowest expenditures. Yet, there is some logic in this approach, for by being totally arbitrary, the report does not create initial disagreements with readers on strictly organizational grounds. Yet, by presentation of findings in an organized fashion, perspectives may be gained, and a continuity of thoughtdeveloped which can be valuable.

An organization is often adopted which fosters the purposes of the research or presents the pet theories of the investigator. As mentioned earlier, Werner Hirsch made no bones about the purpose of the St. Louis research and the publication which reviewed his findings was entitled:

"Expenditure Implications of Metropolitan Growth and Consolidation."[66] His organization was geared to justification for metropolitan consolidation of urban services. He also developed a valuable analogy from industrial production by organizing the production of urban public services into vertically integrated, horizontally integrated and circularly integrated classifications. Or consider another classification system. Public finance economist George Break has presented an approach to how one may go about allocating urban public services on the basis of three criteria. He suggests one economic, one public finance, and one political standard respectively:[67]

1. Economy of Scale: The unit of government should have a large enough area to permit realization of the economies of scale. This economic concept describes a situation in which the unit cost of providing a service would be lower if the output of services were increased.

2. Benefits Spillout: The governmental jurisdiction responsible for providing any service should be large enough to enable the benefits from that service to be consumed primarily within the jurisdiction. The benefits from the service and the social cost of failing to provide it should have a minimum of "spillover" into other jurisdictions.

3. Political Proximity: This is a composite of political criteria.[68]

TABLE 3

BREAK'S CLASSIFICATION OF URBAN SERVICES

Function	Economy of Scale	Benefits Spillout	Political Proximity	Resultant
	Favoring	Areawide	Control	
Transportation	(+	+	+)	+
Police (Spec. Serv.)	(+	+	o)	+
Health & Hosp.	(+	+	+)	+
Water Supply	(+	+	+)	+
Sewage Disposal	(+	+	+)	+
Refuse Disposal	(+	+	+)	+
Libraries (Spec.)	(+	+	+)	+
Air & Water Pollution	(+	+	+)	+
Urban Planning	(+	+	x)	+
	Favoring	Joint	Control	
Local Schools	(x	+	x)	=
Public Welfare	(o	+	o)	=
Parks & Recrea.	(o	+	x)	=
Public Housing	(o	+	o)	=
Urban Renewal	(x	+	x)	=
	Favoring	Local	Control	
Police Service	(o	o	o)	o
Fire Service	(o	o	o)	o
Refuse Collection	(o	o	+)	o
Libraries (Basic)	(o	o	o)	o

KEY: + favors areawide control because economies of scale are important, or benefit spillouts are significant, or political proximity is unimportant
o favors local control for the opposite reasons
= favors joint control
x indicates that allocation yields a debatable result

If the research on economies of scale had been performed in clear cut theoretical divisions such as "the measurement of unit cost versus quantity produced, holding quality and density constant", then a great deal could be learned by using the organization implied by Musgrave earlier. Actually, this is the approach which this investigator feels would be most unique and most beneficial from an analytical standpoint. However, as many investigators do not adequately reveal their assumptions and leave too much to the reader's imagination as to how issues such as variable density and variable quality are handled, this organizational approach would be fraught with conjecture and frustration. Important also, is the fact that it would tend to scatter the sparce empirical findings relating to each functional service under several different analytical classifications. Thus, from the standpoint of gaining the advantages of examining several different findings all concerning the same functional service, this investigator has chosen to present the empirical evidence by function in an organizational framework.

This organization of functions was advocated by Harvey S. Perloff in a speech at the Joint Center for Urban Studies of the Massachusetts Institute of Technology and Harvard University in 1965.[69] Perloff suggests that a useful distinction in the character of governmental services can be made between what might be called the skeletal items, those that hold a large area together as a unit of interrelated functions and thereby favor areawide servicing, as compared to what might be called cellular items, or those functions that are associated with given sizes of population and are repeated over and over again as population increases -

such as elementary and secondary schools, fire and police services, small local hospitals and libraries. The skeletal items are essentially utility-type or systems-flow type in nature, including transportation, communications, water, sewage, electric power, and the like. A second category are the natural resources - environmental setting items. These cover the watershed of the area and the problems of large-scale water supply, flood control, and water pollution, the question of fresh air and air pollution, and the question of open and space consuming recreation. A third category are the highly specialized services or facilities which can be supported only on an areawide basis. These include higher education, the specialized hospitals and the specialized cultural and recreational activities. A final category are those services which provide efficiency and savings through cooperation as in the case of certain types of police and library services.

Let another dimension be added to the organization of functions that Perloff presents: that of publicly provided "off site" service as opposed to privately provided "on site" service. Also, several other closely related services can be added to his list.

TABLE 4

CLASSIFICATION OF SELECTED URBAN PUBLIC SERVICES AS SKELETAL OR CELLULAR WITH PRIVATELY PROVIDED ON-SITE SUBSTITUTE SERVICES INDICATED

Publically Provided Services	Off Site	On Site	Privately Provided Substitutes (in wide usage)
I. Skeletal			
A. Utility or Flow System			
gas system	X	X	bottled gas
electricity system	X	X	home, hospital, industrial generators
water system	X	X	wells
sanitary sewer system	X	X	septic tanks
telephone system	X		
street system	X		
combined sewer system	X	X	septic tanks plus large unpaved yards
B. Environmental			
storm sewer system	X	X	large unpaved yards
flood control	X		
water pollution	X		
air pollution	X		
open-space small parks	X	X	large lot sizes (large yards)
space consuming recrea.	X	X	"cluster zoning" type development
large scale water supply	X		
C. Highly Specialized Serv.			
higher education	X		
specialized hospitals	X		
specialized cultural	X		
specialized recreational	X		
D. Highly Specialized (Coop)			
special police service	X		
special library service	X		
II. Cellular			
elementary schools	X	*	private schools
secondary schools	X	*	private schools
fire service	X	*	volunteer firemen
police service	X		
small local libraries	X		
small local hospitals	X	X	private nursing service &
		*	private nursing homes

* not "on site" but private substitutes

Perloff does not include several functions which other listers have classified: refuse collection, refuse disposal, public welfare, urban planning, public housing and urban renewal. Break's classification indicates that this group tends to be the more difficult for him to classify. It is noted that on a deductive basis, refuse collection can become very costly if the full refuse truck must travel long distances before it is unloaded, i.e. the time of the crew is wasted while the full truck proceeds to a distant disposal point and returns. Therefore, a disposal point centrally located within the collection district would seem most economical *a priori*. The service area could be likened to that of fire service and classified as cellular. Refuse disposal, as presented earlier, can range from private "on site" disposal to capital intensive public "off site" disposal. It is difficult to classify. Depending on the production technique selected, the sites may be limited. If sanitary land fill is selected, there may be only one or two large land sites available; this puts heavy dependence upon the road system and adds the dimension of a skeletal service to its classification. If the incinerator technique is selected, depending on its scale, it would suggest the dimension of larger or smaller cells (collection districts).

Public welfare is somewhat of a truncated service. The service isn't administered to most land parcels or most households. *A priori*, to take advantage of the specialists required to devote full time to their specialty, and to administer to citizens which may be dispersed geographically, a cellular unit of large jurisdiction would appear warranted. Yet if emphasis is placed on cooperational social planning for the area, it may be classified as a highly specialized service of the cooperational type.

Urban planning would probably be classified under Perloff's skeletal, highly specialized - cooperational service. The advantages of area-wide planning need not be labored here.[70] Public Housing and Urban Renewal, again, are not services which every local government produces. Where these services are produced, evidence appears to be mounting that there would be advantages to a cooperational approach among local governments. As they are highly related to urban planning, they logically fall in the latter's classification.

Having set forth an organizational framework to approach the urban public services, the investigator in no way suggests that the above listing of services ranges from services with economies of scale to those without it. Each service or group of services actually warrants individual evaluation. In fact, important subservices do also. Yet, a survey is limited by the studies which have been made and the individual approaches each study represents.

A. SKELETAL SERVICES

The purpose of presenting the "off site service" versus "on site substitute service" primarily relates to consumption of the services in residential areas. One of the chief determinants of whether several urban services will be provided publicly "off site" or privately "on site" is the variable of residential dwelling unit density. This group of services tends to be confusing for by changing residential density local governments appear to unload service responsibility to land owners. As the freeholders are the voters as well, this is a political choice which tends to have the backing of at least the majority of residents. Yet, from the economic standpoint, it seems that the merits of economies of scale are forfeited in the very group of urban services which offer the most scale economies. The many reasons why residents choose to forego demonstrated scale economies is beyond this investigation; however, it has prevented a clear picture of the costs of providing services if when the local government no longer makes expenditures for the service the investigator no longer considers the costs of the service. The public versus private distinction is not an appropriate line of demarcation in the study of the provision of urban services. Since many of the "utility or flow" type as well as "environmental" type services are tied up in the issue of density, attention will be first directed to studies relating to density and the costs of urban services.

1. Utility or Flow Systems

In thinking about utility or flow systems it may be useful to visualize the "distribution" of the services as made up of four sub-systems forwarded by economist John Kain:[71] (1) Inter-neighborhood distribution systems, (2) Intra-neighborhood distribution systems,[72] (3) Lot distribution systems,[73] and (4) Structure distribution systems.[74] The costs of the latter two systems are often borne by the land owner but are no less a cost of providing the service. The inter-neighborhood distribution for utility or flow system services consists principally of a "trunk system". The intra-neighborhood distribution system links each property or lot within a neighborhood to the trunk system. He suggests that this subsystem may be further divided into (a) those parts of the system that depend on the width or amount of frontage of the individual lot (frontage costs) and (b) common or joint elements, e.g., connector mains and sewers in intercepting streets, cross streets, and the like.

a. Whitten and Addams/Streets

Whitten and Adams[75] as early as 1932 showed how cost elements of intersecting streets are principally dependent on neighborhood design and arrangement. They developed an "improvement ratio" which represented the total costs of intra-neighborhood street distribution systems divided by frontage costs and showed that the ratio was most dependent on the size and arrangement of streets, the length of building lots (if area is held constant) the amount of area used for nonresidential purposes, and block length. They found block length to be very important to costs and since the length of intersecting streets in a given neighborhood is affected by both block length and width, the effect of variations in block length on the costs and extent of neighborhood streets can only be specified for a given depth of building lot. They observed, "With the general use of the motor vehicle, the considerations that led to the acceptance of the 600 ft. block as suitable in residence sections are changed. The 800 or even the 1200 ft. block is not unduly inconvenient for the motor vehicle. . . . Increasing the length of the block offers an effective and obvious method of reducing the cost of street improvements and effecting a saving in the use of land for street purposes."[76] See the effect of "improvement ratio" in Table 5.

TABLE 5

IMPROVEMENT RATIOS

Lot Depth	Block Length 600 ft.	Block Length 1200ft.
100 ft.	1.50	1.25
125 ft.	1.58	1.29
150 ft.	1.66	1.33
200 ft.	1.82	1.41

Source: Derived by Kain from Robert Whitten and Thomas Adams, Neighborhoods of Small Homes (Cambridge: Harvard University Press, 1931) p. 51.

The implications to be derived from Table 5 are that the widespread use of automobiles may indeed have reduced the costs of street flow systems in residential areas even if residential dwelling unit densities were lower. For example, consider a 5,000 foot lot on a 600 foot block versus a 10,000 foot lot on a 1,200 foot block (half the dwelling unit density):if each lot had a 50 foot frontage and identical frontage costs per foot, then total improvement costs for the lot 100 feet deep (50' X 100') are 150 per cent of front foot costs while total costs for the 200 feet deep lot (50' X 200') are only 125 per cent of frontage costs. The over-all effect of lower density may have been to reduce rather than increase the costs of some skeletal type services. When these reduced costs are balanced against other services which may be higher at low densities, there is some question as to the importance of residential density as a determinant of the total costs of urban services.

The investigation by Kain suggests that the cost of "lot distribution systems", consisting of driveways, sidewalks, sewer, gas, and water connecting lines, electricity and telephone connections, are "almost entirely a function of structure setback". While two structures may gain economies by sharing a Y connector line when setbacks are very great, care should be taken in comparing the lot distribution costs of multi-dwelling unit structures with single family structures, because the former type of development performs much of the lot distribution function within the "structure distribution system", and the economies of a high density structure may be exaggerated. The cost of "structure distribution systems" would appear to vary little with residential density.[77] Also, the costs of inter-neighborhood "trunk" distribution system do not appear very sensitive to even large variations in residential density. Kain states:

> An increase in average lot size of 25 per cent caused an estimated increase in the length of trunk lines of less than 2 per cent. Since costs do vary somewhat with capacity, the increase in costs might be even less. Also for most urban services, costs of trunk lines, or the inter-neighborhood distribution system, are not a very large portion of total system costs. They are probably greatest for urban transportation systems because peaking is generally more pronounced and because unit costs probably are more closely related to capacity than in most other inter-neighborhood systems.[78]

Thus it is the costs of "intra-neighborhood distribution systems" which appear to be quite sensitive to neighborhood density and design. Many "cellular" type urban services are not considered in studies of density on the assumption that the relationship between density and several urban services, at any rate, is rather tenuous. For example, Ludlow states: "Some costs are roughly proportional to population regardless of density, assuming comparable levels of service. These include schools, health and library services, and playgrounds for active recreation." But, he forwards, "costs of streets and utilities, refuse disposal, and parks for passive recreation vary considerably for a given population depending on density."[79] Apparently researchers in the past have chosen on a priori grounds to follow reasoning such as Ludlow's; but, the list of urban services is long and investigation may produce more services sensitive to density than previously assumed.

Kain has pointed out that the studies of costs of residential development have been of two kinds: engineering cost studies and case studies of the costs of providing urban services for particular communities under actual conditions. Engineering cost studies typically obtain unit engineering costs, e.g., the costs per lineal foot of installing a sanitary sewer of a given capacity, the costs per square foot or lineal foot of an access street or roadway of a specified thickness or load-bearing capability, the costs per front foot of installing a gas or water main of a given diameter, and the like. The Adams and Whitten study is of this type. Two studies performed in 1955, one by Wheaton and Schussheim[80] and another by Oppenheim[81] could be classified as case studies. Statistical cost studies of costs versus density have not been very useful to date.[82]

b. Kain's Use of the Urban Land Institute Study/ Public Improvement Services

A very complete and useful engineering cost study on the relationship between residential density and the costs of urban services was published in 1958 by the Urban Land Institute: The Effect of Large Lot Size on Residential Development.[83] This study considers a very complete set of urban services including private "on-site" costs as well as public "off-site" costs:

Off-Site Costs

1. Local access streets
2. Water mains
3. Sanitary sewers
4. Sidewalks
5. Loam, seeding, and trees
6. Curbing

On-Site Costs

1. Driveway
2. Access walk
3. Water connection
4. Sewer connection or septic tank or cesspool

As comprehensive as this study is, it doesn't include the cost of utilities such as (1) electricity: although electricity service amounts to a significant share of the household budget, its omission may not be too serious as there is evidence that the cost of an electric distribution system for residential development may be only 4 per cent as great as those of a water distribution system;[84] (2) gas: the cost of installing gas mains is similar to that of water mains, i.e., increasing with frontage; but not only is gas less of a necessity than water but at almost any density development, bottled gas can be substituted; also at any density, coal, oil or electricity are substitute fuels; (3) refuse collection, street maintenance, street cleaning and snow removal - all of which might depend on frontage. Actually how these costs relate to density has not been well researched and documented. Kain has commented on this omission:

> It should be noted that for none of these services is even the direction of the relationship between costs and gross or net residential density obvious. Refuse collection costs might be expected to be lower in denser neighborhoods because the dwelling units are closer together. However, there might be less congestion in lower density neighborhoods and this might more than compensate for the greater distance to be covered. Similarly, even if there are more miles of streets in lower density neighborhoods, they may require less frequent cleaning. Streets in lower density neighborhoods may have lower maintenance costs per mile insofar as street maintenance is dependent on traffic.[85]

TABLE 6

UNIT COSTS OF LOT IMPROVEMENTS - FULL STANDARD

Unit Off-Site Costs (In Frontage Street) Per Front Foot

(1) street, including clearing, excavating, grading, and roadway construction, assuming a 27 ft. roadway of bituminous concrete on 12" of gravel and 1" of crushed gravel	$ 4.50
(2) storm drainage, including manholes, catch basins, and culverts	3.00
(3) water main, including valves, hydrants, and fittings	2.50
(4) sanitary sewer, including manholes, and appurtenances	4.00
(5) sidewalk, assuming 4-ft. width asphalt on both sides of street	1.00
(6) curbing of concrete	1.50
(7) grass plot loam, seeding, and street trees	.50
Total off-site improvements (full standards)	$ 17.00

Unit On-Site Costs (On the Lot Itself)

I. House connections, assuming uniform setback:

(8) water connection: $75.00 to connect + $1.25/ft. from house to water main in street

(9) sewer connection: $90.00 to connect + $1.75/ft. from house to sewer main in street

(10) driveway, 10 ft. asphalt surface on crushed gravel: $2.50/ft. from garage to curb

(11) access walk, 3 ft. asphalt walk: $1.00/ft. from house to sidewalk

II. Landscaping costs, including clearance and topsoil removal, rough grading (within 25 ft. of house on all sides), finish grading, loaming and seeding, trees and planting:

for lot of	6,000 sq. ft.	$250.00
	10,000 sq. ft.	350.00
	20,000 sq. ft.	500.00
	40,000 sq. ft. & over	600.00

(Note the above landscaping costs are assumed to level off at about $600 at roughly 40,000 sq. ft., and remain constant for lots over this figure. The portions of large lots in excess of approximately 1/2 acre would remain in a natural state.)

Source: "The Effects of Large Lot Size on Residential Development", Urban Land Institute - Technical Bulletin No. 32, Washington, D.C.: ULI, 1958), p. 13.

Similar to the methodology of Witten and Adams, the Urban Land Institute (ULI) develops a model lot and block and evaluates the effect of changes in the area, width, and depth of the lot, the quality of improvements (full or reduced standards) and the setback on the costs of a good number of urban services. Thus, the information they present allows the quality to be held constant, the ratio of frontage to depth to be held constant, and the output of services to be held constant; the costs of urban services may then be traced with variation in the area of residential lots.

Economist Kain has taken the ULI data on unit costs of lot improvements presented in Table 6 and constructed equations to approximate the average unit cost function for the ULI "package" of urban services. Equation (1) below expresses the cost of a developed lot at a quality of "full standard" served by a sanitary sewer as a function of frontage, F; setback, S; landscaping costs - a non linear function of area (see Table 6), L; and A, which represents the number of square feet including one half of the area needed for street area. Equation (2) represents a substitution of septic tank or cesspool for sanitary sewer in equation 1.

(1) $C = 350.00 + 21.25\ F + 8.12\ S + 1\ A + \$.075\ A$ with sewer

(2) $C = 620.00 + 14.25\ F + 5.91\ S + 1\ A + \$.075\ A$ with septic tank

These cost functions represent the urban service capital outlays cost to develop the intra-neighborhood and lot distribution systems. Figure 16 shows the effect on costs of urban services per lot to develop residential plots of varying area holding the width-to-depth ratio constant at 3 to 5. The solid cost curve in Figure 16 represents unit cost with sanitary sewer while the lower curve in dashes represents unit cost with septic tank or cesspool.

It should be noted that the capital outlays in these development costs reflect inputs, not outputs. Although the assumption will later be relaxed, it is assumed here that the same inputs are necessary at low densities as they are at high densities to insure a constant quality of output. Only the component of sanitary waste disposal is permitted to be varied. The difference in cost between the two curves at any one lot size can be contributed to the difference in input costs between the two sewage service production techniques; but it might be adopted as a dollar and cents estimate of the quality difference between the two techniques.

The implications of Kain's "development cost" curves are valuable. The costs of the development "package" of municipal services does not appear to be as sensitive to lot sizes as might have been expected. Figure 16 shows that unit development costs change far less than in proportion to changes in density or lot size. Kain calculates that a 100 per cent increase in area, from 3,000 to 6,000 square feet, causes development costs to increase by only 31 per cent and from 20,000 to 40,000 square feet, about 30 per cent. Note, that if by shifting to a 40,000 square foot lot permits the use of a privately provided waste disposal system (e.g. the septic tank curve on Figure 16), unit development costs would increase by only 14 per cent. The ability to shift from curve A to curve B in Figure 16 dampens the effect of density on total (public and private) development costs, for the development costs with privately provided waste disposal are lower at all densities than the publicly provided sewage system. The shift from a 20,000 to a 40,000 foot lot size causes public outlays to decline even though total costs increase by 18 per cent. As alluded to before, this explains the attractiveness of large lot zoning for those who only consider the public costs of providing urban services as opposed to total costs (public and private). The Wheaton-Schussheim and Isard-Coughlin[86] studies conclude that low-density developments are less costly than medium-density developments because they approach service costs from the public rather than the total cost standpoint.

Frontage costs are the largest variable component of lot development costs in equations 1 and 2; yet they appear weakly related to area. A lot with constant frontage costs (width) can have any area (length). The curves in Figure 16 used a width-to-depth ratio of 3 to 5. If this ratio of .6 is reduced to a ratio of 1 to 2, a 100 percent increase in area from 3,000 to 6,000 square feet would increase development costs by 21 per cent, rather than the aforementioned 31 per cent. The Urban Land Institute has found that in practice, the ratio does tend to decrease with increases in lot size.[87] Thus, there is a decided weakening (1) of the relationship between frontage costs and area, and derivatively, (2) of dependence of development cost on area or density.

A 30 feet setback was assumed in Figure 16. Reductions in setbacks would appear to offer economies if less expensive development is desired. However, as Kain says, "So long as zoning and subdivision regulations require substantial setbacks, lot development costs will be even more weakly related to area. Of all the components in the two equations, landscaping is strongly dependent on area, but it too decreases as lot area increases."[88]

By constructing a similar cost curve which includes the costs of raw land as part of development costs, Kain was able to conclude that "raw land costs, a privately borne cost, appear far more dependent than

FIGURE 16

Cost of a Developed Lot Excluding Raw Land with and without Sewers by Area: Constant width to depth ratio of 3 to 5

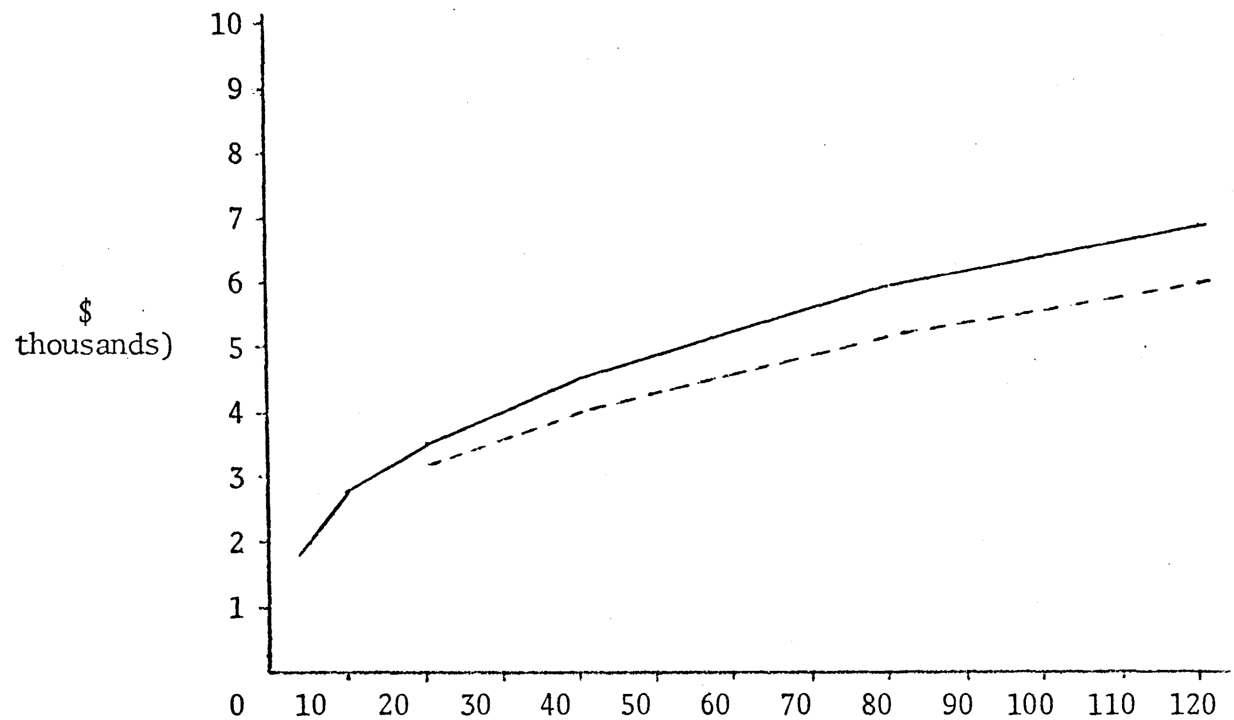


TABLE 7

UNIT COSTS OF LOT IMPROVEMENTS - REDUCED STANDARD

Unit Off-Site Costs (In Frontage Street) Per Front Foot	a	b
(1) street (a) reduced to 24 ft. roadway of oil penetration and asphalt construction	$3.50	
(b) reduced further to 20 ft. roadway of oil penetration and seal coat		$3.00
(2) storm drainage (a) reduced by elimination of manholes, catch basins, and length of pipe under street	2.00	
(b) reduced to minimum surface drains		1.00
(3) water main not significantly reduced	2.50	2.50
(4) sanitary sewer replaced by individual sewage disposal system (see on-site)	-	-
(5) sidewalk (a) on one side of street only	.50	
(b) eliminated on both sides		-
(6) curbing eliminated	-	-
(7) loam, seeding, and treet eliminated	-	-

Unit On-Site Costs (On the Lot Itself)

(8) water connection not significantly reduced

(9) sewer connection eliminated and septic tank and cesspool, or two cesspools, installed at $350.00 per lot

(10) driveway not significantly reduced

(11) access walk eliminated

Source: Urban Land Institute - Technical Bulletin No. 32, 1958, p. 13.

the costs of municipal services or lot improvements on lot size or net residential density. Thus, private costs appear to be far more strongly affected by changes in lot size than municipal or public costs."[89]

Now, consider relaxing the assumption as to the need for the same list of inputs at all lot sizes to maintain a relatively equivalent quality of output in the minds of the public. The Urban Land Institute suggests that the list of on-site and off-site improvements presented in Table 6 can be altered at different densities.[90] For example, in their view the following improvements can be omitted altogether at low density: curbing, "V"-type gutters, sidewalks on both or only one side of the street, and access walks to houses. Also the design of roads is much more dependent on the volume and type of traffic anticipated and on street grade than on the area of the lots lining the road. They suggest that low density area roadways may be reduced in width; less thick pavement may be used; and an oil penetration surface and asphalt can be substituted for concrete. They elaborate that a reduction in the size of water mains and a greater spacing of hydrants and valves may be possible. The storm drainage system may change drastically. Large lots have less run-off per square foot than smaller ones and require less elaborate systems.[91] Consequently, the Urban Land Institute has prepared in addition to a list of improvements at full standards (Table 6), a list with two sets of reduced standards (Table 7). It will be observed that under "reduced standard A" and "reduced standard B" many improvements such as curbing, access walk, loam, seeding and trees and a sanitary sewer system are entirely eliminated.

By formulating equations similar to those presented earlier, Kain has constructed a series of curves showing costs with public sewers versus septic tanks for each of the three ULI standards. In rough terms he finds development costs for a 6,000 square foot lot assuming public sewers and "reduced standard A" to be 82 per cent of those of full standard, and those of "reduced standard B" only 75 per cent; both percentages decline slightly to 80 and 71 per cent at 40,000 square feet. The number of technological trade-offs has increased greatly. As an example:

(a) the development costs of a 6,000 foot lot with public sewer developed at "full standard" is greater than the costs of a 20,000 square foot lot without public sewers developed at "reduced standard B".

(b) the development costs of a 10,000 square foot lot with public sewerage and at "full standard" ($2,602) is greater than the development costs of a 40,000 square foot lot without public sewerage and developed at "reduced standard B" ($2,469) and development costs of an 80,000 square foot lot with the same standard are only slightly greater ($2,996).[92]

This proliferation of alternatives has prompted Kain to conclude:

> These design specifications changes greatly affect the elasticities of residential development costs with respect to lot size and density. When "full standard" and public sewers are assumed, increasing lot size from 3,000 to 160,000 square feet (a 5,233 percent increase in area) causes development costs to increase by 369 per cent. However, if it is assumed that the 160,000 square foot lot may be developed at "reduced standard B" and with an on-site waste disposal system, development costs increase by only 125 per cent.[93]

c. P.A. Stone/Total Public and Private Structure Costs versus Density

Stone's study[94] was made in Great Britain and while it must be treated with caution as to the dissimilarities between construction costs there and in the United States, his study should not be overlooked for its valuable perspective on development costs and density. He has concerned himself with the relationships between the costs of structures and of utilities and public services. The study reveals that there are reductions in public utility service costs as the density of dwellings per acre increase from about 20 to 40. Note that the lot distribution systems become part of the structure costs. He concerns himself with a density range of from 20 to 44 dwellings per acre and concludes that there must be increases in building heights from 2 to 12 stories to achieve his postulated densities. Some of Stone's results are presented in Table 8. His findings certainly suggest that medium density developments have lower costs than those at very high density. Stone comments:

> There is little doubt that under current conditions dwellings within two-storey blocks are the cheapest. Tender prices rise with increases in the number of storeys but the rise is less than proportional. While it is steep from two to five storeys, it tails off among the higher blocks, but it is not possible to be very certain of the price relationships for the very tall blocks as so few have been built.[95]

Table 8 also points up the wide variation in floor area of dwelling units. It could be that high density developments have lower municipal service costs, at least in part, because the floor areas of apartments themselves tend to be smaller than those found in single family houses.

TABLE 8

ESTIMATED NET CONSTRUCTION COST PER DWELLING
(ENGLISH POUNDS STERLING)

Block Height	Three bedroom 910 sq. ft.	Two bedroom 770 sq. ft.	Two bedroom 680 sq. ft.	One bedroom 510 sq. ft.
2	1,470	1,323	1,230	1,034
3	1,764	1,587	1,476	1,240
4	1,999	1,799	1,673	1,405
5	2,176	1,957	1,820	1,530
6	2,308	2,076	1,931	1,623
7	2,411	2,169	2,017	1,695
8	2,499	2,249	2,091	1,757
9	2,573	2,315	2,153	1,809
10	2,631	2,367	2,202	1,850
12	2,720	2,447	2,275	1,912

Source: P.A. Stone, "The Economics of Housing and Urban Development", Journal of the Royal Statistical Society, Part IV, Vol. 122, 1959, p. 426.

In general, most comparisons of municipal service costs and density implicitly assume that the dwelling unit size remains constant - a far from realistic assumption. This variation tends to be inversely correlated with net residential density. Table 8 also shows that the construction economies per dwelling unit become less as dwelling unit size increases. His results indicate that if land costs are disregarded, town house (row house) and two or three story apartment flats will have close to minimum costs.[96]

d. Wheaton and Schussheim/Public and Private Capital Costs Per New Dwelling Unit Versus Unused Capacity and Density

The Wheaton and Schussheim investigation is a case study of the costs of providing services to new residential development in three suburban communities located in the Boston Metropolitan Area.[97] Kain has commented that the findings of Wheaton and Schussheim remain far more dominated by factors peculiar to the individual communities they study than by changes in residential density and similar variables, even though the authors made tremendous efforts to isolate the independent effects of density. Their approach and methodology is intended to illustrate the lumpiness of some kinds of public investments, and also to consider the capital costs precipitated on the community (public and private) by the building of 500 new dwellings at different "densities" and "locations" within the three communities of Natick, Newton and Wayland, Massachusetts. By "location", the authors refer primarily to the availability of various kinds of unused or underutilization of public facilities. The costs of new residential development differ substantially based on their assumptions of whether development occurs in "locations" where presently existing underutilized facilities are present or whether it occurs where new capital investments are precipitated. Thus, they tend to underline the importance of the distinction between the long-run and short-run cost curves. This is in contrast to the previously mentioned engineering cost studies which were concerned with the long-run and treated capital investments as variable. In reviewing some of their findings below, observe that "location" tends to be far more important in cost determination than density variation.

Table 9 below presents the precipitated capital costs of 500 new dwellings at three alternative locations in Natick. The classification of "scattered growth area is to indicate scattered development occurs within built up sections of either moderate-sized clusters or small groups of 10 or fewer dwellings. Development in "concentrated area A" occurs on 10,000 square foot lots with 70 foot frontages. "Concentrated area C" assumes development on 20,000 square foot lots with 110 foot frontages. Their analysis of precipitated costs is dominated by the extent of unused or underutilized capacity (particularly sewers and schools) available in each area of Natick. The Table reveals clearly that it is far cheaper in terms of capital costs per unit to locate development so as to take advantage of unused capacity than to build a new capacity. Also the increased number of users of present capacity may permit fixed operating costs to be spread and a more efficient provision of services may ultimately be derived. Their concern, however, is with precipitated capital costs and their assumption of continuation

TABLE 9

PER DWELLING UNIT CAPITAL COSTS OF FACILITIES PRECIPITATED BY 500 NEW DWELLINGS IN 3 ALTERNATIVE LOCATIONS IN NATICK FOR ALL ITEMS AND BY SERVICE*

(In 1951 Dollars)

	Scattered growth areas	Concentrated Area A	Concentrated Area C
Service	Per dwelling unit	Per dwelling unit	Per dwelling unit
All items	1,956	2.192	2,762
Schools	863	863	1,496
Streets	642	704	892
Sewers	284	439	0
Water	165	176	352
Fire	2	10	22

(Detail will not necessarily add to totals because of rounding.)

* Assumptions: (1) Density in all areas as zoned: Minimum lot size and frontage in scattered growth areas and in concentrated area A, 10,000 square feet and 70 feet; area C, 20,000 square feet and 110 feet. (2) School costs are based upon a probable high population projection and prevailing pupil-room ratios (40 to 45 per elementary class), and include provision for total eventual needs. (3) Sewers are assumed necessary in all new streets in scattered growth areas. (4) Where existing street frontage is available in any of the areas, it is taken as used.

Source: William L. C. Wheaton and Morton J. Schussheim, The Cost of Municipal Services in Residential Areas, (Washington, D.C., Housing & Home Finance Agency and the U. S. Dept. of Commerce, 1955) p. 13.

of community policy to build new neighborhood schools[98] rather than bus pupils to existing schools with excess capacity accounts for most of the higher per dwelling unit capital costs in "concentrated area C." Note that only marginal variations in costs are caused by differences in densities. Thus, this study should not be cited as proof that the public service costs of low-density development significantly exceed those of high density development.

The scattered growth alternative precipitated substantially less capital costs than those of the concentrated development areas because it took advantage of existing capital facilities. Wheaton and Schussheim comment on this point:

> In the case of Natick, the scattered growth areas in which the dispersed development would occur are already serviced in many places with frontage facilities which can be utilized by the new homes. Sewerage facilities and streets are the two major facilities in which the absorption of excess capacity would result in large savings. In these two items alone, a saving of $217 per dwelling unit would be realized in the scattered growth areas over area A.[99]

The authors also evaluate the incremental capital outlays for schools, streets, sewers, water and fire required for 500 new dwellings in four alternative locations and densities in Newton, Massachusetts. The alternatives are: scattered growth areas - predominantly single-family type of lots of approximately 10,000 square feet and 80 foot fronts; areas A and B - single detached houses on lots of 15,000 square feet with 100 foot fronts; and area C - multiple-family units averaging 3,000 square feet and 20 foot fronts. Table 10 presents the findings along with the assumptions for Newton. The analysis prompted the authors to conclude that:

> Changes in the allowable density and type of housing development are capable of producing very substantial differentials in the cost of municipal improvements precipitated by further residential development in Newton. . . Precipitated capital costs, in other words, would be about three times as high in single-family districts as in the multiple-family area.[100]

Whereas the costs presented in Table 9 varied greatly depending on the use of unused capacity and the creation of new capacity, the authors contend that the cost differences presented in Table 10 are "chiefly the product of density and type of housing. They are clearly not associated with location per se." However, the study does not successfully isolate the effects of density over a wide range of lot sizes; and it must be concluded that as valuable and important a study as this one is in illuminating the effects of utilization of unused existing capital facilities and methodology, its findings concerning the relationship between density and the costs of urban public services is somewhat ambiguous.

e. The Utilities/Electricity, Gas, Telephone

There appears to have been a decline in the amount of academic attention devoted to public utility economics[101] for several decades. Such should not be the case for there continues to be technological advances such as the development of nuclear electric power generating stations, space communication satellites and even complete power systems for individual homes, such as those developed by Caterpillar Tractor Corporation, which use gas as the input to produce electricity, heating and air conditioning. Studies of economies of scale using such new techniques of production should be of considerable value.

TABLE 10

PER DWELLING UNIT MUNICIPAL CAPITAL COSTS PRECIPITATED BY 500 NEW DWELLINGS IN SEVERAL ALTERNATIVE LOCATIONS AND DENSITIES IN NEWTON FOR ALL ITEMS AND BY SERVICE *

(Costs per dwelling unit in 1951 dollars)

Service	Scattered growth areas single family housing	Areas A and B single family housing	Area C multiple family housing
All items	1,936	2,196	670
Schools	296	296	296
Streets	770	992	180
Sewers	638	594	138
Water	215	288	52
Fire	17	26	4

* Assumptions: (1) Density and type of structure: Areas A and B: Single detached houses on lots of 15,000 square feet with 100 foot fronts. Scattered growth areas: Predominantly single-family type of lots of approximately 10,000 square feet and 80 foot fronts. Area C: Multiple-family units averaging 3,000 square feet and 20 foot fronts. (2) School costs based on medium-high population projection and prevailing pupil-room ratios of 25 to 30 per elementary and junior high class, and include provision for eventual junior and senior high school needs. (3) Existing unused frontage facilities (streets, water, and sewer) assumed used wherever found. (4) Area B primary outlays assumed identical with those for area A although slightly different amounts of available frontage facilities may be found. (5) No charge is here made for facilities directly serving commercial property.

Source: Wheaton and Schussheim, p. 70.

Empirical documentation of economies of scale in the production of electrical, gas and telephone services found in public utility text books and many sources[102] would seem to require little discussion here. For example, several recent statistical cost studies by Nerlove,[103] Lomax[104] and Johnson[105] have all detected declining average unit cost conditions. K. S. Lomax found long-run average cost functions declining in relation to gas supply and J. Johnston, likewise, found long-run average cost of electricity supply declining. Marc Nerlove correlated production costs with physical output and labor, capital, and fuel prices on a firm basis. The coefficient of multiple determination for 145 privately owned utilities in 1955 was .93 and statistically significant increasing returns to scale were indicated. However, a few tables of closely related information may prove interesting.

The Public Service Commission of Wisconsin[106] has provided considerable data concerning the prices of privately versus publicly provided electricity for different size Wisconsin communities. Table 11 and Table 12 may be contrasted. The former presents residential electricity rates for each of four levels of electricity consumption for publicly served Wisconsin communities ranging in population from "under 500" to "over 20,000" (which includes Milwaukee). Table 12 presents the rates charged by regulated private electric firms for the same consumption levels to the Wisconsin communities which are privately served.

Note that when the number of communities for each population group is a representative size that electricity rates at all consumption levels,

TABLE 11

COMPARISON OF NET BILLS FOR RESIDENTIAL ELECTRIC
SERVICE IN WISCONSIN COMMUNITIES AS OF JANUARY 1, 1967

SUPPLIED BY MUNICIPAL UTILITIES

Population Group	Number of Communities	Avg Net Bills per Month 100 Kw. Hr.*	Avg Net Bills per Month 500 Kw. Hr**	Avg Net Bills per Annum*** 20,000 Kw. Hr.	Avg Net Bills per Annum*** 35,000 Kw. Hr.
over - 20,000	1	2.60	8.30	267.60	447.60
10,000-20,000	5	3.19	8.94	304.46	508.55
5,000-10,000	11	2.87	8.24	288.99	498.60
3,000-5,000	13	3.02	8.74	312.00	527.02
2,000-3,000	14	3.22	9.37	312.35	523.46
1,000-2,000	22	3.51	9.58	338.06	576.05
500-1,000	19	3.86	10.16	363.11	618.36
under - 500	2	4.38	10.85	421.90	721.90

* 100 Kw. Hrs. - low basic residential uses (not water or space heating)
** 500 Kw. Hrs. - basic use and 300 Kw. for water heating

*** Annual Consumption - assumes 400 Kw. per month basic residential consumption, 300 Kw. per month water heating, and balance to space heating.

Source: Public Service Commission of Wisconsin, Rates and Research Departmental Bulletin No. 9, (March, 1967).

TABLE 12

COMPARISON OF NET BILLS FOR RESIDENTIAL ELECTRIC SERVICE IN WISCONSIN COMMUNITIES AS OF JANUARY 1, 1967

SUPPLIED BY PRIVATE ELECTRIC COMPANIES

Population Group	Number of Communities	Avg Net Bills per Month 100 Kw. Hr.	Avg Net Bills per Month 500 Kw. Hr.	Avg Net Bills per Annum 20,000 Kw. Hr.	Avg Net Bills per Annum 35,000 Kw. Hr.
over - 20,000	19	$3.42	$8.98	$329.62	$550.42
10,000-20,000	19	3.45	8.71	320.29	536.13
5,000-10,000	26	3.53	9.04	329.38	549.60
3,000-5,000	20	3.61	9.45	341.74	568.21
2,000-3,000	25	3.79	9.55	339.10	561.79
1,000-2,000	81	3.99	9.88	345.66	569.77
500-1,000	114	4.18	10.17	348.50	574.04

Source: Public Service Commission of Wisconsin, Bulletin No. 9.

both publicly and privately produced, are inversely proportional to the size of the community served. The small communities pay the highest rates. Also note that for almost every size community at all consumption levels, the privately provided electricity is marketed at a considerably higher rate than the publicly provided power.

Actually the privately provided electricity service is produced by 14 companies. This investigator has derived a table of population groups which show unweighted mean rate differentials with each of four population categories served by the private utilities. Although each company may have several plants the data as presented in Table 13 suggest the likelihood of economies of scale in the production of electricity and certainly a relationship between rates and population.

TABLE 13

COMPARISON OF NET BILLS FOR RESIDENTIAL ELECTRIC
SERVICE IN WISCONSIN COMMUNITIES AS OF JANUARY 1, 1967

BY POPULATION SERVED BY PRIVATE ELECTRIC COMPANIES

ulation Served y Companies	Number of Companies	Avg Net Bills per Month 100 Kw. Hr.	500 Kw. Hr.	Avg Net Bills per Annum 20,000 Kw. Hr.	35,000 Kw. Hr.
r-1,000,000	1	$3.35	$8.35	$309.30	$519.38
,000-1,000,000	4	3.51	9.31	326.52	560.83
000-100,000	3	3.98	9.77	359.57	590.78
-10,000	6	4.28	11.15	365.36	614.92

Source: Derived by Grove from Table 12 and other sources.

Economist William D. Shipman[107] has developed the following comparison indicating economies of scale in nuclear and conventional electric power generation by large central stations:

TABLE 14

COMPARATIVE POWER COSTS FOR NUCLEAR AND CONVENTIONAL PLANTS COMMITTED IN 1963

	NUCLEAR*			CONVENTIONAL**		
	300 Mw.	600 Mw.	900 Mw.	300 Mw.	600 Mw.	900 Mw.
Capital cost, $ / Kwh	195	164	151	180	158	148
Fixed Charges, Mills/kwh	3.9	3.3	3.0	3.6	3.2	3.0
Fuel Cost, Mills/kwh	2.0	2.0	2.0	2.5	2.5	2.5
Oper. & Maint. Mills/kwh	.7	.6	.5	.5	.4	.3
Total Cost, Mills/kwh	6.6	5.9	5.5	6.6	6.1	5.8

* Nuclear plants are assumed to be single-unit water reactors and turbine-generators. Fuel is assumed to be government-owned, and fuel costs shown are for equilibrium cores assuming a $9.50/gm Pu credit.

** Conventional plants are single units built to achieve an 8,500 Btu/kwh heat rate and using partial outdoor construction with 30¢/million Btu coal or oil as the principal fuel.

Sources: Shipman derived from United States Atomic Energy Commission, General Electric Company and Westinghouse Manufacturing Company.

Yet, J. A. Stockfisch of U.C.L.A. cautions that electric utilities are not necessarily constructed to take full advantage of economies of scale available:

> [I]t is questionable whether electric utilities, of the size encountered under present conditions (due to state protection and regulated monopolies) are in fact decreasing cost industries. A utility serving several million people appears large enough to exploit most, if not all, of the economies of scale implicit in the technology (this is a question of fact, however). Hence, at best it probably operates under constant cost conditions. Pricing so as to cover long-run marginal cost, and an opportunity return on investment would not be incompatible goals. To point to a utility's ability to sell non-peak-load power at prices below "full cost" does not prove that utilities are decreasing cost industries within the scale they customarily operate. Rather, it indicates a confusion between short-run and long-run marginal costs.[108]

Also as Table 15 shows, smaller Wisconsin communities must pay higher rates for gas service than larger communities. However, note that the differential in gas rates (e.g. for 8 therms for a community "over 20,000" to one between "500-1,000", $1.83 to $1.99 or about 9%) is considerably less than the differential in the basic unit of electricity (e.g. for 100 Kw. Hr., $2.60 to $3.86 or about 50 % for public utilities and $3.42 to $4.18 or about 22% for privately provided electricity).

TABLE 15

COMPARISON OF NET MONTHLY BILLS FOR
RESIDENTIAL GAS SERVICE IN INCORPORATED
WISCONSIN COMMUNITIES OVER 500 POPULATION
as of January 1, 1967

Size of Community	Number of Communities	Average Net Bills per Month 8 Therms*	32 Therms**	Estimated Annual Bill 1800 Therms***
over-20,000	20	$1.83	$4.99	$194.13
10,000-20,000	24	1.84	5.14	201.53
5,000-10,000	37	1.93	5.39	204.79
3,000-5,000	33	1.97	5.56	207.78
2,000-3,000	36	2.04	5.81	207.29
1,000-2,000	89	1.97	5.65	211.87
500-1,000	83	1.99	5.80	215.36

* 8 therms - typical cooking consumption of moderate size family

** 16 therms - large cooking and water heating use, or cooking, refrigeration and automatic storage water heating for average customer

*** 1800 therms (per year) - space heating service for moderate size home, cooking and automatic water heating. The estimated annual bills of 1800 therms are arrived at by assuming that 24 therms were consumed each month for general use (presumably cooking and water heating). For 12 months this accounted for 288 therms. The remaining 1512 therms were allocated on the basis of the average degree day distribution through the year in Madison. This method resulted in the following monthly consumptions:

January	318	therms
February	274	therms
March	233	therms
April	143	therms
May	79	therms
June	40	therms
July	26	therms
August	30	therms
September	52	therms
October	111	therms
November	203	therms
December	291	therms
Total	1,800	therms

Source: Public Service Commission of Wisconsin, Rates and Research Departmental Bulletin No. 10 (March, 1967).

A recent empirical study of local telephone service in Texas by Bowers and Lovejoy concluded that the telephone industry "providing local telephone service for all but small towns in Texas is an increasing cost natural monopoly."[109] A fitted curve for a random sample of exchanges having 0 to 5000 subscriber lines shows a general downward drift as exchange size increases.[110] However, their data shows an increasing average cost curve for exchanges handling from 40,000 to 300,000 subscribers.[111]

The increasing complexity of switching facilities arising because each subscriber must be connected to every other subscriber has been cited as the cause. In a growing subscriber area the investment per subscriber line also tends to rise as the area served expands. Once a calling area becomes too large to be served by a single central office, additional lines must be constructed to connect the offices to each other.

Empirical data on the cost of local exchange service are scarce but the cost studies that have been made appear to support the hypothesis that average cost per subscriber line decreases for small exchanges and rises in large exchanges.[112]

f. Water and Sewer Systems

Perhaps one of the most recent comprehensive studies of water-treatment costs is that of Orlob and Lindorf,[113] who examined the construction and operating costs of thirty-two treatment plants in California. In terms of estimated 1956 construction costs for all plants, they found that unit construction costs decreased with increasing capacity between 1 and 300 acre-feet daily capacity. Operation and maintenance costs per unit processed decreased with increasing flow and flow capacity within the same range. They estimated construction costs for a plant of 30 acre-feet daily capacity at $1,220,000. The operation and maintenance costs for a plant of this size, operated at 70 per cent capacity, were estimated at $10.00 per acre-foot. With an expected plant life of twenty years and interest at 5 per cent, these figures yield a cost per acre-foot treated of about $21.50. Note that Isard and Coughlin have commented on the difference between the real economic and the annual amortized costs and their affect on operating costs:

> From a real economic cost standpoint, the annual costs. . . are overstated. Financial arrangements customarily involve amortization over a period generally considerably shorter than the life of the improvement.[114]

Orlob and Lindorf estimated that the total cost for complete water treatment in a smaller plant, of 15 acre-feet daily capacity, was about $26.00 an acre-foot. Large plants of 150 to 300 acre-feet daily capacity were estimated to have total treatment cost of about $11.00 and $10.00, respectively. The cost of chlorine disinfection alone was estimated to range between $.30 and $.65 per acre-foot treated.

Hirshleifer, DeHaven and Milliman[115] have used the Orlob and Lindorf data to construct Table 16 of water-treatment costs under varying assumptions of (1) expected plant life, (2) long term interest rate of capital and (3) utilization of capacity. The economies of scale in water treatment are obvious from the table.

TABLE 16

WATER TREATMENT COSTS

Plant Capacity (Acre-Feet per Day) (3.07 acre ft=1 mil gal/day)	Operating at 70% Capacity 5 Percent Interest	10 Percent Interest	Operating at 100% Capacity 5 Percent Interest	10 Percent Interest
	f o r t w e n t y y e a r e x p e c t e d l i f			
3.07	52.03	64.20	40.68	49.22
30.7	21.46	26.76	16.68	20.40
307.0	9.56	12.18	7.34	9.18
	f o r t h i r t y y e a r e x p e c t e d l i f			
3.07	47.06	60.48	37.20	46.61
30.7	19.30	25.14	15.17	19.26
307.0	4.49	11.38	6.59	8.61

Source: Hirshleifer, DeHaven and Milliman, Water Supply (Chicago: University of Chicago Press, 1960) p. 177 derived from data of Orlob and Lindorf.

The costs of water "distribution" can vary from nominal costs, when water for public use is locally obtained from wells or surface sources and no transmission facilities are required, to very high costs, when it is necessary to transmit water from long distances through many pumping operations. There is little generalized cost information for large water transmission systems; however, water conveyance costs have been determined by Louis Koenig[116] for smaller systems, with capacities from 20 to about 100,000 acre-feet per year. The largest capacity could supply a city of 500,000 population. Table 17 presents water distribution costs assuming (1) flat terrain, level deliveries at full capacity (2) forty-year average life (3) insurance, interest and taxes at 6 per cent (4) electric power at one half cent per kilowatt-hour, and (5) 84 per cent pumping efficiency. The lower set of costs presented in Table 17 do not include pumping and represent a situation where the terrain allows gravity flow. Not only are economies of scale apparent in this water flow system but Koenig also reveals economies of scale relating to the length of the transmission system. A system 200 miles long costs about 10 per cent more per mile for the same capacity than one of 1,000 miles, one of 100 miles may be 20 per cent more; 50 miles, 25 to 35 per cent more; and one of 10 miles, 50 to 90 per cent more.

TABLE 17

WATER-CONVEYANCE COSTS

Dollars per acre-foot per mile	Capacity (acre-feet per year)				
	22.4	224	1,120	2,240	112,000
With pumping	$13.00	$5.88	$2.90	$2.10	$0.36
Gravity flow	10.40	3.50	1.30	.95	-

Source: Louis Koenig, "Disposal of Saline Water Conversion Brines: An Orientation Study," Office of Saline Water, Department of the Interior, Research and Development Progress Report No. 20 (Washington: April, 1957), quoted in Hirshleifer, DeHaven, Milliman.

Dr. Michael N. Danielson has reported the inability to take advantage of the significant economies of scale available in the production of this urban service because of "political fragmentation".

> In the Sacramento metropolitan area, water supply and distribution are the most splintered of all public functions, with 44 public and 55 private agencies serving the public. Minneapolis-St. Paul and their suburbs have 45 individual water utilities operating without an organizational or operational tie, except for the minimal controls exercised by State agencies. Fifty-six agencies supply or distribute water in Pittsburgh and Allegheny County. This fragmentation for water supply and distribution is concentrated in the suburbs, and parallels a similar pattern for sewage disposal service.
>
> Some utility districts are quite large, serving large areas or entire metropolitan areas. Most however, are quite small. Prior to the creation of the Municipality of Metropolitan Seattle, 82 per cent of the sewer districts in suburban Seattle were less than two square miles in area, and almost half less than one-half a square mile in area. The general tendency has been to create additional water and sewer districts rather than expand the area of existing districts. More special districts, nine, have been created in the Seattle metropolitan area for the purpose of water supply than for any other function. In surburban Nassau county on Long Island, there are 48 water districts and 41 districts for waste disposal and removal.
>
> In Miami, where water has been supplied by six minicipalities and distributed by 15, the higher administrative and operating costs resulting from this dispersion of responsibility have produced up to 75 per cent variation in retail rates for water from the same source. Fragmentation also increases developmental and operational costs. Small systems have a rapid rate of obsolescence, particularly in areas where development is not complete when the initial facility is constructed.[117]

The costs of providing the urban public service of sewage disposal has been demonstrated earlier to affect the cost of development considerably depending on the disposal technique adopted. A definition of the available technologies may be useful as a prerequisite to examining sewage system costs.[118]

One of the first methods used to dispose of sewage was the cesspool - a covered pit dug in the ground. Cesspools are usually lined with pervious material to allow the liquid to leach slowly into the soil. When the cesspool is filled with solids, it is abandoned and a new one dug. It is rarely advantageous to remove the solids from the old cesspool since during the time needed to fill the cesspool, the ground becomes so clogged with leaching solids, it can no longer absorb liquids. Today, cesspools are considered dangerous because of the relative ease with which they pollute ground water supplies.[119]

The septic tank was developed by an Englishman named Cameron and his associates in 1896. The septic process involves biological action within the tank which is similar to the action that disposes of animal waste in nature. Bacteria work in the absence of oxygen to convert a portion of the organic matter in the sewage to liquids. In the process gases are given off, such as carbon dioxide and methane. The effluent from the tank is then transferred into the ground through a seepage pit or leaching bed. Typically, this is a "field" of several narrow trenches arranged in a finger pattern about three feet below ground level. Septic effluent can become a public nuisance if by some means it reaches the surface.[120]

"Failure" of a septic system is usually related to subsoil conditions. If the soil is impermeable, the effluent will not leach into the ground, and will find its way to the surface in back yards, or into basements. If the soil is only slightly permeable, septic tank effluent will sometimes cause it to clog and become impermeable. In very permeable soils the septic effluent may flow through too quickly to allow adequate filtering and biological action before the effluent reaches some undesired location. Septic tanks require periodic removal of the sludge and scum to function efficiently. In most instances, septic tanks must be considered to be a temporary installation which must be replaced at some time in the future by a sewerage system.

When cities began to grow larger during the last century, people who lived near storm sewer systems were usually permitted to empty their sanitary sewage into them, thus creating a combined system. With disease spreading among urban populations and a developing awareness of microbiology, around 1875 growing attention was given to the public treatment of sewage. One method was to use raw sewage in land irrigation. As with cesspools and septic tanks, however, this method tends to clog the soil, and it also requires a large disposal area. A second technique involved the removal of large solids by sedimentation. In Europe, experimentation with this second method centered on the use of chemical precipitation to settle solids. On this continent, the use of screening devices was more common. Neither of these processes were fully satisfactory in the removal of disease-carrying bacteria.[121]

Most off-site systems of sewage treatment in this century have been aerobic, that is, they introduce air into the sewage to induce oxidation. In aerobic systems, primary treatment is usually the first step. This consists of plain sedimentation to remove the settleable solids. The next step is termed secondary treatment, and consists of aerating the settled sewage either by spreading it over a bed of rock (trickling filtration), or by forcing air through the settled sewage (aeration).

Sometimes, municipalities and sanitary districts incorporate a third stage in the treatment process known as tertiary treatment. This may involve putting the sewage through two stages of trickling filter or aeration processes or a combination of both. Other methods of tertiary treatment include the use of fine dram-type screens or sand filters which collect tiny solids suspended in the effluent. Lastly, land irrigation or a final stabilization pond is also a technique of obtaining a clearer effluent.[122]

Whereas the Council of State Governments estimated about 128 million United States citizens served by water utilities, and about 22 million persons served by privately-owned water facilities as of January 1, 1963,[123] a somewhat smaller proportion of the total population is served by public sewerage facilities. The same body estimates approximately 118 million persons in 1962 were served publicly and that "privately-owned sewerage facilities account for a negligible proportion of the total." The distribution of population served by different sewage disposal techniques has been reported by the Public Health Service in Table 18.[124]

TABLE 18

PERCENTAGE DISTRIBUTION OF THE SEWERED POPULATION
BY TYPES OF TREATMENT FACILITIES

Type of Treatment[125]	January 1, 1957	January 1, 1962
None	22.4%	12.4%
Minor	1.9	2.0
Primary	26.1	27.6
Intermediate	5.6	6.3
Secondary	44.0	51.7
Totals	100.0	100.0

Source for 1957 and 1962: U.S. Department of Health, Education, and Welfare, Public Health Service, Statistical Summary of 1962 Inventory of Municipal Waste Facilities in the United States, 1964, tables 15 and 21, pp. 26 and 31.

Major economies of scale are achievable in sewage treatment facilities. "For example, it costs an average of $8 per million gallons to provide primary sewage treatment with a 100,000,000 gallon capacity treatment plant. For a 10,000,000 gallon capacity plant the comparable cost is $23. And costs are $58 for a 1,000,000 gallon capacity facility."[126] It should be noted, however, that these data exaggerate the potential savings from increases in the size of treatment facilities. They do not take account of the additional costs involved in the lengthy trunk sewers needed to collect sewage to a single processing location. Estimated unit costs of construction, operation, and maintenance for this urban service have been compiled by the Office for Local Government of New York State in Table 19.

TABLE 19

ESTIMATED UNIT COSTS OF CONSTRUCTION, OPERATION, AND MAINTENANCE OF SEWAGF WORKS FACILITIES, JANUARY 1962

I. Sewage treatment Plant:	Primary treatment only	Primary and secondary treatment
A. Average cost of construction, per million gallons daily (m.g.d.)		
Plant with 100 m.g.d. capacity	$135,000	$230,000
Plant with 10 m.g.d. capacity	230,000	400,000
Plant with 1 m.g.d. capacity	415,000	720,000
B. Operation and maintenance cost, per million gallons		
Plant with 100 m.g.d. capacity	$23.00	$35.00
Plant with 10 m.g.d. capacity	27.00	39.00
Plant with 1 m.g.d. capacity	44.00	62.00
II. Sewage pumping stations:		
A. Average cost of construction per million gallons daily (m.g.d.)		
Plant with 50 m.g.d. capacity	$11,000	
Plant with 10 m.g.d. capacity	22,000	
Plant with 1 m.g.d. capacity	68,000	

Whereas unit costs of sewage disposal service are related to plant capacity in Table 19, the economies of scale associated with capital costs of laying sewer pipe are derived by this investigator using data from Isard and Coughlin. This investigator has constructed a volume capacity index by calculation of the cross section area of the sewer pipes for given pipe diameters. The capacity index reflects multiples of the cross section area of the 12 inch diameter pipe and may be deemed to be a crude index of the flow transmission capacity. By division of the capacity index into capital outlay costs for each diameter pipe per foot and per mile, dramatic economies in the installation of larger diameter pipe become apparent, especially for the range of diameters up to 36 inches. At larger diameters the rate of economies increase but at a decidedly decreasing rate. Also an analogy may be drawn to the economies revealed in Koenig's data on length of water transmission systems; the more footage of sewer pipe installed at one time the greater the economies i.e. the lower the capital outlay per foot. This is again apparent in Table 20, if the reader visualizes the division of the last two columns by the number of feet in a mile and compares the quotient with the columns on capital outlay per foot of installed sewer pipe.

TABLE 20

UNIT CAPITAL OUTLAYS FOR SEWERS IN PLACE AND
ECONOMIES OF SCALE IN SEWER PIPE CAPACITY
(BY DIAMETER OF PIPE, TRENCH DEPTH 6 FT.)

Diameter (inches)	Capacity (Area in sq. in.)	Capacity Index	Capital Outlay (per foot)	Foot Outlay per Capacity Index	Capital Outlay (per mile)	Mile Outlay per Capacity Index
12	113	1	$5.50	$5.50	$29,000	$29,000
24	452	4	8.50	2.13	44,900	11,225
36	1017	9	12.20	1.36	64,500	7,166
48	1808	16	18.50	1.16	97,800	6,113
60	2826	25	26.50	1.05	140,000	5,600
72	4069	36	34.60	.96	183,000	5,084
84	5539	49	43.10	.88	228,000	4,653

Source: Derived from Isard and Coughlin, op. cit., Table A-25, p. 70.

Isard and Coughlin also collected empirical evidence of economies of scale in the operation of secondary sewage plants in Massachusetts in 1953. Their findings are presented in Table 21. The data presented in Table 21 is typical of the variation and scatter of results experienced when individual plant performance is listed. Yet, a correlation analysis of these data reveal a statistically significant negatively sloping unit cost function. Plants vary considerably in age and obsolescence and in efficiency of operation. Not only this, but within any one production technology there is likely to be wide variations in the quality of the output, even if costs per unit to produce "treated sewage" appear to follow the decreasing cost pattern with increasing scale.

The Northeastern Illinois Planning Commission reports[127] that the treatment plant efficiency is measured in terms of its ability to remove the bio-chemical oxygen demand (BOD) from the sewage. Depending upon circumstances, primary treatment can remove from 30 to 45 per cent of the BOD from municipal sewage, and secondary treatment up to 80 - 95 per cent of BOD.

Measuring the efficiency of plant operations is a difficult task since the amount of BOD removed varies considerably from day to day, because of weather conditions, variations in the strength and volume of sewage that enters the plant, and other factors. It reports that plants doing a poor job one day can be doing a good job on the following day. The efficiencies of the various secondary sewage treatment plants in the Chicago area 'Metropolitan Sanitary District and North Shore Sanitary District"are presented in Table 22. Only 38 per cent of the plants achieve a 90 per cent

TABLE 21

COSTS OF OPERATING SECONDARY TREATMENT SEWAGE PLANTS IN MASSACHUSETTS, 1953

Sewage Flow in Million Gallons/Day	Cost per Million Gallons
.14	$54.00
.15	87.00
.40	40.80
.48	38.30
.50	15.35
.58	26.90
.60	72.50
.60	37.40
1.20	35.20
1.26	29.20
1.49	16.75
1.70	20.30
1.70	17.40
3.50	13.48
4.00	15.80
32.00	10.65

Source: Isard and Coughlin, *op. cit.*, Table A-30, p. 76.

BOD reduction. The table reveals that one plant out of each five operates at less than 80 per cent efficiency.

TABLE 22

EFFICIENCY OF SEWAGE TREATMENT PLANTS, NORTHEASTERN ILLINOIS METROPOLITAN AREA

Per cent Efficient		Sample	90%	85-90%	80-85%	70-80%	50-70%	Below 50%
Plants	number	130	50	34	18	17	8	3
	percent	100	38	26	14*	13	6	2

Source: U.S. Public Health Service Report - 1960, updated 1962. Office of Sanitary Water Board, Offices of North Shore and Metropolitan Sanitary Districts.

* 80% indicated the lowest point at which a secondary treatment plant should operate. Data for 12 plants was not available.

Engineering data relating to economies of scale in operation and maintenance of sewage treatment plants of various sizes proposed for a joint Reno and Sparks, Nevada sewage systems are presented in Table 23. Note the high costs of the flow of 5 m.g.d. in a plant designed for 10 m.g.d. The study also provided data to analyze incremental savings. The engineering concern proposed a 20 m.g.d. plant of which Reno would use 10 m.g.d. treatment immediately and Sparks, 5 m.g.d. Since Sparks contemplates growth over a period of years, the engineers projected population and sewage treatment needs, then estimated total plant and operating costs. Table 24 shows the effects on costs per m.g.d. and the incremental savings for each million gallons daily (m.g.d.). Note that the operation and maintenance costs per m.d.c. (average unit cost) reflect a decreasing average cost curve convex to the origin.

TABLE 23

ANNUAL COST OF SEWAGE TREATMENT PLANT OPERATION AND MAINTENANCE

	Annual Cost	Cost/M.G.D.
20 M.G.D. Capacity	$284,000	$14,200
15 M.G.D. Capacity	234,000	15,600
10 M.G.D. Capacity	184,000	18,400
at a Flow of 5 M.G.D.	142,000	28,400

Source: Kennedy Engineers, Study Plan for Joint Sparks-Reno Sewerage Facilities (San Francisco, April, 1962) Appendix p. d.

TABLE 24

RENO-SPARKS JOINT SEWAGE TREATMENT FACILITY PROJECTED PLANT OPERATION AND MAINTENANCE COSTS 20 M.G.D. CAPACITY PLANT

Date	Required Capacity	Total Annual O & M Costs	O & M Cost per M.G.D.	Incremental Savings per M.G.D.
1964	15m.g.d.	$234,000	$15,600	$350
1968	16	244,000	15,250	310
1972	17	254,000	14,940	274
1976	18	264,000	14,666	245
1978	19	274,000	14,421	221
1980	20	284,000	14,200	

Source: Derived by Grove from Kennedy Engineers, _op. cit._, Appendix p. i.

Table 24 shows that the concept of the short-run cost curve in which capital invested remains fixed and labor and materials are free to vary, when applied to a municipal facility such as a sewage treatment plant, could easily be a period of 16 years rather than the conventional one year selected for accounting purposes. Here, the unit of output is one m.g.d. and the decreasing incremental savings with each unit produced reflect a leveling off of the average cost curve due to increasing marginal costs per m.g.d.

2. Environmental and Highly Special Services

Except for space consuming recreation, and open space parks, environmental services such as air pollution control,water pollution control, and flood control exhibit the characteristic of high physical interdependencies as Eckstein alluded to earlier. Yet all of the above share along with storm sewer systems a rather widely varying rate of output of service. For example, the output of a storm sewer system is dependent largely on the volume of precipitation; the output of recreational service on the season, temperature, precipitation outlook, scheduling of events, etc.; flood control output on the fortuitous circumstances of prolonged rainfalls or swift thaws, etc.; reduction of air pollution on the changes in micro-climatology throughout the year, changing wind patterns and velocities, etc.

Certain economies of the scale variety are achievable in environmental services such as economies in cross section capacity and length of storm drain laid at one time. And there are usually lower costs per square foot of land for large area purchases of parks and recreational sites. However, the type of problem to be met by the service may dictate the scale of the service rendered. Although individual communities may attempt to combat air pollution individually, the service might be rendered more economically by centralizing the service and aggregating the coordinated resources of many communities to tackle the highly intercommunity problem of air pollution. Water pollution too is a complicated case of physical interdependencies. There are so many sources of pollution, e.g., refuse, seepage, industrial wastes, detergents in sewage, raw and processed sanitary sewage and others, which can pollute ground water, surface ponds, lakes, bays, canals, downstream rivers or waterways, etc., that again, the economical scale for providing the service is the one with the proper geographical and political scope to be "cost effective". Thus, the provision of such environmental services in the most optimal way can run far afield of the concept of the average cost curve and the limited set of input variables it contemplates. Several texts[128] on issues related to environmental problems are available, however the availability of economies of scale remains in question and appears to have received little if any empirical attention.

This investigator has not surveyed the literature for evidence of economies of scale in the provision of highly specialized services such as specialized cultural and recreational facilities, specialized hospitals, higher education, special police services, special library services, and other such urban services. Such highly specialized services have the characteristic that the service tends to be rendered to a smaller proportion of the total population than the normal urban service. With the density of service requests rather low, the boundaries of the service rendering area tend to be rather large to justify provision of the service.

B. CELLULAR SERVICES

1. Primary and Secondary Education

Werner Z. Hirsch has performed considerable empirical research on the cost functions of various cellular services using the statistical method. As much of the research of the cellular services used the statistical method, Hirsch's research and methods are the appropriate point of departure. Hirsch has applied some of the terminology used in description of industrial production to the description of production of urban public services, i.e., horizontal and vertical integration of productive units. His argument runs something like the following.[129]

A school district can be looked upon as a horizontally integrated government, which controls a number of units all furnishing a single service, i.e. education. A unified policy is pursued with regard to all its units. For the sake of efficiency, a school is usually built in a location which minimizes the average distance of its pupils. Increases in the number of students or consolidation of schools except in the case of one-teacher schools, usually take the form of more horizontally integrated units.

The consolidated school district, like any government that adds facilities to already existing ones, will seldom operate under genuine long-run conditions. Thus, he says, growth and consolidation, in the strict sense takes place under quasi-long-run conditions which, depending upon the relative importance of fixed factors, and their degree of fixity, can approach long-run conditions.

A school district in a small community faces a short-run expenditure function (or cost function) until it reaches a size where an additional school is needed. While very little is known about the shape of the short-run per pupil expenditure function of a school (his proxy for average unit cost function), he believes that deductive reasoning suggests that it should have a flat-bottomed shape. He theorizes that the flat bottom can be traced back to a certain amount of flexibility in most schools. The right end of the flat bottom function will curve up; and from that point of curvature on, there are more students than can be readily accommodated in the existing facilities. But he contends that schools will seldom operate in this rising expenditure phase of the function. Location considerations, i.e., the distance a child has to travel to school, lead to diseconomies of scale, and in turn will tend to result in the opening of a new school. Schools tend to have indivisible but highly adaptable fixed plants. The law of diminishing returns sets in and leads to a U-shaped short run expenditure function. Since schools are basically flexible, the average expenditure function will tend to be reasonably flat.

What about the per pupil expenditure function of horizontally integrated schools? He contends that if it is assumed that (1) services of equal quality are rendered regardless of the scale of operations and that (2) the various plants are all of about equal size, have about equal service functions, tend to be operated at about optimum capacity, and can be readily added and closed, and that (3) factor prices are fixed, then the long-run per pupil expenditure function will tend to be horizontal.

To what extent are these long-run assumptions empirically met? He argues that location considerations result in schools of about equal size and that upon inspection each school appears to have similar service functions. But, he suggests, whether the schools are of exactly equal size and operate at optimum capacity is not too important a factor as long as the short-run expenditure function is flatbottomed. Except for financing, he argues, problems faced by local school districts, adding schools poses few problems. New schools are additions to existing plants, making for quasi-long-run conditions. "This is not of major importance, since overhead of horizontally integrated school districts is relatively small compared to operating expenditures."

One could take issue with some of his observations. Schools to which children are bussed could vary considerably in size. The overhead costs of teacher supervisors and teachers institutes may raise the overhead costs of larger horizontal districts. Perhaps overhead as a proportion of the total costs increases with size.

On the whole, he observes that conditions which help horizontally integrated manufacturers and marketers benefit from net economies - lower factor costs, larger and more efficient plants, and induced vertical integration - do not occur when school districts grow and consolidate. Since schools purchase a highly diversified array of factors, but virtually none in quantity, few large-scale factor purchases and even fewer significant price concessions are likely to result. While pecuniary economies are likely to be minor, the only factor purchased in large quantities, i.e., manpower, tends to unionize and produce pecuniary diseconomies. It is his belief that the nature of public education, particularly the importance of location, tends to keep schools relatively small. This aspect, together with legal restrictions on salary levels and permissible debt tend to allow only small technological economies. At the same time he suggests, serious technological diseconomies can accompany large school districts, which tend to lose efficiency because of political patronage and general administrative top heaviness.

On a priori grounds, growing and consolidating or consolidating school districts can approximate the conditions under which the long-run expenditure function will tend to be horizontal. He contends that since plant and caliber of the school superintendent are virtually fixed, the quasi-long-run function will resemble a U-shaped curve with a flat bottom over a very wide range. To the extent that relatively little overhead exists, the short-run and long-run functions may tend to approximate one another. They may coincide in their flat-bottomed portion. Net economies are responsible for a negative slope to the left of the flat bottom and net diseconomies for a positive slope to the right of it. The more units that are horizontally integrated, the flatter the short-run function becomes.

Such is the Hirsch deductive argument on elementary and secondary education. A similar argument is forwarded for the other cellular services which tend to be horizontally integrated. He has related services such as education, police protection, fire protection and refuse collection to the economic concepts presented in Chapter II and applied a priori deductive analysis before his examination of data.

Hirsch gathered 1951-52 and 1954-55 expenditure data for administering 27 St. Louis public school districts. The number of pupils in average daily attendance varied from a low of 500 to a high of 84,000.

The following statistical hypothesis was enunciated with regard to primary and secondary education:

$X^1 = a+bx_2+cx_2^2 + dx_3 + ex_4 + fx_5 + gx_6 + hx_7$ where

X_1 = total current expenditures from primary and secondary education per pupil in average daily attendance (ADA) with and without debt service

X_2 = number of pupils in ADA in public primary and secondary schools

X_3 = high school pupils in ADA as a per cent of all pupils in ADA

X_4 = number of public school pupils in ADA per square mile

X_5 = per cent increase in public school pupils in ADA, 1951-56

X_6 = index of scope and quality of public education in primary and secondary schools

X_7 = average assessed valuation of real property per pupil in ADA

The quality index (X_6) was composed of six subindices:[130]

1. the number of teachers per 100 pupils in average daily attendance
2. the number of college hours of average teacher
3. the average teacher salary
4. the per cent of teachers with more than 10 years of experience
5. the number of high school credit units
6. the per cent of high school seniors entering college

The following empirical results were obtained:

$b = -0.00347$

$c = +0.000000317$

$r12.2^2 34567 = - 0.0916$

$r12^2.234567 = + 0.0696$

$R^{*2} = 0.82$

At the 0.05 probability level, the partial correlation coefficients were not significant; but the coefficient of multiple determination was highly significant. Hirsch concluded that there was no significant net relationship between these current expenditures for education and the size of the school district. The average cost curve was about horizontal.[131]

A recent study by Nels W. Hanson[132] claims to have detected economies of scale in a study of 577 school districts in nine states with enrollments ranging from 1,500 to 847,000. He explains his method:

> A unit cost was obtained for each district in the following manner. The regression coefficients from James' study[133] were used to compute a predicted expenditure level for each district, based upon his eight social and economic characteristics of its population. This

prediction was then deducted from the actual expenditures, leaving a residual unit cost per pupil from which the effects of these population characteristics had been removed. This study sought to determine the relationship of these residuals to district size.

The theoretical concepts underlying the study suggests a curvilinear size-cost relationship. The equation selected for the algebraic analysis, therefore, was that of a simple parabola because either a "U"-shaped relationship or a linear one can be described by its coefficients.[134]

Using residual data for 1958-59 he tested the following hypothesis:

$$Y = a + bx + cx^2$$

where Y is the unit cost residual

a is a constant term

x is school district size

b and c are regression coefficients

Some of his results are tabulated in Table 25 and Table 26.

TABLE 25

THE OPTIMUM SIZE SCHOOL DISTRICT
COMPUTED ALGEBRAICALLY FOR THE NINE-STATE SAMPLE

State	# of Districts in the Sample	Optimum Size in ADA
Nebraska	17	20,000
New Jersey	108	30,000
New Mexico	23	40,000
California	52	50,000
Oregon	26	50,000
Massachusetts	83	79,028*
Wisconsin	46	86,667*
Washington	47	91,762*
New York	175	160,000

* The unit cost residuals in each of these states continued to decline up to the size of the largest district, which is shown for Boston, Milwaukee and Seattle, respectively

Source: Nels W. Hanson, "Economy of Scale as a Cost Factor in Financing Public Schools," National Tax Journal, XVIII (March, 1966) p. 94.

TABLE 26

ECONOMY OF SCALE, EXPRESSED IN DOLLARS PER PUPIL, FOR A DISTRICT OF OPTIMUM SIZE WHEN COMPARED TO A DISTRICT WITH 1,500 PUPILS

State	Economy of Scale	Optimum Size in ADA
Nebraska	$15	20,000
New Jersey	19	30,000
California	21	50,000
Massachusetts	26	79,028
Washington	27	91,762
Oregon	28	50,000
New Mexico	33	40,000
Wisconsin	36	86,667
New York	96	160,000

Source: Nels W. Hanson, _op. cit._, p. 24.

Hanson applied a simple regression analysis of school districts' size with residuals of current expenditure per pupil, adjusted for relationships between characteristics of the adult population and the community and school expenditures. However, Hanson's correlation analysis does not adjust for important factors such as the quality of service hidden in the expenditure figures. Also, his results tend to reflect demand as well as cost considerations.

John Riew has recently studied economies of scale in high school operation for 109 Wisconsin senior high schools using 1960-61 data.[135] He suggests that since schools by and large operate independently within a school district, a more meaningful analysis is based on individual schools. Also since secondary schools call for a higher degree of specialization in the teaching staff and for more facilities than do elementary schools, the two levels of public schools should be treated as two distinct industries.

He has attempted to standardize quality by selection of schools which were accredited by the North Central Association but also eliminate schools in which the 1960-61 average teacher salary exceeded $6,500. He then arranged the 109 schools such that expenditures per pupil (proxy for average unit cost) could be compared with pupils in ADA (output proxy) along with six other indicies. The first three are assumed to reflect teacher qualifications, the fourth class size, the fifth breadth of school programs, and the last the degree of specialization in instruction. The cost-size relation, can be observed along with those measures which indicate the nature and direction of quality biases that may be associated with size. The expenditure figures include administration, teacher's salaries, other instruction, operation and maintenance outlays and exclude capital outlays and debt service.

It is apparent in Table 27 that per-pupil expenditures decline fairly steadily from $531 to $374 as enrollment rises from less than 200 to 701-900. Note how the other six indicies improve for the larger school over the smaller school for the same range of enrollments. However, per pupil expenditures abruptly rise after a fairly consistent fall from $374 to $433 as enrollment increases from 701-900 to the next size-class of 901-1,100. This rise in expenditures is accompanied by a notable rise in the proportion of teachers with a master's degree and a considerable broadening of the school curriculum. It appears that, with enrollment in the vicinity of one thousand, the demand for advanced

TABLE 27

AVERAGES OF OPERATING EXPENDITURES AND CHARACTERISTICS OF TEACHERS IN 109 ACCREDITED HIGH SCHOOLS OF WISCONSIN GROUPED BY SIZE, 1960-1961

Number of Schools	Pupils in Average Daily Attendance	Operating Expenditure Per Pupil	Average Teacher's Salary	% Teachers Holding Master's Degree	Average Years Taught	Pupil Teacher Ratio	Credit Units Offered	Average Course Load Per Teacher
6	143-200	$531.9	$5,305	18.1	6.3	17.3	34.7	3.8
12	201-300	480.8	5,187	15.1	6.1	18.2	36.9	2.9
19	301-400	446.3	5,265	18.8	6.3	20.0	39.6	2.5
17	401-500	426.9	5,401	18.5	7.4	20.9	44.0	2.3
14	501-600	442.6	5,574	23.5	7.5	20.7	46.5	1.9
13	601-700	413.1	5,411	22.5	6.8	20.9	45.3	1.7
9	701-900	374.3	5,543	22.3	7.1	24.1	46.4	1.8
6	901-1100	433.2	5,939	34.0	7.3	21.4	57.7	1.6
6	1101-1600	407.3	5,976	36.5	11.9	24.4	63.4	1.6
7	1601-2400	405.6	6,230	54.5	11.2	24.2	80.3	1.6

Source: John Riew, "Economies of Scale in High School Operations", Review of Economics and Statistics XLVIII, (August, 1966) p. 282.

advanced courses and for teachers with advanced training rises and becomes more effective. As enrollment rises from 901-1,100 to 1,101-1,600, the per pupil expenditures fall again, from $433 to $407. Then, with a further increase to 1,601-2,400, the expenditures remain stable while the ratio of master's degrees in the faculty and the number of credit units continue to rise.

Riew suggests that the analysis of economies of scale implied in Table 27 is not sufficient per se. He points out that the figures in Table 27 are average values for each size class and tend to conceal variations within each class. Therefore he applies a least-squares multiple regression analysis to his data which included the following variables:

$X_1 = f(X_2, X_2^2, X_3, X_4, X_5, X_6, X_7)$

X_1 = Operating expenditures per pupil in ADA

X_2 = Enrollment (number of pupils in ADA)

X_3 = Average teacher's salary

X_4 = Number of credit units offered

X_5 = Average number of courses taught per teacher

X_6 = Change in enrollment between 1957 and 1960

X_7 = Percentage of classrooms built after 1950

The variables were all statistically significant at a probability level of .01 and the adjusted coefficient of multiple determination was .557, highly significant at a probability level of .01. He estimated that with an increase in enrollment of from 500 to 1,000 the expected saving in per pupil expenditures would be $111.00 and from 1,000 to

1,675 the expected saving would be $54.67. The trough of the cost function was found to be at an enrollment level of 1,675 students.

A larger school may mean an added transportation cost, especially in a thinly populated area. This additional cost (plus some private costs such as fatigue, time, parental concern, etc.) would have to be subtracted from the savings referred to above. However, he cautions that there are indications that in the great majority of instances a small enrollment is simply a reflection of a small size of a school district rather than population sparsity.

A recent study conducted by the Wisconsin Department of Public Instruction reveals that differences in average transportation costs between rural and urban areas and between districts covering large areas and those covering small areas are considerably less than commonly believed. In the 1961-1962 academic year, the average of per pupil transportation expenditures in the most thickly populated counties of Milwaukee, Racine, Kenosha, and Winnebago (each with population density of more than 200 per square mile) was $54.16 as compared with $65.10 for the most thinly populated counties of Sawyer, Bayfield, Florence and Forest (each with the density of less than ten per square mile) where school districts are much larger in area.[136] Actually the fixed cost component of school transportation costs is greater and the effect of mileage less than usually anticipated.

Herbert J. Kiesling, in a study which measures school output in terms of average pupil achievement test score on standardized tests, checked for economies of scale in primary and secondary New York State schools. He reports that no scale economies were found in school district performance and that he had to fall back upon geographical differences between school districts to avoid finding diseconomies.[137]

2. Police Protection

Using 1955-56 data for 64 St. Louis police departments ranging in size from service to 200 to 865,000 residents, Hirsch enunciated the following working hypothesis in relation to police service:[138]

$X_1 = a + bX_2 + cX_2^2 + dX_3 + eX_4 + fX_5 + gX_6 + hX_7 + iX_8 + jX_9 + kX_{10}$, where

X_1 = Per capita total expenditures for police service

X_2 = Night-time population

X_3 = Total miles of streets

X_4 = Night-time population density per square mile

X_5 = Per cent of non-white population

X_6 = Per cent of night-time population under 25 years of age

X_7 = Combined receipts of wholesale, retail and service establishments

X_8 = Number of wholesale, retail, and service establishments

X_9 = Index of scope and quality of police protection[139]

X_{10} = Average per capita assessed valuation of real property

Economist Charles Tiebout has criticized Hirsch's approach[140] for the use of size of population as the appropriate measure of scale when the issue is that of the scale of a police service production unit. He argues:

> This switch of units raises two problems: (1) For a pure public good there is no necessary relationship between population and either the output or quality of that good, (2) Variations in per capita expenditures for reasons other than cost or efficiency are likely to be present, i.e., demand variations.[141]

Tiebout refers to the public goods argument that the consumption of a public good by one resident leaves another resident no worse off. While it may be true that the cost per capita of rendering a service will be lower as a result of population increase, this is not a decrease in the cost per unit of service. He also states the argument concerning quality (service level) and per capita expenditures. In a service which offers economies of scale such as $5 per unit at an output of 100, and $4 per unit at an output of 250, a community of 100 population which produces 100 units will show a cost per capita of $5, whereas a town of 150 which for reasons of taste produce 250 units, experiencing scale economies of $4 per unit, will show a cost per capita of $6.67. He also argues that variations in population might be associated with changes in per capita expenditures for reasons other than costs. For example, people in smaller rural communities and larger urban communities may have lower preferences for education, fire protection and other services than those living in middle sized suburbs.

Hirsch has answered the criticism[142] that (1) for a pure public good there is no necessary relationship between population and either the output or quality of that good, and (2) the method used by him does not distinguish between quality and population effects on per capita expenditures:

> Apparently, with a few rare exceptions, from a practical point of view pure public goods as defined by Tiebout are not existent. For this reason, much of his discussion and criticism of output measures is tenuous. To be more specific, since most local government services are not pure public goods, for many there appears to be a relationship between population and output or

quality. For example, the total output of a school district, fire department, or police department appears related to the size of the population as well as service level.[143]

As to the second point, Hirsch contends that if the service level (quality) is properly quantified, multiple regression and correlation analysis separates its effect from that of population.

It is important to understand what the long list of variables which Hirsch uses actually does. His hypothesis as to police protection stated above is set forth to measure whether economies of scale exist holding constant taste, preferences, quality, etc. Variables X_3 through X_8 and X_{10}, which include ethnic characteristics, density, assessed valuation, and other variables are included so that tastes and preferences can be held constant. If tastes are not constant, no meaningful relationship can be obtained regarding the scale of operations. To the extent that a least squares regression equation includes virtually all factors that affect per capita service expenditures and succeeds in quantifying them well, their effects on the dependent variable can be partialed out. Thus, in case the scope and quality index effectively measures service levels, on the one hand, its effect on per capita expenditures can be held constant, and on the other hand, the quasi-long-run expenditure function for different service levels within the prevailing range can be estimated. If taste variables are added, also the effect of taste changes can be partialed out. Under these circumstances, statistically insignificant linear and curvilinear partial regression coefficients between per capita expenditures and population size lead to a rejection of the hypothesis that during the period under analysis economies of scale were incurred.[144]

The results of statistical tests using the hypothesized function for police services show that while the coefficient of multiple determination was highly significant at the 0.05 probability level, the partial correlation coefficients were not. Neither a significant linear nor curvilinear relationship was found. This suggests that expenditures for police services in the St. Louis area in 1955-56 do not appear to have varied significantly with the size of the night-time population, once the effect of changes in other factors bearing on expenditures was partialed out. The empirical guasi-long-run per capita expenditure function appears to be about horizontal over the range of observed data Hirsch speculates concerning the results:

> We might have expected some decline in the left hand portion of the expenditure curve, on the assumption that a community needs at least four officers to provide good police protection. But apparently the small communities in the St. Louis area did not offer high quality police services. For example, of the 36 police departments serving up to 4,000 residents 29 offered poor or very poor services, three had satisfactory services, two quite good services, two good services, and none had very good services.
>
> In conclusion, it can be said that in this case relatively poor police services were offered at about equal per capita expenditures regardless of the size of the community partialling out the effect of other factors.[145]

The study mentioned earlier by Schmandt and Stephens analyzed 19 cities and villages of Milwaukee County, Wisconsin and correlated 1959 per capita police service expenditures with service level and population. Schmandt and Stephens suggest, when analyzing the three variables of population, service level, and per capita expenditures, that

> proceeding from simple rank order correlations to Pearsonian to partial coefficients, the direction of the relationship

> between service level and per capita spending for police protection changes slightly positive to negative when population is held constant. Inasmuch as service level and population are so closely related, economies of scale are indicated.[146]

It should be recalled that the Schmandt and Stephens service level index was a hybird index of both output and quality. However, Hirsch has interpreted their findings somewhat differently. He suggests that since the partial correlation coefficient relating per capita expenditure and population size was statistically insignificant for the sample size that no significant scale economies were revealed.[147]

3. Fire Protection

A distinctly different approach to the study of economies of scale has been developed by Robert E. Will.[148] His approach relies on a set of "engineering specifications", which in some manner are related to service level and service requirement.[149] Specifically, Will starts by identifying relevant standard units of effort for particular services. A unit of effort used for the measurement of any given service is some physical unit, or combination of inputs comprising a work unit, such as a street sweeper and its crew. Ideally, a measurable output of service can be associated with the effort unit, and the output can be stated in terms that permit it to be related to a need index. Once standard units of effort have been identified and described their costs are estimated.

Professional expertise is also used to estimate service requirements in terms of standard units of effort. Will relies on the work of professional associations and students of public administration to identify the need determinants of urban services. The need indicators are then translated directly into standard service requirements through professional application of the rules established by experts. Finally cost estimates are made for the total service requirements; these estimates can also be translated into per capita terms.

Will estimated annual per capita standard service requirements for fire protection in dollars, for 38 cities varying in size from 50,000 to one million. He found per capita standard service requirements for fire protection to vary from 23 to 72 dollars.[150] These dollar figures were regressed against city population with the conclusion that, "there are significant economies of scale associated with the provision of municipal fire protection services, at standard levels of service, for central cities ranging from 50,000 to nearly one million in population."[151] The statistically significant geometrical relationship was that of a hyperbola eventually becoming assymtotic to the horizontal axis. Major economies were realized up to size 300,000 population. From there on the economies of scale were barely in existence.

He mentions some of the basic shortcomings of his method. "The major weakness discovered was that the most significant standards, those set by the National Board of Fire Underwriters for aggregate recommended service levels, had economies of scale already built into them."[152] Furthermore, the engineering standards used did not reflect the possibility of large cities suffering from top-heavy management, political patronage, etc.

Hirsch analyzed data for 1952 and 1956 pertaining to 32 city fire departments and fire districts, serving as few as 800 and as many as 865,000 residents.[153] He approximated that the short-run per capita expenditure function for fire service in the St. Louis area is approximated by a parabola whose trough is at a night-time population of about 110,000. However, he indicates that the per capita expenditure decline is not very large, e.g., $1.24 as the population increases from 1,000 to 110,000. Beyond this point substantial increases occur, e.g., $3.62 as the population increases from 110,000 to 300,000 and $12.26 as the population increases from 300,000 to 500,000. The distance between the fire station and the property farthest removed is very important. Larger populations usually occupy areas requiring a number of fire houses which can be more efficiently placed than the single house which serves a small service area.

4. Refuse Collection and Disposal

Recently[154] Hirsch has hypothesized that the average unit cost of residential refuse collection service is affected by five major groups of variables:

1. The amount or quantity of service, i.e., number of basic service units
2. service quality[155]
3. service conditions affecting input requirements,[156]
4. factor price levels, and
5. the state of technology and productivity.

Selecting "a ton of refuse collected and disposed" as a useful physical service unit, he points out that the average refuse collection cost per ton is much larger than the disposal cost per ton. One study found 84 per cent of all refuse service costs related to the collection process and only 16 per cent to disposal. Although he sets forth an "ideal" average cost function[157] which develops various dimensions of the five major groups above, data limitations require him to reduce the working hypothesis to the following variables:

$X_1 = f(X_2, X_2^2, X_3, X_4, X_5, X_6, X_7)$ where,

X_1 = 1960 average annual residential refuse collection and disposal cost per pickup in dollars

X_2 = number of pickup units

X_3 = weekly collection frequency

X_4 = pickup location, where curb pickup is 0 and rear of house pickup is 1

X_5 = pickup density, i.e., number of residential pickup per square mile

X_6 = nature of contractual arrangements, where municipal collection is 0 and private collection is 1

X_7 = type of financing, where general revenue financing is 0 and user charge financing is 1

In order to test whether economies of scale existed, the equation assumes a parabolic relationship between X_1 and X_2. The quality variables are X_3 and X_4 and the other three variables are designed to reflect service conditions affecting input requirements. Since pickup location, nature of contractual arrangement and type of financing are basically non-quantitative, dummy variables are employed.

With the aid of multiple regression and correlation techniques this working hypothesis was tested for 24 municipalities in the St. Louis City-County area in 1960. The multiple correlation coefficient adjusted for degrees of freedom was .874. It was highly significant at a probability level of .05. Thus, about 76 per cent of the variation in average annual per pickup refuse collection cost is explainable in terms of these six independent variables, of which collection frequency, pickup location, and type of financial arrangement were statistically significant. No significant economies of scale were discovered.

Surprised that pickup density was insignificant, Hirsch dropped several variables from the group of six and a new multiple regression equation was fitted to the following linear hypothesis:

$$X_1 = f(X_3, X_4, X_5)$$

The multiple correlation coefficient of .755, was significant at a probability level of .05 and all three independent variables (including pickup density - X_5) were statistically significant at a probability level of .05. Using this equation he estimates that an increase from two weekly pickups to three increased collection costs on the average by about 28 per cent, when the effect of other explicit variables was held constant. In a similar manner, he found that moving pickup location from the curb to rear of house about doubled the cost.

His findings can be compared in part with conclusions from a University of California study which did not make use of multiple regression analysis.[158] The pickup location cost findings are directly comparable. However, when rear of the house collection was substituted for curb collection, the California Study indicated about a 65 per cent increase. He suggests that a comment is in order concerning economies of scale:

> That the St. Louis data did not reveal significant scale economies cannot be considered conclusive, mainly because municipal and collection area boundaries may not have coincided in all cases.[159]
>
> It is quite possible for the municipality that does not collect the refuse by itself to employ more than one private collector, and conversely, one and the same collector may serve more than one municipality.[160]

As observed from Hirsch's ideal average cost function there is tremendous flexibility and a vast number of alternative methods and conditions under which refuse is collected as well as disposed. Aside from having a convenient unit of output, there are many variables to control to arrive at comparable collection costs for different scales of operation. Even the word "refuse" may be subdivided into components. Hirsch's variable "nature of pickup" allows for variability in the refuse itself. See Table 28. For example, the municipality may collect garbage separately, process it through a city grinder and discharge it into the city sewage system to be treated along with sanitary wastes. Table 29 reflects four different pickup patterns and a time study analysis approximation of the difference in man-minutes of labor per ton of refuse collected. Hirsch's variable of "pickup location" corresponds to such variable pickup patterns, several of which may exist within one municipality.

TABLE 28

CLASSIFICATION OF REFUSE

Classification		Description	Origin
Refuse subject to routine collection	Garbage	Wastes from the preparation, cooking, and consumption of food. Food wastes from produce markets and food processing establishments.	From homes, hotels, institutions, stores, markets, etc.
	Rubbish: Combustible rubbish	Paper, fiberboard (cardboard), wood, excelsior, tree and yard trimmings, grass, rags, rubber, and plastics.	
	Rubbish: Non-combustible rubbish	"Tin" cans, scrap metal, bottles, glass, crockery, ceramics, ashes, and other mineral refuse.	
Refuse not subject to routine collection	Refuse from Residences	Large discarded appliances, bed springs, logs, stumps, rubble, construction waste, dirt, junked automobiles, dead animals.	From homes.
	Refuse from Municipal Functions	Street sweepings, park refuse, catch basin dirt, paving, rubble, dirt, construction wastes, dead animals	From streets, sidewalks, alleys, vacant lots, parks, etc.
	Refuse from Industry	Solid waste resulting from industrial processes and manufacturing operations.	From manufacturing and processing plants.

TABLE 29

PATTERNS OF REFUSE COLLECTION
(PICKUP LOCATION)

	Approximate # of man-minutes of labor per ton collected
A. Curb Service	100
1. Residents carry refuse to curb 2. Collection by crew 3. Residents return empty containers	
B. Set-out Service	135
1. Set-out crew carries refuse to curb 2. Collection by separate crew 3. Residents return empty containers	
C. Set-out and Set-back Service	170
1. Set-out crew carries refuse to curb 2. Collection by separate crew 3. Set-back crew returns empty containers	
D. Backyard-Carry Service	150
1. Collection crew travels with truck Transfers refuse to tubs or baskets in backyard 2. Same crew loads refuse directly into collection truck. Refuse containers remain in backyard.	

Source: "Planned Refuse Disposal, A Report to the Directors of the County Sanitation Districts of Los Angeles County, California," (September, 1955)

Studies have been made of the effect of "pickup density" on the cost of collection. A Field investigation by the University of California Sanitary Engineering Research Project indicates the relationship between pickup time in man-minutes per ton and the average pickup density in collection services per route mile. Pickup densities between 30 and 180 services per mile have relatively little effect on the labor requirements of the pickup operation. However, a pickup densities less than 30 collection services rendered per mile, the labor requirement increases markedly. Pickup labor, per ton of refuse collected, increases rapidly on sparsely settled routes, that is, on routes with less than 30 services rendered per mile.[161]

To reduce the costs of long hauls of refuse trucks to disposal sites, transfer stations are frequently constructed in a "cellular" area (local collection area) which permit the dumping of many small trucks into a large trailer truck for the long hauls. Economies of scale have been identified in the capacity of transfer stations and are presented in Table 30.

Economies of scale are present in disposal techniques; however, it is difficult to collect comparable data. For example, the fixed cost of land for the sanitary land fill disposal technique can be very large for one city and very small for the same number of acres in another city. A city may own large amounts of vacant land, such as around an airport, or a land owner who needs land filled may lease land to the city at nominal charges for many years, or a city may be forced to purchase

TABLE 30

REFUSE TRANSFER COSTS

Operating Costs are Shown as Function of Station Capacity for Earthfill Construction, Direct-Dump, Single Shift Stations

Transfer Station Capacity (tons per day)	Total Unit Transfer Cost (dollars per ton)
100	$ .58
150	.39
200	.31
250	.26
300	.24
350	.22
400	.21
450	.20

Costs for stations larger than 500 tons per working day cannot be generalized; however, operating costs will seldom be less than $0.20 per ton

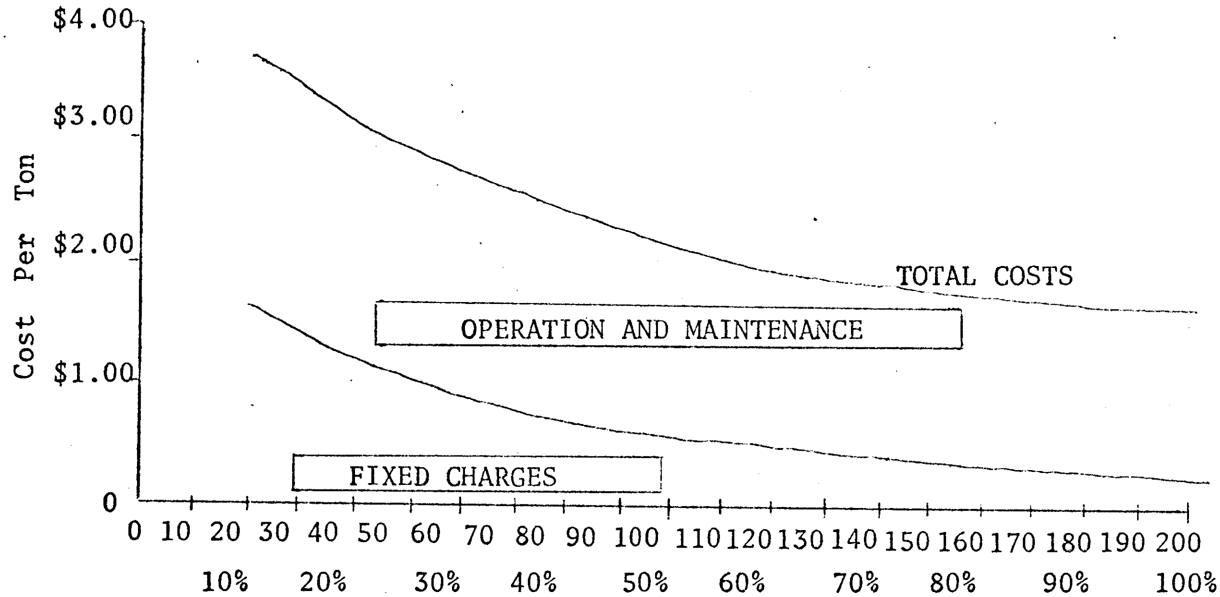
Source: "Planned Refuse Disposal", A Report to the Directors of the County Sanitation Districts of Los Angeles County, California, p. 66.

land on the market for the site. Even comparing incinerators is not an easy task. Incinerators are constructed with a rated capacity in tons per 24-hour period. Cities seldom operate at the rated capacity. For example, a large incinerator operating at an inefficient output level may have higher operating costs per ton than a small incinerator operating near its rated capacity. Figure 17 shows the estimated cost curves for a 200 ton per 24-hour rated capacity incinerator. Note that the fixed charges curve decrease with increasing output whereas there is little variation in the amount of operation and maintenance costs over the complete range of output. Table 32 shows that four Cincinnati incinerators with yearly outputs ranging from 14,600 to 140,700 tons experienced little variation in total operating and maintenance costs per ton, i.e., from $2.01 to $2.67 respectively. Note also that the labor component proportion of total cost per ton is very stable averaging about 88 per cent.

One California study very carefully calculated the amortization of capital investment on several incinerators in Los Angeles County. Table 31 shows a decided decrease in operating cost per ton as higher rated capacity incinerators are used. Note also that all incinerators except one range in age from 1947 to 1952 and can be considered of roughly comparable technology. Thus, it can be demonstrated that the capital intensive technique of incineration definitely displays scale economies.

FIGURE 17

ESTIMATED COST CURVES FOR A 200 TON INCINERATOR
AT VARIOUS PERCENTAGES OF UTILIZATION



Tonnage Incinerated Daily
Rated Capacity - 200 Tons Per 24 Hours

Fixed charges are based on $2000 per rated ton of capacity initial construction cost, amortized over 20 years at a 3% interest rate.

Source: Sanitary Engineering Research Project, <u>Municipal Incineration</u>, University of California Technical Bulletin No. 5 (June, 1951) p. 76.

TABLE 31

MUNICIPAL INCINERATORS IN LOS ANGELES COUNTY, 1955

Location	Year Built	Rated Capacity in Tons/24 hrs*	Capacity Cost per Ton**
Beverly Hills	1947	300	$2.80
Santa Monica	1952	300	3.40
Pasadena	1933	250	3.80
Pomona	1951	225	4.00
Glendale	1952	175	4.25
Alhambra	1950	150	4.50
Signal Hill	1949	75	6.25

* None of the incinerators are operating at 24-hour capacity. Some reduction in the amortization charges would result from around the clock operations.

** Calculated to include amortization of capital investment. Amortized at 3% interest for a 20-year life.

Source: "Planned Refuse Disposal", A Report to the Directors of the County Sanitation Districts of Los Angeles County, California, p. 72.

TABLE 32

INCINERATOR COST REPORT
CITY OF CINCINNATI, DEPARTMENT OF PUBLIC WORKS, 1965

	Labor Cost per Ton	Total Cost per Ton	Percent Labor	Tons Burned (000)	
West Fork Incinerator	$2.35	$2.67	88%	140.7	
Dunbar Incinerator	1.89	2.19	86	72.4	
Crookshank Incinerator	2.19	2.46	89	60.2	
Center Hill Incinerator	1.92	2.01	96	14.6	
Average	2.18	2.47	88	287.9	Total

WEST FORK INCINERATOR

	Labor	Labor Cost per Ton	Equipment	Supplies Contract Services	Total	Total Cost per Ton
Charging	$95,152	$.68			$95,153	$.68
Firing	83,859	.60			83,859	.60
Ashes	55,589	.39	$16,213		71,802	.51
Plant Maintenance	67,732	.48	65	$19,789	87,585	.62
Operating Expenses				8,817	8,817	.06
Overhead	28,723	.20			28,723	.20
Total	$331,056	$2.35	$16,278	$28,606	375,939	$2.67

Source: 1965 Annual Report, City of Cincinnati, Department of Public Works, Waste Collection Division, p. 13.

It is simply that the techniques and methods of industrial and economic analysis appropriate to urban planning and redevelopment programs are still, in many respects, crude and elementary. A difficult task lies ahead in developing and refining these methods. It is a task, however, that promises worthwhile results, not only for official planning and redevelopment agencies, but also for those who are concerned with the economic and social health of urban and metropolitan areas in this country.

Coleman Woodbury

V. CONCLUSION AND RECOMMENDATION

The hypothesis of this investigation was that empirical study would disclose the presence of economies of scale in the provision of urban public services. After definition and description of the concept and enumeration of many measurement considerations, the last chapter reviewed the present state of empirical studies of scale economies in urban services. It is now appropriate to briefly summarize the empirical findings. Table 33 lists the studies and their findings as to the estimated shape of the long-run average cost curve.

The Table indicates that economies of scale appear to be well established in the utility and flow system type of skeletal service, such as electricity, gas, water treatment and conveyance, and sewage treatment and conveyance. With respect to cellular services, only fire protection, refuse incineration, refuse transfer stations, and possibly secondary education appear to exhibit economies of scale.

What is all too clear from the above survey of empirical work is the fact that too little research has been done on urban services to state with a substantial degree of confidence that scale economies do exist in the cellular service area, and if they do, under what conditions of quality, density and output they may be expected. The past studies of the cellular services have only scratched the surface of this very important area. This investigator contends this area is important with a great deal of justification. A cursory examination of the operating budget of any school district or general government unit would reveal the substantial and increasing outlays annually in labor factor costs. Here is an area in pressing need of labor-saving innovations.

Also absent from the above survey are empirical studies to test the presence of scale economies in the environmental services such as storm sewer systems, air and water pollution control, park and recreational facilities, or in the highly specialized services of urban planning, public housing, urban renewal, specialized cultural and recreational facilities, higher education or special police and library services. A decided dearth of research into the economics of such urban activities exists although these services are duplicated over and over again across the nation.

It has been estimated that the national investment in storm drainage facilities in urban areas is expected to be between one and three billion dollars per year during the next 35 years.[162] Very large sums will also be spent during this period on efforts to reduce pollution caused by storm water overflows from existing combined and sanitary systems in the older cities. Surely such enormous investments of funds deserve to be wisely invested. Yet each local government in its usually piecemeal approach to undertaking its environmental engineering will not feel justified to perform elaborate research nor will their task oriented engineering consultants. Clearly the needed research and development costs would be minuscule compared to the vast sums mentioned above, yet an agency to organize and undertake the financing of the sorely needed empirical research is not yet in being.

TABLE 33

COST CURVE STUDIES OF ECONOMIES OF SCALE

Name	Service	Result
1. Skeletal Services		
A. Cost versus Density		
Whitten and Adams	Streets	Cost decreases as lot size increases
Kain/M.I.T. (Urban Land Institute)	Development Costs	Cost increases as lot size increases (not including land costs)
Stone	Structure Cost	Costs decrease from 40 to 20 D.U. per acre
Wheaton and Schussheim	Public Capital Costs	Costs decrease from single family 15,000 sq.ft./D.U. to multi-family 3000 sq.ft/D.U
B. Cost versus Output		
Shipman	Electricity	AVC is declining
Nerlove	Electricity	AVC is declining
Johnston	Electricity	AVC is declining
Lomax	Gas	AVC is declining
Bowers and Lovejoy	Telephone	AVC is declining from 0 to 5000 subscribers AVC is increasing from 40,000 to 300,000 subscribers
Orlob and Lindorf	Water Treatment	AVC is declining
Koenig	Water Conveyance	AVC is declining
N.Y. Office of Local Govt.	Sewage Plants	AVC is declining
Isard and Coughlin	Sewage Plants	AVC is declining
2. Cellular		
Hirsch	Primary and Secondary Education	AVC is about horizontal
Kiesling	Primary and Secondary Education	AVC is about horizontal
Riew	Secondary Education	AVC is U-shaped with trough at about 1700 pupils
Hirsch	Police Protection	AVC is about horizontal
Schmandt and Stephens	Police Protection	AVC is about horizontal
Will	Fire Protection	AVC is declining with major economies reached at 300,000 population
Hirsch	Fire Protection	AVC is U-shaped with trough at about 110,000 population
Hirsch	Refuse Collection	AVC is about constant
Los Angeles County Study	Refuse Transfer Station	AVC is declining
Los Angeles County Study	Incineration Disposal	AVC is declining

It would appear that the institutional vehicles for capitalizing on economies of scale may be progressing at a swifter pace than our knowledge of factual information which should guide our policies and decisions. By this, the investigator refers not so much to the historical evolution of annexation, city-county consolidation, special authorities, metropolitan government or the brighter hope of contractual arrangements and voluntary cooperation. Rather he refers to the current policy of the Federal Government in requiring the review of a metropolitan or area-wide planning agency (and its inter-governmental approach) before a grant-in-aid is made to local governments. This investigator has traced the evolving federal policy regarding the institution of a planning agency with area-wide jurisdiction in another source.[163] Metropolitan level planning agencies are acquiring professional staffs and beginning to function as a whole more effectively. The recent Demonstration Cities Act came within "one letter" of requiring review of model city applications by such a planning agency. The legislation prescribed that such applications be submitted to "any" area-wide planning body for review. Soon the letter "y" may be stricken and the word "an" make submission and a fortiori, agencies, mandatory. However, the submission of applications for review by such agencies has become a "boiler-plate" provision in many other pieces of urban related legislation already.[164]

The American Institute of Planners has set forth the jurisdiction and mandate of such bodies in "The Role of Metropolitan Planning"[165] which states inter alia:

> [T]he metropolitan area development plan includes multi-community action programs involving land use, resource development, transportation, water supply, storm water and sanitary sewage disposal systems, garbage and rubbish disposal, recreation and openspace, major public buildings and services such as hospitals, libraries, police and fire facilities. River basin and watershed areas are recognized and treated as significant elements in the metropolitan planning program.[166]

The agency is to develop policies and programs regarding nearly the full range of urban public services. One of the key criteria used in making its recommendations should be the most efficient use of economic resources including the advantages of economies of scale. Yet for policies and proposals to be sound, they must be based on facts. And facts are the product of empirical research. It would appear essential that such metropolitan and other governmental bodies should be supplied with the facts.

The Federal government policies regarding urban areas are examples not only of conflicting piecemeal legislative programs to satisfy various interest groups but also of an evolution of steps away from the prescription of a sweeping solution. From the Urban Redevelopment Act in 1949 with its legislatively prescribed steps to conquer urban ills, through a chain of changing programs (e.g. urban renewal, general neighborhood renewal, and community renewal) the Federally prescribed solutions have not worked smoothly. Indeed the Federal Government also is in great need of factual information to make its policies. In a certain sense the Demonstration Cities Act is a controlled experiment to develop factual information. The job of research has been put into the hands of the selected Model Cities, each with its individualized "chemistry set", and the national government will pick up the check to find out what works empirically. When the results of each of these on-site research and development projects is in and evaluated, the engineering approach of cannibalizing the good elements, culling out the specific ideas and developing generally applicable ideas will proceed.

The recent drive to introduce program budgeting techniques into governmental decision-making will have the effect of greater consideration of alternative production techniques. To adequately assess alternative approaches to accomplish particular tasks or achieve stated objectives requires vast amounts of factual data relating to costs. The widespread application of this budgeting technique should be a useful spur to research concentration on the production economics of urban public services.[167]

As yet the amount of spin-off from space research and development to commercial application has not been great. It is certainly worth investigation whether significant amounts of federal financial assistance should be invested in applications engineering and product development to test the character and importance of spin-off for urban application. For example, a closed system which uses, purifies and reuses water over and over designed for single and multiple residential dwellings could sever dependence upon certain skeletal systems and have serious implications for scale economies in providing urban services.

The recent Woods Hole Conference during the summer of 1966 was an attempt to develop approaches to initiate greater research and development in urban problems such as environmental, engineering, new housing, rehabilitation, transportation and health services. It called for the application of new engineering and technology to the urban scene. But as Professor Walter Rosenblith of M.I.T. entreated the conferees:

> Research and innovation cannot be done with the resources that are at the present time available. What we need more than anything else in this area is new blood and not just transfusions of blood. One needs to find oneself a mechanism, several mechanisms, by means of which excitement that exists today in the universities, in industry, among the technologically potent, will be translated into something that is going to be action-program-oriented.
>
> Technological muscle [must be mobilized] in a manner that will make it possible to use what people have called the economies of scale, what I might call the economies of industry and technology, to deal with the problems that have been yours and that are more critically yours today than ever before, the human problems at a scale that is going to make being a technological society and being a human society commensurate.[168]

As Coleman Woodbury reminds us, a difficult task lies ahead in developing and refining these techniques and methods of industrial and economic analysis appropriate to urban planning; and as Lloyd Rodwin has cautioned: "The best university trained minds follow what interests them, what they think is important - not what others think is useful. Any research program that ignores this stubborn reality is doomed to triviality."

Yet, these limitations must be met and overcome, for before a National Urban Policy is formulated and developed in detail, a tremendous amount of research and analysis should be performed. Certainly, no such simple and sweeping policy as to reduce the number of local governments by 80 per cent as proposed by the Committee for Economic Development should be underwritten at the present time, or most likely, ever. Immediate further research into the area of economies of scale at both the functional and sub-functional level of the important cellular and environmental services is strongly recommended by this investigator. Recommendations such as those posed in the introduction of this study must be quickly deflated with the skeptical request of "What do you have to back that up?" Such has been the practice in private industry. Such is direly needed to remove the half-truths, hunches, impressions, guesses, and prejudices which linger on in urban planning in place of carefully arrived at, tested knowledge.

FOOTNOTES

1. Minnesota Institute of Governmental Research, Inc., Improving Education In Minnesota By Reorganizing Local School Systems, State Governmental Research Bulletin No. 25 (January, 1949) p. 19.

2. Public Administration Service, The Government of Metropolitan Sacramento (Chicago, 1957) pp. 137-38.

3. Id. at p. 139.

4. Charles M. Tiebout, "Economies of Scale in Metropolitan Governments."

5. Review of Economics and Statistics, XL (November, 1960) p. 442-444 at p. 442.

6. Id. at p. 443.

7. Committee for Economic Development, Modernizing Local Government (New York, 1966) p. 7.

8. See criticism of the report by Frank Smallwood, 'Modernizing Local Government: A Second Look," Nations Cities (March, 1967) pp. 21-23.

9. Committee for Economic Development, op. cit., p. 17.

10. Id. at pp. 33-43.

11. Id. at pp. 34, 35, 36, 41, and 47.

12. Revealed in a conversation between the investigator and Robert F. Steadman on March 31, 1967.

13. E.g., Eli Winston Clemens, Economics and Public Utilities, The Century Studies in Economics (New York: Appleton-Century-Crafts, 1950); Martin G. Glaeser; Public Utilities in American Capitalism (New York: The Macmillan Co., 1957); Eliot Jones and Truman C. Brigham, Principles of Public Utilities, (New York: The Macmillan Co., 1931); National Civic Federation Commission on Public Ownership and Operation, Municipal and Private Operation of Public Utilities (New York: National Civic Federation, 1907). Part I, Vol. I.

14. Floyd R. Simpson, "Cost Trends in the Telephone Industry", Journal of Land & Public Utility Economics, XXI (August, 1945) pp. 289-294.

15. John R. Shaeffer, "The Problem of Refuse Disposal," Metropolitan Planning Papers No. 5 (Chicago: Northeastern Illinois Metropolitan Area Planning Commission, September, 1962)

16. Elmira, New York; see "City Adopts Composting for Refuse Disposal", Public Management, XLVI, (December, 1964) p. 300.

17. Charles P. Kindleberger, Economic Development (New York: McGrawHill Book Co. Inc., 1958) pp. 93-95.

18. See the recent theoretical work of Richard A. Musgrave; for empirical work see e.g., Werner Z. Hirsch, Elbert W. Segelhorst and Morton J. Marcus, Spillover of Public Education Costs and Benefits (Los Angeles: University of California, Institute of Government and Public Affairs, 1964).

19. Otto Eckstein, Public Finance (Englewood Cliffs, N. J.: Prentice-Hall Inc., 1965) p. 45.

20. Id at pp. 46-47.

21. William S. Vickery, Microstatics, (New York: Horcourt, Brace & World Inc., 1964) p. 180.

22. G. M. Neutze, Economic Policy and the Size of Cities (Canberra: The Australian National University, 1965).

23. Id at p. 69.

24. Rothenberg's ideas were presented in class lectures in the Spring of 1967 at M.I.T. and the discussion has been taken from the investigator's lecture notes.

25. Richard A. Musgrave, The Federal Concern with Regional Finance (Cambridge, Mass.: mimo. copy, December 14, 1966).

26. Id. at pp. 10-11.

27. When other variables were taken into account the following studies did not discover significant correlation between per capita expenditures and population size: Harvey Brazer, City Expenditures in the United States (New York: National Bureau of Economic Research Occasional Paper No. 66, 1959); Stanley Scott and Edward L. Feder, Factors Associated with Variations in Measuring Municipal Expenditure Levels (Berkeley: Bureau of Public Administration, University of California, 1957); Amos H. Hawley, "Metropolitan Population and Municipal Government Expenditures in Central Cities," Journal of Social Issues, VII (1951).

28. John J. Carroll and Seymour Sacks, "The Property Tax Base and the Pattern of Local Government Expenditures: The Influence of Industry," Regional Science Association Papers, IX (1962) pp. 173-189 at p. 183.

29. Advisory Commission on Intergovernmental Relations, Performance of Urban Functions: Local and Areawide, Report No. M-21 (1963).

30. Norman Beckman, "Performance of Urban Services - Area-Wide or Local," Public Management, XLVI (May, 1964) pp. 98-101.

31. Id. at p. 99.

32. Id. at p. 100.

33. David C. Ranney, A Fiscal Crisis in East St. Louis, Illinois (Edwardsville, Ill.: Southern Illinois University, Public Administration and Metropolitan Affairs Program, February, 1967) p. 16.

34. Id. at p. 5.

35. See Harvey Shapiro, "Economies of Scale and Local Government Finance," Land Economics, XXXIX, (May, 1963) pp. 175-186.

36. Clarence E. Ridley and Herbert A. Simon, Measuring Municipal Activities (Chicago, International City Managers Association, 1938) p. 1.

37. Id. at p. 10.

38. Herbert A. Simon, "Administrative Decision Making," Public Administration Review, XXV (March, 1965) pp. 31-37 at p. 31.

39. Ridley and Simon, op. cit., p. 2.

40. See Alice J. Vandermeulen, "Guideposts for Measuring the Efficiency of Governmental Expenditures," Public Administration Review, X (Winter, 1950) pp. 7-12.

41. See Chapters 14 and 15 in John C. Bollens (ed.), Exploring the Metropolitan Community (Los Angeles: University of California Press, 1961) p. 354.

42. Id. at 355-356.

43. Herbert A. Simon, Fiscal Aspects of Metropolitan Consolidation (Berkeley, Calif.: University of California, Bureau of Public Administration, 1943) pp. 28-29.

44. See Hirsch's discussion in Bollens, op. cit., pp. 356-365.

45. Id. at p. 366.

46. Id. at p. 368.

47. Henry J. Schmandt and G. Ross Stephens, "Measuring Municipal Output," _National Tax Journal_, XIII (December, 1960) pp. 369-375. They refer to the three studies mentioned in footnote 27, _supra_.

48. _Id_. at p. 369.

49. _Id_. at p. 370.

50. See Harvey Shapiro, "Measuring Local Government Output, A Comment," _National Tax Journal_, XIV, No. 4 (1961) pp. 394-397.

51. Werner Z. Hirsch, _About the Supply of Urban Public Services_ (Los Angeles: University of California, Institute of Government and Public Affairs, 1967) p. 6.

52. See Hirsch's monograph for an extensive development of proxies at p. 9.

53. _Id_. at p. 5.

54. See Vandermeulen, _op_. _cit_. pp. 7-12.

55. Council of Economic Advisers, _The Annual Report_ (Washington: United States Government Printing Office, 1965) pp. 261-262.

56. Markley Roberts, _Trends in the Supply and Demand of Medical Care_, Joint Economic Committee Print, 86th Congress, 1st. Session (Washington, United States Government Printing Office, 1959) p. 82.

57. _Id_. at p. 76.

58. See A. A. Walters, "Production and Cost Functions: An Econometric Survey," _Econometrica_, XXXI, No. 1-2, (January-April, 1963) p. 11.

59. Walter Isard and Robert E. Coughlin, Municipal Costs and Revenues (Wellesley, Mass.: Chandler-Davis Publishing Company, 1957).

60. In the area of urban services see Massachusetts Department of Commerce and Urban and Regional Studies Section, Massachusetts Institute of Technology, _The Effects of Large Lot Size on Residential Development_. Technical Bulletin No. 32 (Washington, D.C.: Urban Land Institute, 1958); Sanitary Engineering Research Project, _Analysis of Refuse Collection and Sanitary Land Fill Disposal_ (Berkeley, Calif.: Sanitary Engineering Research Project of the University of California, December 1952) Technical Bulletin No. 8, Series 37.

61. Lawrence R. Klein, _An Introduction to Econometrics_, (Englewood Cliffs, N.J.: Prentice-Hall Inc., 1962) p. 118.

62. Allen Richmond Ferguson, "A Technical Synthesis of Airline Costs" (Ph.D. dissertation, Harvard University, 1949) and "Empirical Determination of a Multidimensional Marginal Cost Function," Econometrica, XVIII (July, 1950) pp. 217-235.

63. Hollis B. Chenery, "Engineering Bases of Economic Analysis" (Ph.D. dissertation, Harvard University, 1949).

64. Joel Dean, Statistical Cost Functions of a Hosiery Mill (Chicago: University of Chicago Press, 1941) and The Relation of Cost to Output for a Leather Belt Shop (New York: National Bureau of Economic Research, 1941) and Statistical Determination of Costs, with Special Reference to Marginal Cost (Chicago: University of Chicago Press, 1936).

65. Werner Z. Hirsch, Measuring Factors Affecting Expenditure Levels for Local Government Services (St. Louis: Metropolitan St. Louis Survey, 1957)

66. Werner Z. Hirsch, "Expenditure Implications of Metropolitan Growth and Consolidation," Review of Economics and Statistics, XLI (August, 1959) pp. 232-241.

67. George F. Break, Intergovernmental Fiscal Relations in the United States (Washington, D.C.: The Brookings Institution, 1967).

68. Such political criteria may include:
   a. The unit of government carrying on a function should have a geographic area of jurisdiction adequate for effective performance;
   b. The unit government performing the function should have the legal and administrative ability to perform services assigned to it;
   c. Every unit of government should be responsible for a sufficient number of functions so that it provides a forum for resolution of conflicting interests, with significant responsibility for balancing governmental needs and resources;
   d. The performance of functions by a unit of government should remain controllable by and accessible to its residents; and
   e. Functions should be assigned to that level of government which maximizes the conditions and opportunities for active citizen participation and still permits adequate performance.

69. Harvey S. Perloff, Commentary on Metropolitan Planning: The Past and the Future, in Joint Center for Urban Studies of the Massachusetts Institute of Technology and Harvard University (ed.), Issues & Problems of Boston Metropolitan Area Development, 1965, p. 36.

70. See William R. Grove, Jr., Metropolitan Planning?, University of Miami Law Review, XXI, Fall 1966 pp. 60-98.

71. John F. Kain, Urban Farm and the Costs of Urban Services (Cambridge: Harvard University, Program on Regional and Urban Economics, 1966).

72. *Id.* at p. 23.

73. *Id.* at p. 28.

74. *Id.* at p. 29.

75. Robert Whitten and Thomas Adams, Neighborhoods of Small Homes (Cambridge: Harvard University Press, 1931).

76. *Id.* at p. 51.

77. John F. Kain, *op. cit.*, at p. 31.

78. *Id.* at p. 32.

79. William H. Ludlow, "Urban Densities and Their Costs: An Exploration into the Economics of Population Densities and Urban Patterns," in *Urban Redevelopment: Problems and Practices*, ed. Coleman Woodbury (Chicago: University of Chicago Press, 1953) p. 142.

80. William L.C. Wheaton and Morton J. Schussheim, The Cost of Municipal Services in Residential Areas (Washington: U. S. Government Printing Office 1955).

81. Adolph D. Oppenheim, Cost Factors in Suburban Development (Bridgeport, Pa.: Southeastern Pennsylvania Regional Planning Commission, 1955).

82. This is the opinion of Kain after surveying the research. He later in his study discusses the reasons more fully.

83. Massachusetts Department of Commerce and Urban and Regional Studies Section, Massachusetts Institute of Technology, *The Effects of Large Lot Size on Residential Development*. Technical Bulletin No. 32 (Washington, D.C.: Urban Land Institute, 1958).

84. Kain reports "Robert Jones has estimated in an unpublished manuscript that the costs of an electric distribution system for a residential development are only about 4 per cent as great as those of a water distribution system. If Jones' estimates can be expected, the omission of electric distribution studies is not particularly serious." Kain, *op. cit.*, p. 37.

85. *Id.* at pp. 37-38.

86. Walter Isard and Robert Coughlin, Municipal Costs and Revenues (Wellesley, Mass.: Chandler-Davis Pub. Co., 1957).

87. "Actually the lot proportions produced by most area and frontage and width requirements under local zoning vary considerably with area. In average practice, lots of 10,000 sq. ft. or less approach the proportions of a square, while large lots tend to be increasingly oblong as area requirements increase." Urban Land Institute, op. cit., p. 19.

88. "The items collectively labeled landscaping are quite varied, depending on topography, soil characteristics, vegetation, character of neighborhood, and individual preference. On the average this cost has a rough correlation with lot area for small lots and tend to level off and approach a fixed amount for large lots. This is due to the relative economies of scale in grading and landscaping larger tracts, as well as the recent trend of remaining large lots partially in a natural state, except for a small landscaped portion around the house." Ibid.

89. Kain, op. cit., p. 47.

90. "Land for relatively dense rows of houses or apartment buildings requires concrete sidewalks, wide, heavy streets, and auxiliary pavements for automobile parking, while land for detached dwellings may need only narrow, light paving and no curbs or walks. Dense developments require fewer linear feet of utilities per dwelling unit, although their capacity will necessarily be greater than a dispersed arrangement. In general, however, no single standard of improvement specifications or costs can be established." Miles L. Colean and Arthur P. Davis, Cost Measurement in Urban Redevelopment (New York: National Committee on Housing, Inc., 1945) p. 26.

91. For example, at lower densities the area of surface draining may be increased, the length of drainage pipe reduced, and the spacing of catch basins and manholes increased.

92. Kain, op. cit., p. 57.

93. Id. at 59.

94. P. A. Stone, "The Economics of Housing and Urban Development", Journal of the Royal Statistical Society, Part IV, Vol. 122, 1959.

95. Id. at 437.

96. This conclusion was also reached by Ludlow:

> [I]t appears that the costs of providing public service to a residential area are greatest at very high and at very low densities. At some intermediate point in the middle ranges, public service costs are the lowest. . . .
>
> In general the row house or row flat offers the lowest cost housing. Compared with the detached or semi-detached house, the row house offers greater economy of land, of street and utility improvements, and of construction materials because of fewer end walls, etc. Having less exterior wall, upkeep and heating expense are generally less for row houses. Ludlow, op. cit., p. 123.

97. Wheaton and Schussheim, op. cit., p. 3:

> Three representative suburban committees were analyzed in detail to ascertain the costs of additional residential growth in those communities. The communities were selected to reflect the widest possible range of suburban conditions in income, stage of development, distance from the metropolitan center, level of municipal services and other factors deemed likely to affect the costs of residential growth.

98. The most serious deficiency in area C is the absense of any elementary school within the neighborhood. Making the reasonable assumption that the municipality would continue its policy of constructing new schools where needed rather than transporting pupils in the kindergarten and the first six grades to elsewhere in the community, a complete school unit with kindergarten would be required in area C. Id. at p. 16.

99. Id. at p. 14.

100. Id. at p. 20.

101. Robert W. Mayer, "The Decline of Academic Attention to Public Utility Economics," Land Economics XXXVII November 1961, pp. 374-378.

102. See texts in footnote and the following: R. M. Hofmeister, A Cost Analysis for Local Electric Supply, Ph.D. Thesis, M.I.T., 1964; R. Konuya, "Technological Progress and the Production Function in the United States Steam Power Industry, Review of Economics and Statistics (May, 1962); P. J. Dhrymes and M. Kury, Technology and Scale in Electric Generation, Institute of Mathematical Studies in the Social Sciences, Stanford University, Technical Report No. 116, Stanford 1962; Federal Power Commission Annual Supplement, Steam Electric Plant Construction Costs and Annual Production Expenses, Washington 1957, 1958, 1959; Charles W. Meyer, Marginal-Cost Pricing of Local Telephone Service." Land Economics XLII (August, 1966) pp. 378-383.

103. Marc Nerlove, Returns to Scale in Electricity Supply (Standord, Calif.: Institute for Mathematical Studies in the Social Sciences, Stanford University, 1961) p. 11.

104. K. S. Lomax, "Cost Curves for Gas Supply," Bulletin of the Oxford Institute of Statistics, Vol. 13, 1951, pp. 243-246.

105. J. Johnston, Statistical Cost Analysis (New York: McGraw-Hill Book Co., 1960) pp. 197.

106. Public Service Commission of Wisconsin, Rates and Research Department, Departmental Bulletin No. 9 (Electric) and No. 10 (Gas), (March, 1967).

107. William D. Shipman, "Some Economic Implications of Nuclear Power Generation in Large Central Stations," Land Economics XL (February, 1964) pp. 1-17.

108. J. A. Stockfisch, "Fees and Service Charges as a Source of City Revenues: A Case Study of Los Angeles," National Tax Journal, XIII, (June, 1960) p. 118.

109. David A. Bowers and Wallace F. Lovejoy "Disequilibrium and Increasing Costs: A Study of Local Telephone Service," Land Economics (February, 1965) p. 38.

110. Id. at p. 37.

111. Id. at p. 35.

112. Bowers and Lovejoy, op. cit. pp. 33-38; Floyd R. Simpson, "Cost Trends in the Telephone Industry," The Journal of Land & Public Utility Economics (August, 1945) pp. 286-94; Joseph R. Rose, "Telephone Rates and Cost Behavior," Land Economics (August, 1950) p. 252.

113. Gerald T. Orlob and Marvin R. Lindorf, "Cost of Water Treatment in California," Journal American Water Works Association, L (January, 1958) pp. 44-55.

114. Isard and Coughlin, op. cit., p. 18.

115. Jack Hirshleifer, James C. DeHaven and Jerome W. Milliman, Water Supply: Economics, Technology, and Policy (Chicago: University of Chicago Press, 1960) pp. 177.

116. Louis Koenig, "Disposal of Saline Water Conversion Brines: An Orientation Study," Office of Saline Water, Department of the Interior, Research and Development Progress Report No. 20 (Washington: April, 1957).

117. Advisory Commission on Intergovernmental Relations, Intergovernmental Responsibilities for Water Supply and Sewage Disposal in Metropolitan Areas, 1962.

118. Sewage treatment plants that serve motels, golf courses, state institutions and individual industries are not included.

119. Leonard Metcalf and Harrison P. Eddy, American Sewerage Practice, Vol. III (New York: McGraw-Hill Co., 1928) p. 788.

120. Harold E. Babbitt and E. Robert Baumann, Sewerage and Sewage Treatment (New York: John Wiley and Sons, Inc., 1958).

121. Metcalf and Eddy, *op. cit.*, Vol. I, pp. 23-27.

122. R. L. Bolton and L. Klein, "Better Sewage Effluents, Their Need and Attainment," *Public Works* (October, 1962) pp. 109-112.

123. Robert W. Rafuse, Jr., Water Supply and Sanitation Expenditures of State and Local Governments: Projections to 1970 (Chicago: The Council of State Governments, 1966) p. 26.

124. *Id.* at p. 32.

125. For detailed definitions of these terms, see U. S. Department of Health, Education, and Welfare, Public Health Service, Statistical Summary of 1962 Inventory of Municipal Waste Facilities in the United States, 1964, pp. 31-38.

126. Advisory Commission on Intergovernmental Relations, *op. cit.*, p. 39.

127. Northeastern Illinois Planning Commission, Metropolitan Planning Guidelines, Phase One: Background Documents, Sewage Treatment, 1965) p. 11.

128. See John A. Logan, Paul Opperman and Norman E. Tucker, Environmental Engineering & Metropolitan Planning (Chicago: Northwestern University Press, 1962); Harold Wolozin, *The Economics of Air Pollution* (New York: W. W. Norton & Co., 1966).

129. See Werner Z. Hirsch, Analysis of the Rising Costs of Public Education, Study Paper Number 4, 86th Congress, 1st Session, Joint Economic Committee, Congress of the United States (November 10,1959) pp. 41-43; Werner Z. Hirsch, Expenditure Implications of Metropolitan Growth and Consolidation," *Review of Economics and Statistics*, XL, (August, 1959) pp. 232-241.

130. See John C. Bollens, *Exploring the Metropolitan Community* (Los Angeles: University of California Press, 1961) pp. 323-330.

131. Hirsch, Expenditure Implications. . ., *op. cit.* p. 239.

132. Nels W. Hanson, "Economy of Scale as a Cost Factor in Financing Public Schools," *National Tax Journal*, XVII (March, 1966) pp.92-95.

133. H. Thomas James *et al.*, Wealth, Expenditure, and Decision-Making for Education (Stanford: Stanford University Press, 1963) pp. 69-100. A coefficient of multiple correlation of .88 was obtained for the relationship between current expenditures per pupil and the following characteristics of the district's population: (1) full equalized property values per pupil, (2) median family income, (3) per cent of homes owner-occupied, (4) median years schooling of the adult population, (5) per cent of the working force unemployed, (6) per cent of the population non-white, (7) per cent of the population living in rural areas, (8) per cent of the school-age population enrolled in private schools.

134. Nels W. Hanson, op. cit., p. 93.

135. John Riew, "Economies of Scale in High School Operations," Review of Economics and Statistics, XLVIII (August, 1966) pp. 280-287.

136. Wisconsin Department of Public Instruction, Transportation Facts 1962-63 (Madison, Wisconsin, March 1963) pp. 12-13.

137. Herbert J. Kiesling, "Measuring A Local Government Service: A Study of School Districts in New York State," Review of Economics and Statistics (forthcoming, 1967).

138. Werner Z. Hirsch, "Expenditure Implications of Metropolitan Growth and Consolidation," Review of Economics and Statistics, XL (August, 1959) pp. 237-238.

139. The index of scope and quality of police protection was obtained on the basis of independent ratings by five police experts who were instructed to take into consideration: qualifications and leadership ability of police chiefs; qualifications, training, and strength of police force; supporting equipment; morale of police force, and basic conditions bearing on the magnitude of the policing problem.

140. Charles M. Tiebout, "Economies of Scale and Metropolitan Government," Review of Economics and Statistics, XLII (November, 1960) pp. 442-44.

141. Id. at p. 444.

142. Werner Z. Hirsch, "Expenditure Implications of Metropolitan Consolidation Revisited," Review of Economics and Statistics, XLIV (August, 1962) pp. 344-45.

143. Id. at p. 345.

144. Id. at p. 344.

145. Werner Z. Hirsch, "Expenditure Implications of Metropolitan Growth and Consolidation," Review of Economics and Statistics, XL (August, 1959) p. 238.

146. Schmandt and Stephens, op. cit., p. 374.

147. Werner Z. Hirsch, About the Supply of Urban Public Services (Los Angeles: University of California, Institute of Government and Public Affairs, 1967) p. 41.

148. Robert E. Will, "Scalar Economies and Urban Service Requirements," Yale Economic Essays, V (Spring, 1965) pp. 1-62.

149. _Id_. at p. 33.

150. _Id_. at p. 43.

151. _Id_. at p. 60.

152. _Id_. at p. 59.

153. Hirsch, _op_. _cit_. _supra_ note 145 at p. 236.

154. Werner Z. Hirsch, "Cost Functions of an Urban Government Service: Refuse Collection," _Review of Economics and Statistics_, XLVII (February, 1965) pp. 87-92.

155. Quality differences are based mainly on the number of weekly pickups, care and reliability of the removal services, and the cleanliness, quietness, and courtesy of collection crew. They also effect the effort the resident must make, which constitutes a convenience factor and finds its main expression in the pickup location and the nature of pickups, i.e., whether separation into garbage and trash is required.

156. Some physical, human, legal, and political factors can bear on the difficulties in providing residential refuse collection services: density of pickups, mixture of uses (apartments, commercial low density residential), average distance to disposal site, per capita income, type of financing (user charge or out of general revenue), collection contractual arrangements (e.g., city operation, city contract, city license, and private arrangement) and others.

157. $AC = f(A, Q_1, Q_2, Q_3, Q_4, Q_5; P, U, H, B, Y, K, F; L; T)$

AC = average annual residential refuse collection cost per ton,
A = annual amount of residential refuse collected,
Q_1 = weekly collection frequency,
Q_2 = pickup location,
Q_3 = nature of pickup,
Q_4 = disposal method,
Q_5 = type of hauling equipment,
P = pickup density,
U = residential-non residential land use mix,
H = hauling distance,
B = number of people per pickup unit,
Y = per capita income,
K = nature of contractual arrangement
F = type of financing
L = factor price level, and
T = state of technology and productivity

158. Sanitary Engineering Research Project, An Analysis of Refuse Collection and Sanitary Land Fill Disposal, Technical Bulletin No. 8, Series 37 (Berkeley, Calif.: University of California, 1952) p. 2.

159. Hirsch, *op. cit. supra* at note , p. 92.

160. *Id.* at p. 91.

161. See American Public Works Association, *Refuse Collection Practice* (Chicago: Public Administration Service, 1966) pp. 478-479.

162. Department of Housing and Urban Development and Office of Science and Technology, *Summer Study on Science and Urban Development*, Transcript of Summary Report (June 5-25, 1966) pp. 56-57.

163. William R. Grove, Jr., "Metropolitan Planning?" *University of Miami Law Review*, XXI (Fall, 1966) pp. 60-98.

164. *Id.* at p. 78-82.

165. American Institute of Planners, *Background Paper - The Role of Metropolitan Planning* (Washington, D.C.: American Institute of Planners, September, 1965)

166. *Id.* at p. 7.

167. The Budget Department of the City of New York City recently succeeded in its recommendation to close down two inefficient city incinerators. Its recommendation was based on a program budgeting comparative cost analysis of several refuse disposal techniques in use in the city.

168. Department of Housing and Urban Development and Office of Science and Technology, *op. cit.*, p. 90-91.