THE COMMUNITY COSTS RESULTING FROM GROWTH

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Dear Sir:

In partial fulfillment of the requirements for the Degree of Master in City Planning, I submit herewith this thesis entitled:

The Community Costs Resulting from Growth.

Respectfully,

Robert E. Coughlin

ABSTRACT

This study of the community costs resulting from growth is an attempt to develop from the basic approach of Schussheim more general theoretical models relating several variables affecting the growth of towns and to treat their requirements for community facilities and services with more generalized cost data than has been applied in earlier studies. The models developed treat explicitly density and pattern of growth for residential development. They also provide for industrial and local commercial development. Space requirements and requirements for municipal facilities are taken from planning and engineering standards and from current experience. The cost data for specific facilities and services are taken from the experience of many cities and towns, and are developed in the light of theoretical and engineering knowledge. Particular attempt is made to distinguish among levels of service provided and to discover economies or diseconomies of scale in providing various municipal services.

Yearly costs are computed for several theoretical models for key years throughout the period of growth. All capital and operating costs incurred in the developing area are analyzed, but the analysis does not treat specifically the costs of facilities in the center of town which must be expanded because of the more intensive activity associated with the new growth. Nor does it treat the effect on community costs of the existence of public facilities in the developing area which can serve the new growth.

Cost analysis of the theoretical models shows that density has a major effect on costs but its effect is not as great as that of the level of service provided. With the same complement and standard of service, low density growth always costs more than high density growth. However, at low densities some services can be eliminated without harm to the town (e.g. public sanitary sewers). When these services are not provided, costs of low density development drop below costs for fully serviced medium density developments. In all models, but especially in jump growth models, the cost per capita decreases as the development proceeds.

Thesis Supervisor _____

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CHAPTER I

THE PROBLEM AND PREVIOUS STUDIES

The Problem

One continually hears municipal leaders make strongly voiced statements about the way in which a town can afford to grow. Some say, "We cannot afford to spread out at low densities as some very rich suburbs do. It costs far more to provide roads, utilities and other municipal services for low density developments than for high density developments." Others say, "We must have a large minimum lot size--one or two acres--for then houses will have a higher valuation and we will be able to collect enough taxes to pay for the education of the new children who come with the new houses. Our community will grow more slowly if we zone only for large lot sizes because fewer people want to pay the extra money for large lots. Therefore, our needs for new capital outlay will be small." Some leaders have said, "We don't want any industry in our town. It brings more expense than revenue. When industry comes, congestion increases. The town has to spend more for police and fire protection and utilities service for the industry. Along with industry come workers who live in houses which cannot be valued highly enough to pay their way in taxes. The rest of the town has to pay for the schooling of the workers' many children. Let some other town take the industry, we want a prosperous town of homes." Today more leaders are likely to say, "We must get industry in our town to strengthen its tax base. Tax revenue

from industry and commerce are necessary if we are to provide municipal services to our residents."

There is truth in each one of these statements, but no one of them tells the whole truth. For a particular town any one of these policies might be wisest. To decide which policy is best for a particular town, one must consider the interrelations of many factors.

City planners, managers, and other officials can bring about many decisions that influence the type, location, amount and speed of growth. It is important that they understand the effect on community cost of the amount, density, location, and pattern of growth of new residential development. Is the difference in cost small enough that a certain type of development can be justified for noneconomic reasons even if the municipal costs associated with it are greater than for another less desirable type of development? What is the effect on community costs of the amount, location, and type of industry or other economic activity which develop within the town? How much do community costs change when various levels of service are provided by the municipality?

When growth of a community occurs, existing facilities and services are more intensively used in both the developing area and the older parts of the community. New capital outlays become necessary to serve the immediate needs of the new area and to serve the more intense activities in the old parts of town.

Some of the increased services can be provided by only small increases in the number of municipal employees. As the city grows it becomes less expensive to provide a unit of these services. In order to increase other services it becomes necessary to make sizeable capital outlays when growth overburdens existing facilities. New facilities cannot always be constructed to fit exactly the existing need. For example, a sewage treatment plant or a trunk sewer must be built all at once, not bit by bit each year. Often when they are first built, they are not fully utilized. As the community continues to grow, more and more people use the new facilities so the cost per unit of service provided decreases.

The community gets larger and the cost of a unit of service generally becomes less, but at the same time more units of service per person may be needed. The increased concentration of activity in the community causes increased congestion. Better fire and police protection is needed, more elaborate roads are called for, increased recreation facilities are necessary, the general level of municipal service must be raised. To what extent increased economies of scale balance the increased cost of higher levels of service is a complex and unresolved question.

Even if we could resolve all the intricacies of new costs precipitated it would be premature to judge the economic feasibility of any development without studying the new revenues which also arise. With any

complexity of urban costs due to growth there must be associated a complexity of increased revenues. Increased tax revenue comes from the newly developed areas and also from commercial enterprises in the city which then operate more intensively and expand their plant to serve the new growth. Only when these new revenues as well as the new costs are estimated can we judge the effect of growth upon a city.[1]

Previous Studies

Few adequate sutdies have been made of urban costs and revenues. Most that have been made were not specifically concerned with the problems of growth, but with costs and revenues at some particular time. Little advance has been made from the case study level to a level of greater generality. As far as the author is aware, Schussheim's study[2] of municipal service costs precipitated by growth is by far the most incisive and complete study yet made. However, even it falls short of being a general study of the interrelations between costs, revenues, and growth. We lack a general framework within which analysis of the community costs of growth can readily be carried out. This study is an attempt to develop a model which will recognize more of the interrelations than have been set down previously.

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[1]For an exploration of these new revenues and an analytic framework which could be combined with that presented for new costs in this paper, see J. H. Larson, A Technique for Measuring the Effect of Industrial Growth on Municipal Revenue, unpublished Master's Thesis, M.I.T., 1955.

[2]M. J. Schussheim, Residential Development and Municipal Service Costs: Case Studies in Three Communities in the Boston Metropolitan Area, unpublished Doctoral dissertation, Harvard University, 1952.

Perhaps one reason that good studies have been few is the difficulty of carrying out a valid cost analysis. Data exists on the expenditures of many towns, but an historical analysis of this data leads to many difficulties.

1. Over any period of time there have been significant changes in the prices of different types of goods and services. These price changes are bound to distort any analysis. Since these price changes vary differently for different goods and services, they cannot adequately be compensated for by any cost index. A useful analysis must be based on present-day cost levels and relationships.

2. Change in the level of municipal service is almost inevitable over the history of any town, but it is extremely difficult to identify this variable in historical data.

3. In a town, many different types of growth in different areas are usually present. It is difficult to isolate the effects of one particular growth. Since one cannot isolate the costs of a particular growth it is impossible to get the precipitated or marginal costs due to that growth. The analysis can only uncover average costs at any time.

It is not necessary to consider changes in prices and in level of service if costs and revenues of an area at any one time are analyzed. However, the resulting analysis throws light only on average costs and revenues, not on the specific costs and revenues which would arise from development of certain type and size in a particular location in the city.

One of the earliest cost-revenue studies was carried out by the Boston Planning Board in 1933 and 1934 /4/.[1] It compared the cost of providing municipal services to particular residential sections, with the tax income from those areas. Costs were often apportioned arbitrarily. Varying percentages were allocated as general costs on the basis of assessed values, or as service rendered on basis of actual cases served, or by population. No notion can be gained of whether unit costs increase or decrease as the city grows. Capital costs for all purposes were evidently all lumped together as City Debts; debts entered into by the city at many different times under many different price levels and for many different levels of service are lumped together and simply allotted to each tract by assessed value. There is no way to determine what new capital investments are required for the development of an area in a certain way. Municipal costs of new development are not likely to be the same as average costs of previous development. Both capital and current costs are treated as average costs; no light is thrown on marginal costs.

Homer Hoyt has made several studies using this basic analysis /8 and 9/. He treats only service costs, not capital costs for municipal plant. He has attempted more complex formulas for apportioning costs than were used in the Boston study. However, the simple approach of the Boston study often seems more acceptable than Hoyt's sophistication. For example, Hoyt states /8/ p. 24, "Apartment residents, having smaller

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[1] A number enclosed in slant lines stands for the corresponding reference in the bibliography.

space for libraries at home, use library facilities much more intensively than single family residents." He therefore apportions library service costs: apartments, 60 per cent; single family homes, 35 per cent; other types, 5 per cent. When population in each type is considered, this shows that apartment dwellers use library facilities about 2.5 times as intensively as do single family home dwellers. In the same study /8/ p.34, in explaining how he allocated police service costs, Hoyt states, "Because apartment areas occupy only one-seventh as much land area as single family home areas, and have six times as great a density, the cost of policing per dwelling unit is less for apartments than for single family homes. Instead of allocating the total cost to apartments on an area basis alone, an average of 14 per cent on area basis and 43 per cent on a proportion of total dwelling unit basis or 29 per cent $(\frac{14 \times 43}{2} = 29)$ is used." These procedures have an element of logic behind them but that logic is not a rigorous basis for Hoyt's precise arithmetic.

Recently the Greenwich, Connecticut Planning and Zoning Commission /6/ has made a painstaking allocation of the costs of Greenwich's municipal government to classified property uses. Their procedure is more sensitive, but the scope of their study is similar to that of the Boston and Hoyt studies.

Had these studies even been unassailable in the logic of their cost apportioning they could not throw any light on the marginal costs of new development or on the variation of these costs with density, pattern, and speed of growth.

A study of new capital costs caused by growth will throw light on these questions. New capital costs vary with the location, type, density, size and pattern of new development. They also depend, to a large extent, on the unused capacity in existing municipal services and facilities.

In an outline of suggested research, William T. Ludlow /12/, p. 144, suggested that in order to understand how costs for newly developed areas vary with density and pattern of settlement, one should study the estimated public costs for various theoretical developments in various areas. Such theoretical developments should be similar in all respects except for variation in density and design. The estimated costs would be based on unit costs for various similar services and facilities in a specific city.

Such a study had been made of the cost of residential areas by Thomas Adams in 1934 /2/. This study indicated that in the low ranges of density much larger savings could be achieved by increasing density moderately than by increasing skill of design. By efficient design Adams could show only a 9.5 per cent reduction in the cost of public improvements for a development at a density of 6.5 dwelling units per gross acre. But when the density was increased to 10.25 dwelling units per gross acre, costs could be brought down by 54 per cent from the most expensive 6.5 acre development.

An important study carried out by F. Dodd McHugh /14/ in 1941 was aimed at discovering the municipal costs of redeveloping urban areas. It considered the capital costs as well as the maintenance and operating costs of providing services for alternative types of developments of a 160-acre community. It then considered the effect on cost if the site were in different locations with respect to existing facilities which could be used by the new population. The study found that for one site total imporvement costs per capita declined as net density increased to 250 persons per net acre, then stayed constant until density reached 450 persons per acre, when it began to rise again. It would appear that for this very high density range characteristic of apartment areas of large central cities diseconomies are not encountered until extremely high densities are reached.

In the same study the public improvement cost per person of a development in Brooklyn, where no municipal facilities were available, was estimated by McHugh to be 340 per cent that of the same development in East Harlem, where many existing facilities could be used. In McHugh's study, capital cost data was taken directly from bids for similar work in New York. Current-costs data were taken directly from New York City operating agencies. The study made no attempt to discover any economies or diseconomies of scale, nor did it make explicit the yearly costs incurred due to amortization and interest on the capital cost of new facilities.

In a 1944 study for the Rye, New York Planning Commission, Frederick J. Adams /1/ estimated the cost of hypothetical residential development of varying type and density. However, the study did not consider the location of the development with respect to existing unused capacity in municipal facilities.

Ten years later, Morton Schussheim /18/ carried out a similar, but far more comprehensive study of hypothetical residential development in small and medium sized towns.[1] This study specifically attacked the question of the municipal costs precipitated by growth. By case studies of three Massachusetts towns he showed the effect of density and size of development on capital costs and operating and maintenance costs.

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[1] Several other less exhaustive case studies have been made. The South East Pennsylvania Regional Planning Commission, in an unpublished study, has compared the municipal costs of the actual development of a specific area with what they might have been had the area been completely planned from the start.

An Analysis of the Probable Effects of the Extension of Levittown into Middletown Township, Bucks County, Pennsylvania /5/ considers new capital and operating costs and concludes that the extension would cause Middletown residents little extra expense and the standard of several municipal services would improve.

The Institute of Public Service of the University of Connecticut /17/ has compared "the property tax yield of the small low cost home to its property tax cost." /17/ p. 3. In this study (p.3) "the property tax cost of a small home . . . is the net cost to the local property tax after deducting income from all other sources." The costs peculiar to a growing area are not considered.

The study also considered the differentials of cost caused by the availability of existing facilities in various locations. Three cases were considered:

1. A filling in of existing development.

2. Concentrated development in an area with some unused services.

3. Concentrated development in an area with few unused services.

Schussheim separated public capital facilities into three groups and investigated the requirements of growth on each:

1. Primary facilities--capital inprovements that serve exclusively a new growth area (e.g. local streets and sewers).

2. Secondary direct facilities--facilities that have service districts wider than the growth area (e.g. trunk water and sewer mains, fire stations, elementary schools).

3. Secondary indirect facilities--town wide facilities used by old as well as new residents (e.g. junior and senior high school, water reservoir, central water pumping station, sewage disposal plant).

With his capital cost data organized this way he was able to show the effect on municipal costs of the current typical policy of requiring the developer to provide all primary facilities.

Unfortunately, it is difficult to generalize from Schussheim's results. He approached each town as a case study. Cost data for each town is different and was taken from the specific experience in each town. The availability of unused services is different for each location

of theoretical development. The level of service provided by each town is different. So many factors are different in his various theoretical developments that it is often most difficult to isolate the effect of a decision about density, pattern of growth, or level of service provided.[1]

Schussheim's framework could profitably be generalized to treat the impact of both residential and nonresidential development on a community's cost structure.

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[1]The Division of Planning of the Massachusetts Department of Commerce is now carrying out a promising study of "The Effect of Large Lots on Residential Development." They are studying in a general way the effect of lot size on (a) lot development costs, (b) municipal costs and income, and (c) metropolitan development.

CHAPTER II

THE SCOPE AND METHOD OF THIS STUDY

This study is an attempt to develop from Schussheim's framework a more comprehensive method of analysing the community costs associated with new industrial development and population growth and to provide a better understanding of the intricate interrelations of the various cost elements. The study treats theoretical models, but develops them with a large amount of cost data from actual cities. Basic cost relations are identified on a somewhat general basis so that they will be relevant for the study of a good number of communities. Several different general theoretical growth patterns are described. Then by the use of theoretical knowledge, engineering computations, and sample data from a few actual developments, diverse community costs of new development are estimated. This is done for all direct costs and for as many indirect costs as are understood.

The analysis does not throw light on the cost of facilities in the center of town which must be enlarged to serve the intensified activity that will follow new growth. Neither does it treat explicitly the magnitude of cost advantage that will be enjoyed if development occurs near existing facilities which can serve it. We consider the enlargeability of existing municipal plant and the availability of not completely utilized plant to be special conditions in any particular town which modify our

basic cost analysis. These conditions must be determined by a survey of the particular city in which growth is to be studied.

In the analysis undertaken, a first step is to identify some basic spatial dynamic growth patterns for towns under 100,000 population for a period of 10-20 years. We assume that residential values, behavior patterns, and technology (especially transport technology) will remain as we know them today and as they have been for the past five years. These patterns are intended to reflect rational behavior only. They are also typical patterns. These patterns relate to broad characteristics like the density of residential development and the extent of spatial continuity or discontinuity in growth. Other factors which influence the growth pattern are handled later in the analysis.

Theoretical physical models are designed for each of these patterns. Each of these models provides for an increase of the same number of residences and the same number of acres of industry. The area and spatial distribution of the development differs in different density models. This is unlike the study of McHugh /14/ which kept area constant. We conceive of the spatial extent and arrangement to be the result of an increase of residents and workers. We want to know what that growth costs; what are the low cost patterns, what are the high cost patterns and what variation there is in cost between the extremes. This approach makes it a bit more difficult to design the

physical models but leads to the simplification of many variables and makes it possible to relate cost to new population immediately.

Design of the physical layout is only one part of the design of the model. It is also necessary to construct a picture of the growing area's pattern of work places and how it is related to its town and region. We must know the rate of residential and industrial development. We must know the special requirements of industry in the area and the composition of the population. To the physical model is added the description of these relationships--the "social model." This complex model describes the physical facilities and services which the community must provide for its development.

The study treats the growth of one spatial sector of a town only. An important future study would be to study the development of several sectors at once or in sequence. Such a study would throw light on whether the costs of several sectors are simply additive or, because of the mutual interdependence of the various sectors, must be combined in some complex way. It could also investigate economies or diseconomies of operating at a much larger scale.

Cost of various municipal facilities and services are studied (roads, schools, police, fire, sanitation, etc.). Special attention is paid to distinguishing among levels of service and determining the extent of economies of scale in providing services. Cost data is derived from estimates of engineers, from theoretical analyses, and from actual costs

for comparable facilities and services. As much as possible, the resulting cost functions are presented as a set of charts.

The total yearly costs of public physical facilities and services called for by the model are computed for four key years spaced through the period of growth and the effects of variation in density, pattern of growth, and level of service are analyzed in turn.

CHAPTER III

THE MODEL

1. The Physical Model

a. The Basic Density and Pattern of Growth Situations

In order to study various possible general combinations of the density of residential development and the extent of spatial continuity or discontinuity in growth pattern, it was necessary to design several physical models.

All growth patterns can be thought of as a combination of three basic patterns of growth:

1. Spatially continuous concentrated growth outward from the existing town development.
2. Jump growth out from the town of a concentrated development with a subsequent filling in continuously back toward the original town.
3. Scattered growth
    a. Outside the existing developed area;
    b. Within the existing developed area.

It is very expensive to provide a given standard of municipal facilities and services to an area in which scattered growth occurs outside the existing developed area. Roads and utility lines must be extended long distances and are never fully utilized. Fire and police

protection must be spread thin. Either school busses or many small schools must be provided. By inspection, it appears that this pattern of growth will always be more expensive than any other. How much more expensive will depend on the degree of scatter. Since this pattern is inefficient from the point of view of municipal costs, we discount this pattern of development as irrational and inefficient and do not analyze it further.

Scattered growth which fills in the existing developed area will probably be the least expensive pattern of growth[1] because existing facilities are likely to be available. Roads and sewer lines, fire stations and schools serve the existing population. Usually with only small capital expansion these can serve the needs of the in-filling population. With this pattern of development, the unused capacity of existing facilities and services is even more critical than usual. If large unused capacity exists, the public costs of development will be small indeed, but if roads must be widened, inadequate sewer lines replaced, and school sites enlarged, costs will mount extremely rapidly. Under extreme circumstances the excessive cost of expanding such facilities could make the cost of this type of growth more expensive than any other. Since this study is not concerned with methods of estimating existing unused capacity or the

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[1]See Schussheim /18/, p. 119.

special costs of expanding and redeveloping public facilities, this pattern of development is not analyzed in detail.

If we eliminate analysis of scattered growth and consider the other two basic growth patterns and three densities, six possible basic physical models are theoretically necessary:

1. Continuous growth outward from the existing town development.
    a. Low density
    b. Medium density
    c. High density.
2. Jump growth out from the town of a concentrated development with a subsequent filling-in back toward the original town.
    a. Low density
    b. Medium density
    c. High density.

However, the physical model for jump growth is equivalent to that for continuous growth. The chief difference lies in the order in which different parts are developed. Therefore, we have but three basic physical models. These correspond to the three densities. We do not consider the high density-jump situation explicitly because due to the extremely short distances considered its physical development and resulting community costs are nearly equivalent to those of the high density-continuous situation.

In order to examine all situations, jump-growth and continuous-growth models should be developed with respect to both industry and

residence. However, we are interested only in the more efficient spatial arrangements. It is believed most efficient to place all industry in one industrial estate. If this estate is placed as close as possible to the town, journey-to-work patterns, goods movement patterns and utility service lines are minimized, for by assumption our sector is on the hinterland side of a town on the edge of a metropolitan sector. Therefore, in all models, we locate the industrial estate as close as possible to the already developed part of the town.

Diagrams of the three basic physical models are shown in figures 1-3. In our models low density refers to an average of one dwelling unit per net acre, medium density to four dwelling units per net acre, high density to sixteen dwelling units per net acre. This range of densities is typical of present development in medium-sized towns.

b. Criteria for the Detailed Design of Each Physical Model.

Several criteria were borne in mind for the design of the physical models:

1. The design should be as simple as possible in order that it may have as wide validity as possible and in order that it may permit the easiest calculations. Basic road patterns should change as little as possible in all models. (However, road spacing length and capacity does change with density.)

2. The same degree of design skill or ingenuity should be applied to each of the designs at different densities. Variations in cost due to the skill of the designer should be minimized.

3. A module or pattern should be created which can be repeated as many times as the study requires.

4. The design should be rational and efficient, should provide all necessary facilities but no "luxury" facilities. Cost should be minimized to the degree of best current practice. Cost savings are not to be achieved at the expense of space standards commonly used by planners.

5. At the beginning of growth no excess capacity of any sort is available. At end of the growth considered no excess capacity should remain.

6. No unusual topographic or geological conditions are considered. We work with a "flat plain," uncomplicated by the random effects of landscape. Only such variables as can be contolled by man (e.g. types and density of settlement, pattern of growth) are considered.

7. The design is conceived of as being executed in four stages--one every five years. Provision of special facilities should be apportioned equally among the four stages, except when because of the logic of development a facility must be built in the first stage or is definitely not needed until a certain later stage is reached. It is particularly important that the same facilities be assigned to the same stages in different density models unless the density of development definitely

dictates some different order of development. For example, a large playground around which roads and utilities must be extended should not be assigned to one stage, in one density model and to another stage in another density model.

To satisfy all these criteria is a difficult task. When, occasionally, demands conflicted it was necessary to work out compromises.

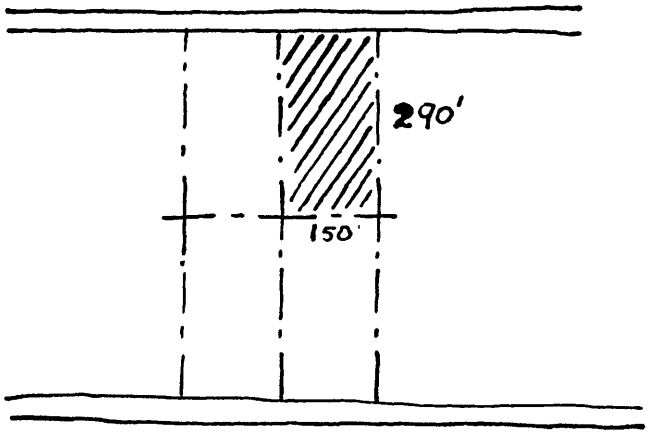
c. An Example of the Resolution of Conflicting Criteria: The Shape of the Building Lot.

The shape of building lot is a basic design element. Its choice required that two conflicting criteria be resolved. We want our design to be most efficient in its use of road and utilities. At the same time we must recognize planning standards for lot layout and shape.

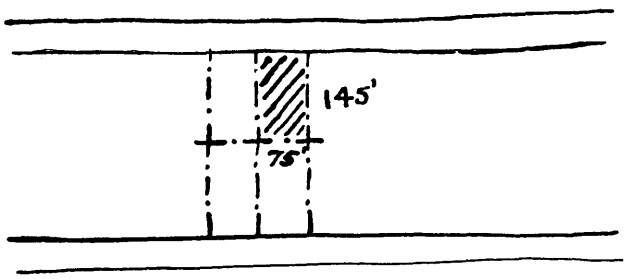
It is well known that in a rectangular road system for any given acreage a square shape will minimize perimeter-road length. This indicates that the block should always be square, and, in fact, this is true as long as one has access to the interior land of the block. To achieve access, there can be but two lots between roads in a rectangular road system. A square block of four square lots is the most efficient use of road if only four lots must be served. But if more than four lots are to be designed for, it is obviously a more efficient use of road to string lots together two lots deep and many lots long than to create several square blocks of four lots each. These long blocks of many lots become

more efficient users of road the more nearly square they are. They can be made to approach a square if the frontage of the individual lot is decreased and its depth increased. However, there is a minimum width which must be met to make a lot useful. One must choose between designing the block which is the most efficient user of road and the lot which is of desirable shape. To compromise, we choose a lot of typical shape, with depth about twice its frontage.

In the low density (one dwelling unit per acre) model, we design a lot 150' x 290'. This means the local streets must be 580' apart.



In the medium density (four dwelling unit per acre) model, a lot is 75' x 145'. This means the local streets must be 290' apart.



In the high density (sixteen dwelling units per acre) model, individual lot size loses meaning because most of the development will be in row houses or garden apartments. For simplicity, we develop our model with streets spaced 290' apart once more.

Diagrams of the three basic physical models are shown in Figures 1-3. Their design could be undertaken only after we had posited the types, amounts and rates of growth expected. The next sections spell out this phase of our model building.

2. The Social Model

The requirements during the period of development for roads, schools, and sewerage cannot be determined until we have built up a "social model" which describes the amount and rate of residential and industrial growth, the expected number of children, and the expected traffic pattern.

In order to build up a model with which to work, we assume a set of "normal" requirements. These "normal" figures are simply estimates which fall within the range of experience and describe a norm. A particular town could not be described entirely by this norm. To use our model to describe the cost of growth of a particular town it would be necessary to substitute the town's requirements which vary widely from our norm and which lead to major cost differences.

a. Population Growth

We conceive of a town of about 25,000 population on the edge of a metropolitan area. During the period of growth to be considered, it is assumed that the town will approximately double in size. The theoretical sector in which growth is analyzed is conceived of as one of six radial sectors in the town. The population of this sector (sector X) will grow by nearly 8,000 people in 20 years.

We conceive of this twenty-year growth as the sector's ultimate growth. We neither plan for nor build facilities with capacity for any larger requirements. Implicit in our model building is the assumption that we foresee the complete development from the start. Therefore, we can always plan, purchase, and build efficiently. We do not face the problem of replacing overburdened facilities and redeveloping areas to meet new conditions.

During the twenty years for which we analyze growth, we assume that:

Sector X will increase by 2,480 dwelling units[1] or by 7,940 people;
Sector A will increase by 2,480 dwelling units or by 7,940 people;
Sector B and C will increase by 1,650 dwelling units or by 5,280 people;
Sector D and E will increase by 825 dwelling units or by 2,640 people.
Therefore, the total new population will be 23,800 people.
We assume the central town remains at 25,000 people.
Hence in twenty years the total population will be 48,800.

At the start sector X is undeveloped except for a poor secondary road which leads from the town through the area of sector X. We posit that sector X will develop at a constant rate as follows:

	Year 5	Year 10	Year 15	Year 20
Barren except poor secondary road	620 DU 1980 persons	1240 DU 3970 persons	1860 DU 5950 persons	2480 DU 7940 persons

[1] We assume 3.2 persons per dwelling unit. This is the median number of persons per dwelling unit in the seventeen towns of over 25,000 population in Massachusetts, Rhode Island, and Connecticut whose population increased by over 10 per cent between 1940 and 1950. See Table 39 in Appendix.

b. Number of School Children and the Requirements for Schools.

For our purposes, the number of school children is the most important information concerning the composition of the population, for variation in the number of school children can cause significant differences in public costs. In order to determine the characteristics of a growing population, we examined data on twenty-four cities in Massachusetts, New York, Connecticut, and Rhode Island whose population had grown by 10 per cent between 1940 and 1950. For each of these cities we calculated the number of children per dwelling unit in the elementary school age group and the secondary school age group. We than calculated the average number of children per dwelling unit for each age by dividing by the number of years in each school age group (see Table 1).

TABLE 1

NUMBER OF CHILDREN PER DWELLING UNIT

PER ONE-YEAR AGE GROUP IN 1950

	Growth Cities Average	Northeast Average	U.S. Average
7-13 Years Old			
high	.0550		
median	.0490	.0494	.0563
low	.0435		
14-17 Years Old			
high	.0535		
median	.0430	.0440	.0494
low	.0362		

Source: Computed from statistics given in the County and City Data Book, 1952.

Little variation was noted between the average of "growth cities" and the Northeast average. (See Table 1.) The high U.S. Average may be partly because a larger percentage of rural families is found in the United States as a whole than in the Northeast or the growth cities.

The "7-13 years old" group shows more children per dwelling unit than does the older group. This reflects the recent rise in the nation's birth rate. Since we expect this birth rate to continue, we will make our calculations of both grammar and high school population with the "7-13 years old" figures.

Not all children attend school. Some secondary school-age children especially are likely not to attend school. We examined the per cent of children in growth cities who were in school. It appears that compared with the Northeast and U. S. average a slightly higher per cent of the children in "growth" cities will be enrolled in school. (See Table 2.) From the "growth" cities figures we interpolated the per cent attendance expected in each of the school-grade groups. (See Table 3.)

TABLE 2

PER CENT OF CHILDREN IN AGE GROUP ENROLLED IN SCHOOL IN 1950

	Growth Cities	Northeast Average	U.S. Average
7-13 Years Old			
high	97.5		
median	96.5	95.6	95.7
low	90		
14-17 Years Old			
high	95		
median	88.3	86.8	83.7
low	80		

Source: Computed from data given in the County and City Data Book, 1952.

TABLE 3

PER CENT OF CHILDREN IN AGE GROUPS

WHO WILL BE MEMBERS OF SCHOOL-GRADE GROUPS

School Grade	K	1	2	3	4	5	6	7	8	9	10	11	12
From "Growth Cities" Data	←				96.5				→	←	88.3		→
Estimate	←	93	→	←		98			→	←	94	→	← 87 →

Source: Interpolated from Growth Cities median 7-13 years old data of Table 2.

Our basic model shows an increase of 620 dwelling units every five years. We assume that public schools will provide all the service required. If we assume a median number of children per dwelling unit, and apply our estimate of the per cent of children in each age group in school (Table 3), then we find that school service must be provided for the following number of pupils:

TABLE 4

NUMBER OF PUPILS FOR WHOM EDUCATION SERVICE MUST BE PROVIDED IN THEORETICAL MODELS

	Year 5	Year 10	Year 15	Year 20
Kindergarten and Elementary School (K, Grades 1-6)	206[1]	412	618	824
Secondary School (Grades 7-9)	86	172	258	342
(Grades 9-12)	79	158	237	316

Source: Computed from data of Tables 2 and 3 and population projection for model.

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[1] Examples of computations made to derive table:

We compute the number of children expected in grades 1-6: (620 D.U.) (0.0490 children per D.U. per one-year age group) (6) (98 per cent) = 178 children.

We compute the number of children expected in kindergarten: (620 D.U.) (0.0490 children/DU/one-year age group) (1 year) (93 per cent) = 28 children.

The total is 178 + 28 or 206 children.

The school requirements for these pupils are summarized in Table 9. In the high density model walking distances are short so only one large elementary school has been provided. In more spread-out models two elementary schools are provided.

c. Industrial Growth; Home-Work Patterns

In our model, industry is confined to a single industrial district. This minimizes goods transportation lines and is in line with the current recommendations of many town planners. If in our design we allow 17.6[1] workers per acre, the industrial district will cover 57 acres.

We assume that the industrial district will employ:

In 1960: 400 workers, of whom 100 will live in sector X

In 1965: 600 " " " 180 " " " " "

In 1970: 800 " " " 260 " " " " "

In 1975: 1000 " " " 350 " " " " "

This allows for a slowly increasing percentage of total workers who live in sector X. For each family living in sector X there are 1.4 workers,[2] a total of 3,540 workers from sector X. We assume that those who do not work in the industrial district or in local shops find their

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[1] This figure is approximately the median number of employees per acre found in a survey of 220 plants made by the Urban Land Institute. See Urban Land Institute /24A/, Table 20, p. 21).

[2] This is the median number of workers per dwelling unit in the seventeen towns of over 25,000 population in Massachusetts, Rhode Island, and Connecticut whose population increased by over 10 per cent between 1940 and 1950. See Table 40 in Appendix.

employment in the direction of the center of town. The metropolitan center can be reached from sector X only by going in the direction of the center of town.

Industry requires certain municipal facilities and services. Requirements for roads and sewage systems are the most important. They are analyzed for both industrial and residential needs in sections d, f, and g following. Because of the limited time available we did not analyze the need for police, fire protection, and other services which results from industrial growth. Instead, we make the crude assumption that these requirements can be projected on a constant per capita basis.

d. Traffic Pattern in the Sector and the Requirements for Roads.

In order to be able to determine the highway needs of the sector, we must analyze the expected traffic pattern of the sector. How much traffic will sector X generate?

To answer this question, we have made several assumptions about the journeys-to-work of the people who live in sector X. With these assumptions we have calculated the peak traffic expected on the main road. The assumptions and calculations are shown in Appendix II. Our calculations show that under the expected condition in year 20 at the intersection of the main road and the subsidiary road at the industrial district, there will be a peak traffic load of 1,910 vehicles per hour.

Such a traffic load is too great for a two-lane highway but can be handled easily by a four-lane highway.[1] In all models we have specified a main road with 44 foot pavement. This allows two ample lanes for traffic moving in each direction. Since the main road is a limited access parkway, no parking lanes have been provided. Traffic further out on the main road will be less, but rather than narrow the road to two lanes we have continued the 44 foot pavement.

If people living in the sector have a different pattern of work places than those outlined above, the resulting peak traffic pattern will be different. If we make different assumptions about where people work, will the amount of traffic vary widely enough to require different highway capacity? The largest possible traffic load would occur if no one who lives in the sector works in the sector. Then all workers living in sector X would have to pass along the main road on their way to town. At the same time all the workers in the industrial district would have to pass along the same road as they come out from town. We analyzed this situation (see Appendix II, section 2) and found that the resulting maximum 2,500 vehicles per hour could be handled easily by the same four-lane raod which was adequate for the "normal" home-work pattern.

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[1]The practical capacity of a 2-lane highway is 900 vehicles per hour under rural condition, 1,500 vehicles per hour under urban conditions. The practical capacity of a 4-lane road is 3,000 vehicles per hour under rural conditions and 4,500 vehicles per hour in urban areas. Three-lane roads are considered hazardous so we did not consider using one. Source: Highway Capacity Manual, 1950, p.46-7.

No traffic analysis was carried out for the subsidiary roads. We based their widths on current practice. (See Table 5.) In the low density models it is possible to provide narrower subsidiary roads than in the high density models. In low density residential areas parking as well as traffic is likely to be less intense per unit length of road. Note, for example, that in the medium density model, local roads provide two-lanes for moving traffic and one lane for parking. In the high density model, it is necessary to provide an extra parking lane. In the low density model it is possible to eliminate the parking lane.

TABLE 5

WIDTH OF ROAD PAVEMENT IN THEORETICAL MODELS

	Main Road	Secondary Road	Local Road
Low Density	44'	24'	24'
Medium Density	44'	38'	30'
High Density	44'	44'	38'

e. Public and Commercial Land Use Requirements

The public and commercial land use allowances for our models are shown in Table 6. In positing nonresidential land requirements for our models we have allowed more land for these uses than do APHA /3/ minimum standards. Allowances based on APHA standards are presented in Table 7 in order that the reader may compare them with allowances for our model in Table 6.

We assume that commercial development will serve the primary needs of the residents and occasional needs of workers in the developing sector. More specialized needs will continue to be met by the existing shopping facilities in the center of town. We assume that one-half the ultimate required shopping facilities will be constructed during stage 2 of development; the other half will be constructed during stage 3 of development.

TABLE 6

NONRESIDENTIAL LAND ALLOWANCES

FOR USE IN THEORETICAL MODELS

	Low Density Model 1 DU/A	Medium Density Model 4 DU/A	High Density Model 16 DU/A	Number of School Children (2480 DU)
Elementary School	2 @ 9A or 18A	2 @ 9A or 18A	1 @ 18A or 18A	824
Junior High and High Schools	1 @ 17A or 17A	1 @ 17A or 17A	1 @ 17A or 17A	342
Commercial	7A	7A	7A	
Park		6A	10A	
Community Facilities	4A	4A	4A	
	46A	52A	56A	
Playgrounds[1] 4 @ 4A	16A			
	62A			

[1] In medium and high density models, it is assumed that the school playgrounds are sufficent for sports which require large area like football and baseball. Four local playgrounds were provided in the low density model because with such spread-out development the distance from home to elementary school playground is too great for the convenience of many children. The result is that the low density model, which already has the largest private areas, also ends up with the larges amount of land in public use. The low density model enjoys an inordinately high level of service in land use. However, since in our cost calculations we do not consider specifically the development and maintenance of various public recreation lands, this high level of service is not reflected in our cost comparisons. We do not consider the purchase price of the land but assume that the subdivider deeds land to the community for public purposes. We see as a cost only the additional road and utility lines which must be constructed around the park.

TABLE 7

NONRESIDENTIAL LAND ALLOWANCES BASED ON THE STANDARDS OF THE AMERICAN PUBLIC HEALTH ASSOCIATION IN PLANNING THE NEIGHBORHOOD

For a Neighborhood of 2480 D.U. (2480 Families)

	1 D.U. per Acre	4 D.U. per Acre	16 D.U. per Acre
School and Playground*	14.8A	14.8A	14.8A
Park*	0	6.3	10.8
General Community Facilities*	3.4	3.4	3.4
Commercial*	5.4	5.4	5.4
Secondary Schools	17	15	15
Total	40.6A	44.9A	49.4A

Source: Requirements for all items marked (*) are from Planning the Neighborhood, A.P.H.A. Secondary school requirements as posited in Table 6 for use in our theoretical models.

f. Requirements for Sewage Treatment

Now that we know the size, type, and pattern of development in our models, we can determine the sewerage system requirements. Soil characteristics determine the area needed for safe individual domestic septic tanks or cesspool systems. However, these are not often advisable

in densities much higher than two dwelling units per acre when water supply is private or four dwelling units per acre when water supply is public.[1]

We assume that municipal sewerage service is provided in the low density model only for sewage from industry, business, and schools. Domestic sewage is assumed to be disposed of by individual private sewage disposal. In higher density models, complete public sewerage is provided.

In order to specify the public sewerage facilities necessary we must make rough calculations of requirements. Since our theoretical town is in a metropolitan area, we assume that complete treatment of sewage is necessary. Total sanitary sewage treatment requirements are considered to be the sum of requirements for residential, commercial, and industrial sewage.

The capacity of a sewage treatment plant must be greater than the average daily flow expected for there are bound to be seasonal and daily peaks and the plant must be able to handle them. Engineers characteristically design on a basis which allows for peak requirements. Stanley & Kaufman /70/ have collected sewer design data from many cities. From their

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[1]Private sewerage systems can be provided with difficulty in heavy clay, shallow bedrock or impervious layer. It is impossible to provide them in flooded, swampy or high water table land. Hoover /68/ p.36 estimates that when water supply is from private wells, and sewage disposal is also private, minimum lot size should be at least 20,000 square feet for all types of soil in which private sewage systems are possible. When the water supply is public, it is possible to allow lots as small as 5,000 square feet under optimum soil and slope conditions. For worse soils and steeper slopes minimum lot size must be increased up to the 15,000 square feet required for steeply sloped clay soils with some sand and gravel.

data we have estimated typical high, average, and low capacity allowances. (See Table 8.) These capacity allowances were developed for the design of sewers and therefore probably contain a larger safety factor than if they were to be used for the design of the treatment plant itself. (This is so because peak loads in individual sewers are likely to be more extreme than peak loads from the whole system which reach the treatment plant.) However, for our rough calculations we use these capacity allowances for design of treatment plant as well as for design of sewers. Sample computations for one density model are shown in Table 47 in Appendix III. The industrial capacity allowances of Table 5 are for industries without liquid process wastes. Some industries have large flow rates of liquid process wastes. For them, special sewerage facilities are often required and the resulting municipal sewerage costs may be appreciably higher than for industries without liquid process wastes. Discussion of special industrial waste problems can be found in Eldridge /63/ and Besselievre /60/.

Sanitary sewage treatment plant allowances for various models are summarized in Table 9.

TABLE 8

SANITARY SEWER CAPACITY ALLOWANCES

MADE IN U. S. CITIES

	Residential (gallons per person per day)	Commercial (gallons per acre per day)		Industrial[1] (gallons per acre per day)
		Downtown Areas	Outlying Areas	
High	330	50,000	20,000	16,000
Average	250	40,000	14,000	10,000
Low	200	30,000	8,000	6,000

[1] Industrial here refers to industries without liquid process wastes and not industries with large flow rates of liquid process wastes.

Source: Estimated from Stanley, W. E. and Kaufman, W. J. "Sewer Capacity Design Practice" in Journal of the Boston Society of Civil Engineers, October 1953, Table 2, p. 317; Table 3, p. 320; Table 4, p. 321

g. Requirements for Sewers

Instead of computing separately the requirements for storm and sanitary sewers, we have simplified the problem by designing combined storm and sanitary sewer systems. Sanitary engineers may well take issue with the short cuts we have taken in calculation, but it should be borne in mind that it is not our objective to produce a sound engineering solution. Instead we are concerned with fixing only the approximate diameters and sizes of pipe necessary.

We were particularly interested to see whether significant differences in size of pipe would be caused by extreme sanitary sewerage requirements of residential, commercial, and industrial areas. It turns out that storm water requirements are so great in relation to sanitary requirements that any variation in the latter has no significant effect on pipe size in a combined system.

Pipe requirements at various key points in our models were computed by adding to storm requirements, computed by the rational method, the sum of residential, commercial, and industrial sanitary sewerage requirements. Once requirements (in millions of gallons per day) were known, pipe diameters were found by Kutter's formula. This was done with the diagram presented by Davis /61/, p. 868, using a slope of 2 feet per 1000 feet and $n = 0.013$. Sample computations for one model are shown in Tables 48, 49, and 50, Appendix III.

Requirements for sewers in the three basic density models are summarized in Table 9.

3. Summary

The set of relations and requirements outlined in this chapter and diagramed in Figures 1-3 make up the models which we will use in our analysis. Table 9 summarizes the specific requirements for public capital facilities of the various models. Before we calculate the community costs of these models, we must examine the costs of various municipal facilities and services and derive a generalized set of costs which we can use in our analysis.

TABLE 9

SUMMARY OF CAPITAL FACILITIES REQUIRED FOR DIFFERENT DENSITY MODELS

	Year 5	Year 10	Year 15	Year 20
LOW DENSITY CONTINUOUS				
Land for Main Road	21.8A	21.8A	21.8A	21.8A
Main Road[1] equiv. mi.	1.9	1.9	2.7	2.7
Subsidiary Road, equiv. mi.	10.8	21.7	32.4	43.1
Sidewalks (both sides main road, one side all subsidiary roads)	14.5 mi. 4½' wide	25.6	40.1	50.8
Sewage Plant, mgd cap.	0.261	0.451	0.637	0.788
Sewers, sanitary sewers only	1.02 mi. 12" pipe	1.02	1.78	1.78
Number of Elementary Schools	1 E.S. 210 pupil capacity	1 E.S. 420 pupil capacity	1 E.S., 420 pupils 1 E.S., 210 "	2 E.S., 420 pupil cap.
Number of Secondary Schools	1 S.S. 180 pupil capacity	1 S.S. 360 pupil capacity	1 S.S. 540 pupil capacity	1 SS, 680 pupil cap.
MEDIUM DENSITY CONTINUOUS				
Land for Main Road	8.5A	8.5A	8.5A	8.5A
Main Road[1] (port. cem.)	1.01 equiv. mi.	1.01	2.06	2.02
Subsidiary Road[1] (bit. mac.) equiv. mi.	7.8	15.6	23.5	29.6
Sidewalks (both sides)	17.6 mi. 4½' wide	33.2	51.26	67.1

	Year 5	Year 10	Year 15	Year 20
Sewage Plant, mgd cap.	0.720	1.369	2.016	2.620
Sewers (combined storm and sanitary sewers)36" pipe	2900'	2900'	2900'	2900'
33" pipe	2000'	2000'	2000'	2000'
27" pipe	1000'	2500'	2500'	2500'
10" pipe	8500'	18500'	18500'	18500'
8" pipe	17400'	34800'	60900'	87,000'
Elementary School	1 ES, 210 pup.cap.	1 ES, 420 pup.cap.	1ES, 420 pup.cap. 1ES, 210 pup. cap.	2 ES, 420 pupil cap.
Secondary School	1 SS, 180 " "	1 SS, 360 " "	1SS, 540 " "	1 SS, 680 pupil cap.
HIGH DENSITY CONTINUOUS				
Land for Main Road	4.8A	4.8A	4.8A	4.8A
Main Road[1], equiv. mi.	0.57	0.57	1.14	1.14
Subsidiary Road[1]	2.87	5.15	7.87	10.59
Sidewalks, 6' wide	6.88 mi.	12.62 mi.	19.20 mi.	24.64 mi.
Sewers, 27" pipe	1640'	1640'	1640'	1640'
24" pipe	1000'	1000'	1000'	1000'
21" pipe	700'	2400'	2400'	2400'
10" pipe	7600'	15200'	22300'	29400'
Elementary Schools	1 ES, 210 pup.cap.	1 ES, 420 pup.cap.	1 ES, 630 pup.	1 ES, 840 pupil cap.
Secondary Schools	1 SS, 180 " "	1 SS, 360 " "	1 SS, 540 "	1 SS, 680 " "

[1] Road lengths given in miles of pavement 24' wide.

Source: See text.

FIGURE 1

DIAGRAM FOR LOW DENSITY DEVELOPMENT

EXISTING DEVELOPED AREA

INDUSTRY

COMMERCIAL

SEC. SCHOOL

COMM. FAC.

EL. SCHOOL

EL. SCHOOL

PL.

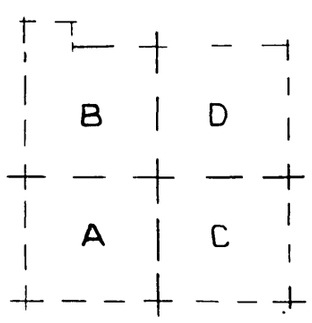
PL.

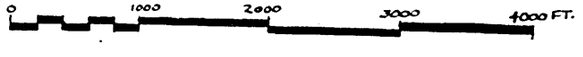
PL.

PL.

SEQUENCE OF DEVELOPMENT

CONTINUOUS GROWTH: ABCD





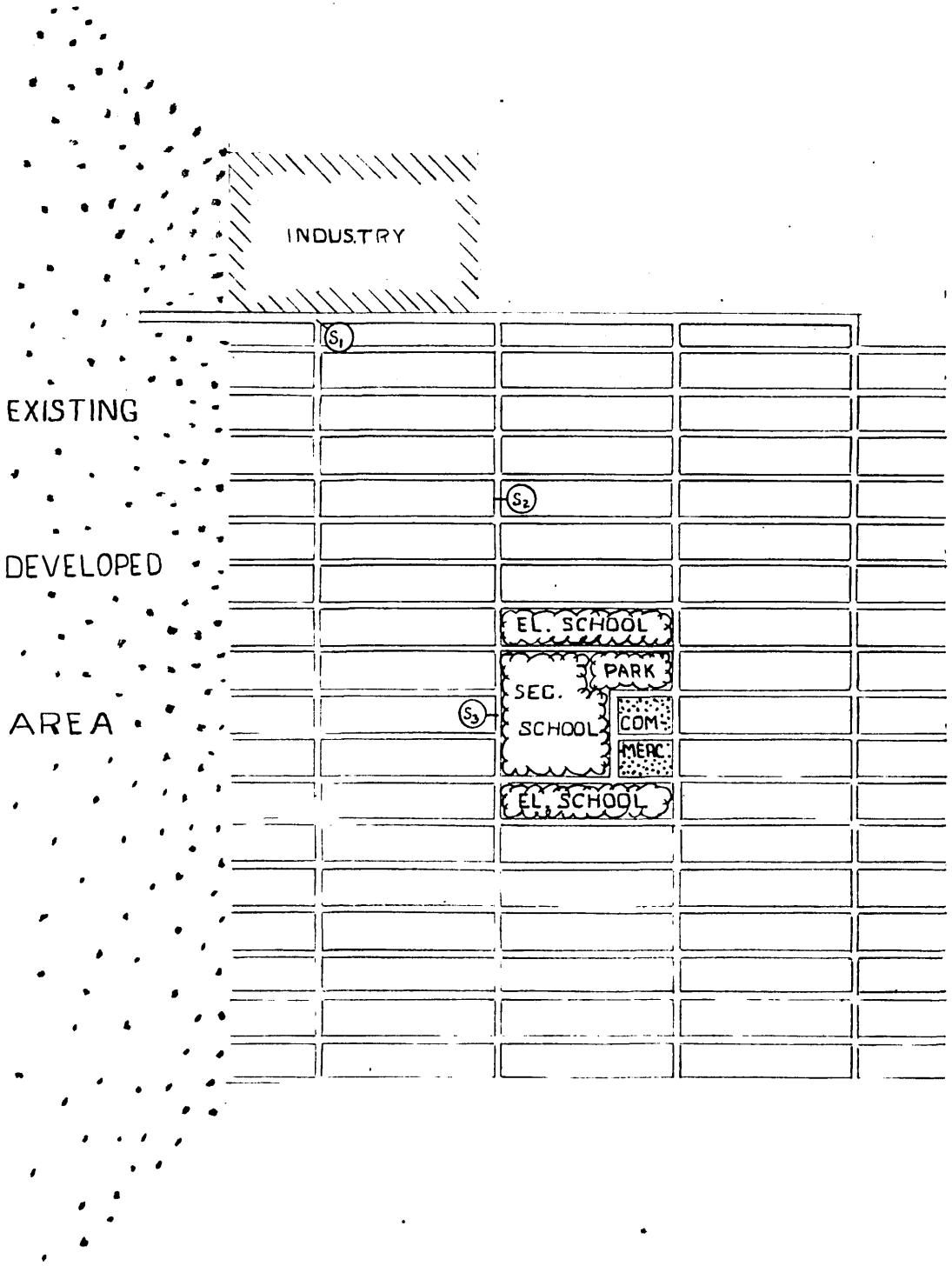
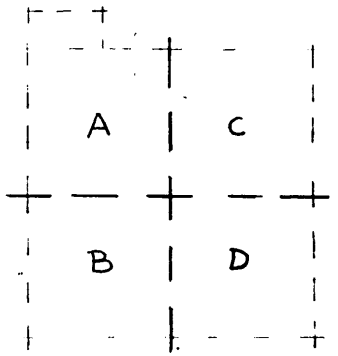


FIGURE 2

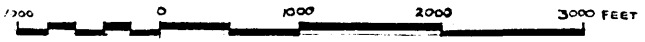
DIAGRAM FOR MEDIUM DENSITY DEVELOPMENT

SEQUENCE OF DEVELOPMENT

CONTINUOUS GROWTH: A,B,C,D
JUMP GROWTH: D,B,C,A



S, S_2, S_3 - SEWER LINE COMPUTATION POINTS



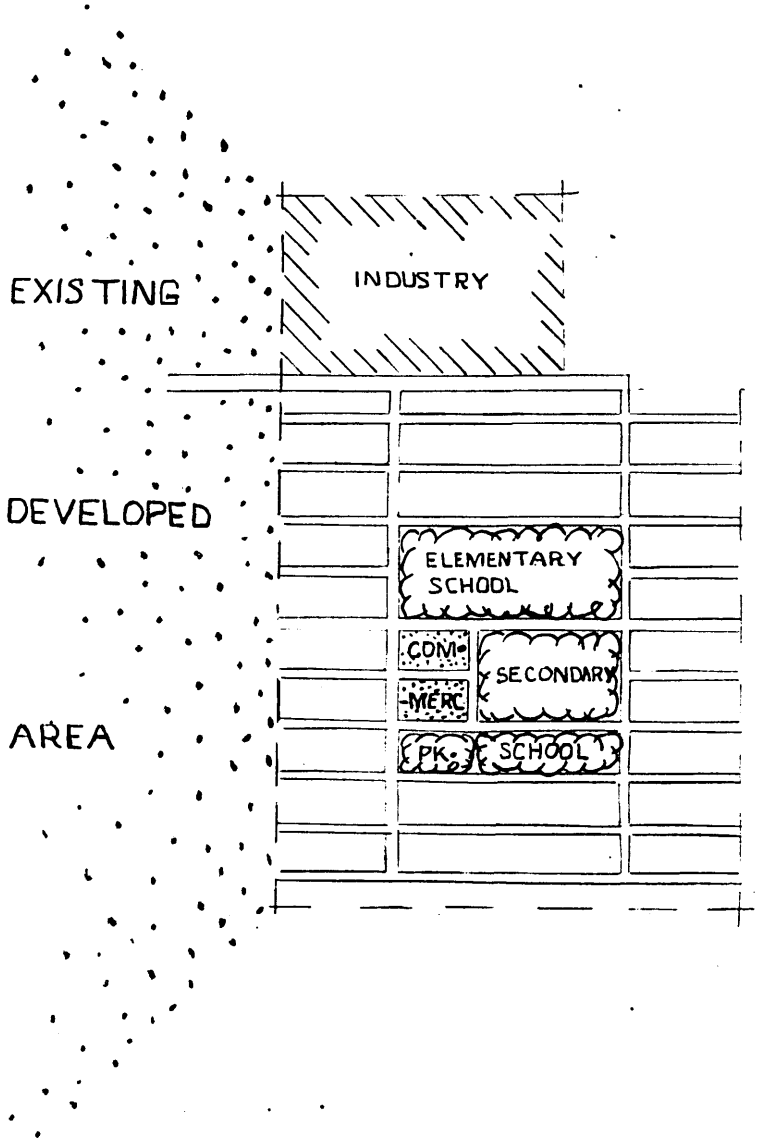
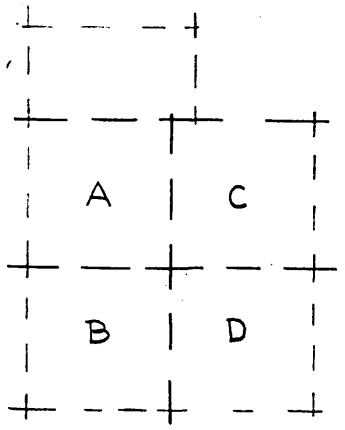


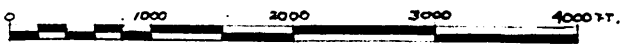
FIGURE 3

DIAGRAM FOR HIGH DENSITY DEVELOPMENT

SEQUENCE OF DEVELOPMENT

CONTINUOUS GROWTH: ABCD





CHAPTER IV

THE COST DATA

1. General Considerations

This study does not consider total public and private costs, but only the major local government costs of the developing area. The cost of roads, schools, sanitation, fire, and police protection, health and hospitals, general public buildings, general government control, recreation and welfare are considered. The cost of service for electricity, gas, and water is not considered, for these services are often run as a private business in which revenues meet costs. These costs are not usually met out of general revenues. Although transit service is usually necessary and usually must be subsidized by the government, its cost was not considered. Its cost is undoubtedly affected by density, but it is also affected importantly by variables our model does not treat; the location of the developing area with respect to the city's existing transportation system, and the availability of private transportation.

If the desirability of various types of development is to be evaluated from a wider point of view than that of community cost, all costs public and private should be totaled. In general the non-municipal costs are not considered in this study. However, with any type of development there are implicit costs which must be met as well as explicit ones. At one density a service may appear as an implicit cost, at another density as an explicit one. For example, in a low density residential development

there is no public cost for storm and sanitary sewerage. However, the need for these services must be met by the individual who must provide drainage ditches and septic tanks.

Variation in the level of public services provided has an important effect on public costs. Two distinct concepts make up level of service: the complement of services (which services are provided), and the standard of services (the quality of services which are provided).

The complement of services is the same for nearly all urban areas. Schools, roads, police and fire protection and the other standard services are necessary in some form or other. Occasionally a particular public service need not be provided. For example, in very low density development (less than 2 dwelling units per area), it is possible to replace public sanitation service with private measures. Individual septic tanks can do the work of a public sanitary sewer system efficiently and at less expense. Municipal rubbish collection can be eliminated.[1] Instead the individual will have to store his rubbish on his ample grounds and make a weekly or bi-weekly trip with it to the town dump. At very low densities, the public water system can be replaced by private wells.

The standard of each service provided is determined by the desires of the community. A community can provide a minimum health service or an

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[1] In our low density model, we do not provide a public sanitary sewer system for residential areas but do provide a sanitary sewer line alone the main road, where it can serve schools, shops and the industrial center. In this model, current costs of sanitation service are projected on the basis of the volume of sewage which the public sewer system will dispose of.

average one, a good school program or a minimum one, an excellent fire department or an average one. We attempt to distinguish between the costs of only three standards of service: high, medium, and low.

It is not within the aims of a general study of this sort to make detailed operational definitions of levels of service for each individual municipal service. Instead, we set out to show that there is a relation between level of service and expenditure. Then we measure level of service against the range of cost data available without attempting to define specifically the equipment and labor that are necessary to produce a unit of high level service or a unit of low level service. For example, we say that under certain conditions it will cost a city $370 per high school pupil to provide a high level of education service. For a low level of education service it will cost only $150. We assume that the school administrator specifies the elements of a high or low level system which can be provided at these prices.

We want to develop cost data that are as general as possible. Costs that are taken from the specific experience of just one town are likely not to be relevant for another town. Therefore we examined costs from many towns.

2. Crude Costs for Selected Municipal Services

There follows a table (Table 10) of average expenditures for various services as per cent of total general expenditures (including

both capital and noncapital expenditures) for Massachusetts cities of population between 25,000 and 50,000 in 1953.

TABLE 10

TOTAL EXPENDITURES FOR VARIOUS SERVICES
AS PER CENT OF TOTAL GENERAL EXPENDITURES FOR MASSACHUSETTS' CITIES
OF POPULATION 25-50,000 IN 1953

Schools	30.3 Per Cent	
Public Welfare	20.7	
Highways	9.15	
Fire Protection	8.15	
Sanitation	5.0	
		73.5 Per Cent
Police Protection	5.94	
Health and Hospitals	5.94	
General Control	3.74	
Recreation	2.32	
Libraries	1.1	
General Public Buildings	1.1	
Interest on General Debt	0.68	
Other	5.45	
		26.5 Per Cent

Source: Computed from data in Compendium of City Government Finances in 1953, U. S. Department of Commerce, Bureau of the Census, Washington, 1954.

The first group of five services constitutes 73.5 per cent of total general expenditures. For four of these (schools, highways, fire protection, and sanitation) we have compiled relatively refined cost data showing the effect of different levels of service and economies of scale. These will be presented in section 4, 5, 6, and 7 of this chapter. The other service in this first group is Public Welfare. Expenditures for it are extremely high in Massachusetts (20.7 per cent of all municipal expenditures), but in most states welfare payments are not made by municipalities. The Compendium of City Government Finances in 1953 /21/ shows that in only eleven other states (Connecticut, New Jersey, Delaware, Georgia, Maryland, Maine, New Hampshire, Rhode Island, Tennessee, Vermont, and Virginia) do all cities make welfare payments. In another fifteen states only occasional cities list welfare expenditures. Since public welfare is not generally considered a municipal cost and since it depends on the economic health of the region rather than any of the variables which our model explores, we have not attempted to investigate welfare costs in detail. But in order that our model will show costs comparable with the magnitude of costs experienced in Massachusetts towns, we have included welfare costs, and for them we have simply used average Massachusetts costs. (See Table 12.)

The remaining eight categories--police protection, health and hospitals, general government control, libraries, general public buildings, interest on general debt, and "other"--total only 26.5 per cent of 1953

Massachusetts municipal expenditures in towns of 25-50,000 population. (See Table 10.) Perhaps these costs vary significantly with density, pattern of growth or type of development, but in the short time available for this study, we did not analyze these costs in depth. Lack of precision in any one of this group is of less importance than in any of the first groups, for variation in any one of them could lead only to a relatively small saving or expense.

We turned to the Compendium of City Government Finances in 1953 to get cost data for this second group of categories. In the Compendium capital and noncapital expenditures were not separated for police, health, general control, libraries, or "other" services, so we satisfied ourselves with total expenditures for all eight categories in the second group. Capital outlay in these categories is not likely to be a large percentage of total capital outlay. In Massachusetts cities of 25-50,000 in 1952 it totaled 21.4 per cent of all capital outlays. In 1953 it was but 8.8 per cent. We can estimate that on the average the first group of five categories accounts for 85 per cent of all capital outlays.

For police, health and hospitals, general control, and recreation, we calculated median per capita total costs in Massachusetts cities of three size ranges. These data are presented in Table 11.

TABLE 11

MEDIAN PER CAPITA TOTAL EXPENDITURES

FOR VARIOUS SERVICES IN MASSACHUSETTS, 1953, BY SIZE GROUP OF CITY

	25,000 to 50,000	50,000 to 100,000	100,000 to 200,000
Police	$7.62	$8.23	$7.95
Health and Hospitals	3.01	3.82	6.74
General Control	4.29	3.46	3.77
Recreation	3.31	2.90	2.09

Source: Computed from U. S. Department of Commerce, Bureau of the Census, Compendium of City Government Finances in 1953, Washington 1954, Table 16.

It is impossible to say without detailed investigation whether the variation in cost between different size groups of cities was due to economies or diseconomies of scale, difference in level of service, or whether some service was being provided for or by other government units. Therefore, we made no attempt to refine these cost figures but took the averages for the size group 25,000 to 50,000 population as our working figures for calculations.[1] Per capita cost figures for all eight

[1]We noted a sizeable range in costs for particular services in towns of anyone size, but we were not able to explain the differences in any general way. Therefore, we present and use only median cost per capita data rather than data showing the range of costs which towns incur.

categories[1] in the second group are summarized below:

TABLE 12

YEARLY PER CAPITA TOTAL COSTS OF SELECTED SERVICES

FOR USE IN COST CALCULATIONS OF THEORETICAL MODELS

Public Welfare	$26.73
Police	7.62
Health	3.01
General Control	4.29
Recreation	3.31
Libraries and General Public Buildings	2.80
Interest on General Debt[2]	0.87
Other[3]	7.20

Source: U. S. Department of Commerce, Bureau of the Census, Compendium of City Government Finances in 1953, Table 16.

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[1]We include the average cost of interest on general debt in the table but will not use it in calculating the costs of our theoretical models. We have noted that on the average the first group of categories accounts for about 85 per cent of all capital outlay. Roads, schools, and sanitation account for most of the capital outlays in this group. Interest on these outlays is computed directly. The remaining interest costs are of the order of $10-$20 per capita. These we consider small enough so that they can be neglected in our cost calculations.

[2]Included in table but not used in cost calculations.

[3]This category includes minor activities which it is not possible to allocate to specific listed function (e.g. protective inspection and regulation, conduct of elections, air ports, etc.) and activities that have major significance for the cities in which they occur (e.g. port facilities, miscellaneous commercial activities, local housing authorities, etc.).

In using these costs for our calculations, we make the conservative assumption that no economies will be realized when a department expands its operations.

Schussheim made the assumption that when an operating department expands, its fixed costs do not increase but variable costs continue to be incurred at the same amount per unit of service produced.[1] Schussheim was interested in an increase of the output of services large enough to provide for only 500 new families. For such a small increase his assumption is probably the best that could be made for many services. But in our model, services must be made to provide for 2,480 additional families. For such an increase of most services substantial new capital investments would be necessary. Therefore we feel that a more refined assumption about the behavior of the cost of services lies between our assumption, which results in high cost estimates and Schussheim's which leads to low cost estimates. Since we are unable to define such an assumption with precision, we continue with our crude assumption and project total costs for the second group of services on an unchanging per capita basis.

3. The Cost of Land

We assume that the developer deeds to the town all land which is needed for subsidiary roads, schools, parks, and other public uses.

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[1] Schussheim /18/, p. 103.

This land will all be used for the benefit of the people who come to live in the developing sector. The town, however, buys the land necessary for the main road. We set its cost roughly at $300 per acre. We consider land to be a nondepreciable asset so its value stays constant and the cost of owning it is the yearly cost of interest on its value.

4. Road Costs

On the average, in established cities in Massachusetts, the municipal cost of roads is exceeded only by the costs of welfare and education. (See Table 10.)

It is quite clear that the development of any area in a city requires the immediate construction of new roads. Their standard of construction, width, and the necessity of special design for handling traffic is related to the traffic pattern which is expected. But the length of road required and also its width is sensitive to changes in density and pattern of development. Because our model is explicitly concerned with these last variables and because roads are known to be one of the major municipal costs, we are particularly concerned with getting reliable road cost data.

We must determine both the capital and noncapital costs of roads with pavements which are suitable for various traffic loads.

a. Total Capital Costs

Capital cost of a unit length of roadway varies widely. The presence of rock, swamp or hill, and the local availability of borrow and paving materials have a major effect on the cost of the road. Relative to these, variations in cost due to different types of paving are sometimes small. The planner or developer cannot determine the terrain in any city. All he can do is choose the most favorable sites for development. Once this has been done, he must decide what pavement to use. It is possible that this decision can result in important cost differentials. Terrain conditions being equal, what pavement types are cheapest to construct for a given traffic load? Which types are cheapest in the long run? What is the magnitude and range of these costs?

The developer can decide how much road to build at once. Can any economies or diseconomies be expected if a long length of road is constructed at one time or is the cost of a unit length of road the same no matter how long the job?

In order to answer these questions we had first to determine the average total construction costs for various standard types of roads.

We gathered average costs for construction of various standard types of roads from many sources.[1] The most complete set of estimates was

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[1] The Engineering News-Record is a leading source of such actual cost data and estimates. Seelye, Data Book for Civil Engineers presents comprehensive data for quick estimates.

that of A. J. Bone, Associate Professor of Highway & Airport Engineering, M.I.T. These are presented as Table 41 in Appendix I. His tabulation differentiated between construction costs and grading and drainage costs. He also made estimates for maintenance cost, permissible traffic limit, and probable life of the various types of roads. His estimates reflect demands and practices of the New England region. Since we found that his estimates were not in conflict with others,[1] we used them as a general guide for estimating the cost levels for various types of road pavement.

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[1]Schussheim derived his cost figures from published reports of costs for similar items or from discussions with municipal officials and private builders. He went to Natick reports and officials to get cost data to apply to theoretical growth in Natick. He got cost data for Wayland from Wayland sources, for Newton from Newton sources. He makes "the working assumption that the unit costs for primary frontage facilities are roughly constant over a wide range of units served" (p. 76). As a consequence, he assigns road costs on a per mile basis with no regard to the total length constructed at one time. He does show variations in cost for different standards of construction, for the towns from which he gathered data have different traffic loads and construct streets of widely different specifications.

The capital costs for roads which Schussheim used in his 1951 study are comparable with the costs we use. They are summarized below (see Schussheim pp. 333-336):

Natick--permanent service streets (gravel base, asphalt macadam pavement, 26' wide, plus sidewalks and storm drainage). $84,500/mi.

Wayland--unpaved service street (12" water-bound gravel base, surface treated and seal coat, 22' wide, catch basins every 500 feet). $52,800/mi.

Newton--permanent service streets (gravel base, asphalt macadam pavement, 29' wide, catch basins and sidewalks). $105,600/mi.

Our model is not concerned with unusual topographic conditions so we assumed low grading and drainage costs ($22,500-$25,000 per mile) in all estimates. These estimates of the total cost of construction are presented in Table 13.

TABLE 13

ESTIMATED COST LEVELS OF ROADS WITH VARIOUS TYPES OF PAVEMENT

	Grading and Drainage Cost	Pavement Cost	Total Construction Cost
Bituminous Concrete, Concrete Base	$25,000	$54,000	$79,000
Portland Cement Concrete	25,000	42,000	67,000
Bituminous Concrete, Flexible Base	23,500	38,500	62,000
Bituminous Macadam	22,500	27,500	50,000
Road Mix	20,000	20,000	40,000

Source: Derived from data of A. J. Bone, Table 41.

We were unable to find any evaluation in the literature of the probable unit savings from constructing a large amount of road at once instead of several short stretches at different times. However, a North Dakota Study showed that substantial economies of scale can be

expected in projects which require considerable earth extraction and grading.[1] The consensus of several road engineers interviewed was that such economies can be expected in road construction. Since no detailed studies were available, we turned to these road engineers for their best informed estimates of expected economies. Their estimates were in general agreement. Their opinion was strong that considerable increase in economy can be expected as the length of roadway increases up to five miles. Above five miles slight further economies are to be expected. From their estimates and our own judgment we derived construction cost indices for use in our calculations. These indices show how total construction cost varies with the number of miles constructed at one time. They are presented as Table 14.

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[1] J. M. Doyle, "How to Determine Economic Project Size," Roads and Streets, Vol. 83, p. 66, Oct. 1940. This study of the contract costs (exclusive of major drainage structures) of about 40 North Dakota projects shows that the minimum cost per cubic yard of unclassified earth excavation occurred at a job size of 147,673 cubic yards. The data is comparable to what might be expected from a study of the grading and drainage costs of roads. It is summarized below:

Number of cubic yards unclassified for the extraction in project	Cost per cubic yard
20,000	41 cents
40,000	27
80,000	203
120,000	19
147,673	186
200,000	193
280,000	203
300,000	213

TABLE 14

ESTIMATED AVERAGE ROAD CONSTRUCTION COST INDEX

DEPENDING ON THE NUMBER OF MILES CONSTRUCTED AT ONE TIME

	1 Mile	5 Miles	10 Miles	20 Miles
Road Mix	1.12	100	92.5	90
Concrete	1.18	100	10.5	88.5

We assumed that the economies of scale to be expected in other types of roads would follow these two. There follow estimated construction costs per mile according to the number of miles constructed at one time for various types of roads.

TABLE 15

TOTAL ROAD CONSTRUCTION COST PER MILE

ACCORDING TO NUMBER OF MILES CONSTRUCTED AT ONE TIME

	Cost[1] per Mile of 24' Wide Road When Number of Miles Constructed at One Time Is:			
	1 Mile	5 Miles	10 Miles	20 Miles
Bituminous Concrete, Concrete Base	$95,000	$79,000	$71,000	$69,500
Portland Cement Concrete	79,000	67,000	60,500	53,500
Bituminous Concrete, Flexible Base	72,000	62,000	56,400	50,200
Bituminous Macadam	57,000	50,000	46,000	41,200
Road Mix	44,800	40,000	37,000	33,300

[1]Cost includes cost of grading and drainage.

Source: Computed from Road Cost data of A. J. Bone, Table 41 and from economies of scale indices of Table 14.

These data are also presented as Road Cost Chart R-1. Note that Table 15 and Chart R-1 are for roadway 24' wide. To find the cost of a wider roadway it is necessary to express its length as equivalent length of a 24' roadway (e.g., 1 mile of 36' wide road is equivalent to 1.5 miles of 24' wide road). Using this equivalent length, the cost per mile is found from chart R-1. Economies of scale are realized from greater width as well as from greater length.

b. Yearly Capital Costs

The capital cost of a road is not paid in a lump sum but in payments over the life of the road. We calculated depreciation at a constant absolute amount each year. This is a crude procedure. A more refined method, which would have involved considerably more computation, could have been devised. However, because of the rough character of the data with which we were forced to work, we did not feel that a more refined method would have contributed significantly to the reliability of our final computations.

When the pavement reaches its end-of-life, considerable value still remains in the road. The road can be restored to good condition, but only by a major investment. Life of pavement varies between 10 and 25 years for different types of roads. The value of the pavement at its end-of-life is considered to be the difference between the total cost of construction of the original pavement and the total cost of resurfacing.

Depreciation of the sub-base structure is usually complete in forty years for all types of roads.[1] Assuming a constant yearly depreciation, we calculated the value of the sub-base for various types of roads at the end-of-life of their pavements. These calculations are presented in Table 42 in Appendix I.

The total depreciation of the road at the pavement's end-of-life is equal to the difference between the original construction cost of the road and the sum of the remaining values of the sub-base structure and the pavement. We first calculated the total depreciation for various types of roadways (see Table 42 in Appendix I) and then calculated the depreciation on a yearly basis. See Table 16.

Yearly depreciation per mile varies with the number of miles constructed at one time just as total construction cost does. Table 17 shows the yearly depreciation per mile for various types of pavement depending on the number of miles constructed at one time. This data is the basis of Road Cost Chart R-2.

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[1]See Toll Roads and Free Roads, House Document 272, 76th Congress, First Session Public Roads Administration 1939 quoted in Hewes, L. I. and Oglesby, C. H., Highway Engineering, John Wiley & Sons, New York, p. 63.

TABLE 16

DEPRECIATION PER MILE OF ROADS HAVING VARIOUS TYPES OF PAVEMENTS

(It is assumed that five miles of road were constructed at one time.)

	Total Depreciation Over Life of Pavement	Life (Years)	Yearly Depreciation	Capital Value at Half Life
Bituminous Concrete, Concrete Base	$34,500	20	$1,720	$61,750
Portland Cement Concrete	42,000	25	1,680	46,000
Bituminous Concrete, Flexible Base	33,700	20	1,680	45,150
Bituminous Macadam	27,800	17	1,630	36,100
Road Mix	18,100	10	1,810	30,950

Source: Computed from Cost data of A. J. Bone, Table 41 in Appendix I. For calculations see Table 42 in Appendix I.

TABLE 17

YEARLY DEPRECIATION PER MILE FOR VARIOUS TYPES OF PAVEMENT ACCORDING TO THE NUMBER OF MILES CONSTRUCTED AT ONE TIME

	Cost per mile when number of miles constructed at one time is:			
	1 Mile	5 Miles	10 Miles	20 Miles
Bituminous Concrete, Concrete Base	$2,060	$1,720	$1,550	$1,510
Portland Cement Concrete	1,980	1,680	1,520	1,490
Bituminous Concrete, Flexible Base	1,950	1,680	1,530	1,495
Bituminous Macadam	1,860	1,630	1,510	1,460
Road Mix	2,030	1,810	1,670	1,630

These data are also presented as Chart R-2.

Source: Computed from basic road cost data of A. J. Bone. (Table 41 in Appendix I.

We assume that the money to pay for the roads is borrowed. Therefore, we must add yearly interest cost to the yearly depreciation costs. From a purely theoretical standpoint, annual interest charge should be greater in the first year of the road than in its last years. The quality of the road is obviously greater in the first years and so is its capital value. However, again because the basic data are so crude and

because it is desirable to simplify computations as long as accuracy is not sacrificed, we compute interest cost at a constant annual amount.

We calculated annual interest cost on the value of the road at half life. Interest costs per mile resulting from an interest rate of $2\frac{1}{4}$ per cent[1] are presented in Table 18 and Chart R-3. Interest cost per mile varies with length constructed at one time just as total construction cost does, for the value at half life varies as the construction cost for any given road.

By choosing for the depreciation period the expected life of the road surface and calculating constant yearly interest on the half-life value of the road, we find that the yearly cost for the road is always the same before and after the road surface is brought back to value be resurfacing. The total yearly capital costs of roads are the sum of the depreciation cost and the interest cost. For calculations in our theoretical model, these costs per mile are estimated from Charts R-2 and R-3.

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[1]Two and one-fourth per cent is a typical current interest rate in Massachusetts for municipal bonds for facilities of this sort.

TABLE 18

YEARLY INTEREST COST PER MILE @ 2¼ PER CENT

ACCORDING TO NUMBER OF MILES CONSTRUCTED AT ONE TIME

	1 Mile	5 Miles	10 Miles	20 Miles
Bituminous Concrete, Concrete Base	$1,670	$1,390	$1,250	$1,220
Portland Cement Concrete	1,220	1,030	934	914
Bituminous Concrete Flexible Base	1,190	1,010	918	894
Bituminous Macadam	927	812	746	726
Road Mix	780	695	643	625

This data is also presented as Road Cost Chart 3.

Source: Computed on Capital value at half-life of roads with various pavements from Table 16. Cost variation with number of miles constructed at one time based on Road Construction Index, Table 14.

c. Yearly Noncapital Cost

Maintenance costs must be added to capital costs in order to find the complete cost of a new road. What is the magnitude of maintenance costs? Do they vary significantly for various types of pavement? Over what range can economies of scale in maintenance be expected and how great will these economies be?

To answer these questions we turned to published and unpublished maintenance cost data.[1] Because of different definitions of what constitutes maintenance and what new construction cost, data from different sources is rarely comparable. Even the significance of data from any one source is clouded for it is affected by varying traffic conditions that have existed over the different periods for which maintenance records are available. Varying proportions of roads of different age which have been subjected to different traffic loads also confuse maintenance cost data.

Once again the estimates of Professor A. J. Bone seemed to be the most reliable, were most comprehensive and most explicitly stated. His data were the chief basis for our basic maintenance cost estimates which are presented in Table 19.

TABLE 19

YEARLY ROAD MAINTENANCE COST PER MILE

FOR VARIOUS TYPES OF PAVEMENT

(Assuming five miles of road are to be maintained)

	Surface	Other*	Sand, Snow Removal	Total
Bituminous Concrete, Concrete Base	$200	$100	$150	$450
Portland Cement Concrete	150	100	150	400
Bituminous Concrete Flexible Base	250	100	150	500
Bituminous Macadam	270	100	150	520
Road Mix	375	100	150	625

*For main highways this item, which includes grass mowing, etc., is $250.

Source: Based on data of A. J. Bone, "Approximate Cost of Construction and Maintenance for Different Types of Pavement," mimeographed. See Table 41 Appendix I.

[1] Notably data of the Massachusetts Department of Public Works and Professor A. J. Bone.

We were unable to find published any discussion of the possibility of economies resulting from maintaining a large stretch or road instead of a small stretch, but the road engineers we queried generally recognized that these economies can be expected. Again we were forced to rely on the best estimates of road engineers. Sizeable diseconomies are to be expected if less than five miles of roadway are to be maintained, but since these economies apply to the total amount of road to be maintained, not to each individual job, diseconomies due to small lengths of road will not be experienced by any town of the size with which we are concerned.

We assume that the town manager integrates maintenance requirements with maintenance requirements of other towns, that he possesses a minimum of his own equipment and force, and contracts out most of the work to private contractors. This assumption is made in order that we may consider that the maintenance force and equipment is fully utilized throughout the year.[1]

Our assumption of contracting work out means essentially that all maintenance crews are fully utilized or caring for at least thirty miles of roadway.

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[1] Massachusetts Department of Public Works Maintenance Engineers estimate that 35 miles of roadway will on the average keep one foreman and maintenance crew busy all year. Cost of yearly maintenance per mile increases if crew has less than 35 miles to maintain and drops slightly if the crew is required to maintain more than 35 miles. About the maximum one crew can care for is 50 miles of roadway over a year. Relative cost of maintenance per mile depending on length maintained by one foreman and crew is estimated by Mass. Department of Public Works Maintenance Engineers as follows:

Number of Miles Maintained by One Foreman and Crew	10	20	35	50
Cost Index of Maintenance per Mile	110	106	100	98

Under this assumption, we estimate economies of scale by total length of road to be maintained:[1]

TABLE 20

ROAD MAINTENANCE COST INDEX ACCORDING TO NUMBER OF MILES TO BE MAINTAINED

Total Number of Miles to Be Maintained	1	5	10	20
Cost Index per Mile (economy of scale index)	110	100	99	98

Source: Conversation February 1955 with Mr. Pyne, Maintenance Engineer, Massachusetts Department of Public Works.

This economy of scale index is presented as Chart R-4. From the chart the applicable economy of scale index can be found for the total number of miles which must be maintained. This index is then multiplied by the basic maintenance cost for each type of pavement to get the maintenance cost per mile for each type of pavement to be maintained. Maintenance expenses for a road, theoretically and in fact, are smaller in early years and mount as the road ages. To our knowledge, the only adequate study of the variation in maintenance cost with age of roadway was done under the direction of Professor A. J. Bone at M.I.T. in 1934. The data of this study are, of course, now hopelessly out of date but Table 42A is presented in Appendix I to show the relative variation.

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[1] Conversation, February 1955.

For our purposes, however, which is to investigate long-run fiscal balance, we assume maintenance cost constant annually regardless of age. This vastly simplifies computations and goes to balance our bias in computing interest charge. In effect we are assuming a long-run manager who averages cost out over the life of road, so as to be able to keep a stable tax rate after due allowance for change in prices.

Table 21 brings together the capital and noncapital costs of roads. In the last column they are summed for roads of various types of pavement. Note first that there is not great difference in cost between roads with various types of pavement. The most costly is but 1.2 times the cost of the least costly. Note that a road mix road, which requires the least capital investment, is not the cheapest in the long run. Bituminous macadam is the least expensive road over the long run, but it cannot be used if heavy traffic is expected.

TABLE 21

TOTAL YEARLY COSTS PER MILE FOR ROADS WITH VARIOUS TYPES OF PAVEMENT

(Assuming Five Miles Were Constructed at One Time)

	Approximate Traffic Limit per Day Vehicles/day	Yearly Depreciation Cost	Yearly Interest Cost	Yearly Maintenance Cost	Total Yearly Cost
Bituminous Concrete, Concrete Base	full capacity	$1,720	$1,390	$450	$3,560
Portland Cement Concrete	full	1,680	1,030	400	3,110
Bituminous Concrete, Flexible Base	full capacity	1,680	1,010	500	3,190
Bituminous Macadam	3000	1,630	810	520	2,960
Road Mix	800	1,810	695	625	3,130

Source: See Tables 17, 18, 19.

e. Road Cost Summary Charts

The road cost data which we shall use for determining the costs of our theoretical models is summarized in Charts R-1 through R-4.

Chart R-1 is used to determine the Construction Cost (including grading and drainage) per mile of 24' wide (2 lane) roadway given the type of pavement and the number of miles which are to be constructed at one time.

Chart R-2 is used to determine the total yearly depreciation cost per mile given the type of pavement and the number of miles which was constructed at one time.

Chart R-3 is used to determine the yearly interest cost per mile given the type of pavement and the number of miles which was constructed at one time.

Chart R-4 is used to determine the economy of scale index to be expected in maintenance costs given the total length of roadway to be maintained. This index is then multiplied by the basic maintenance cost per mile (from Table 19) to get the expected cost per mile.

e. Yearly Capital Costs for Curbs and Sidewalks

We assumed that economies of scale are unlikely in the construction of curbs and sidewalks. We calculated unit costs for sidewalks and curbs from Seelye's 1949 data /19/, and brought it up to 1954 price levels by applying the Engineering News-Record Construction index. We assume total depreciation in 50 years and complete interest cost on the value at half life. Depreciation and interest are computed at a constant annual amount.

We assume that maintenance costs of curbs and sidewalks are included in the maintenance costs for roads.

TABLE 22

YEARLY CAPITAL COSTS FOR SIDEWALKS AND CURBS

	Costs per Mile		
	Depreciation Cost Per Year	Interest Cost per Year at 2%	Total Yearly Cost
Sidewalk			
4" concrete 4' wide	$196	$110	$306
4-5' wide	220	124	344
6' wide	293	165	458
8' wide	391	220	611
Curbs			
Stone	630	354	984
Concrete	210	118	328

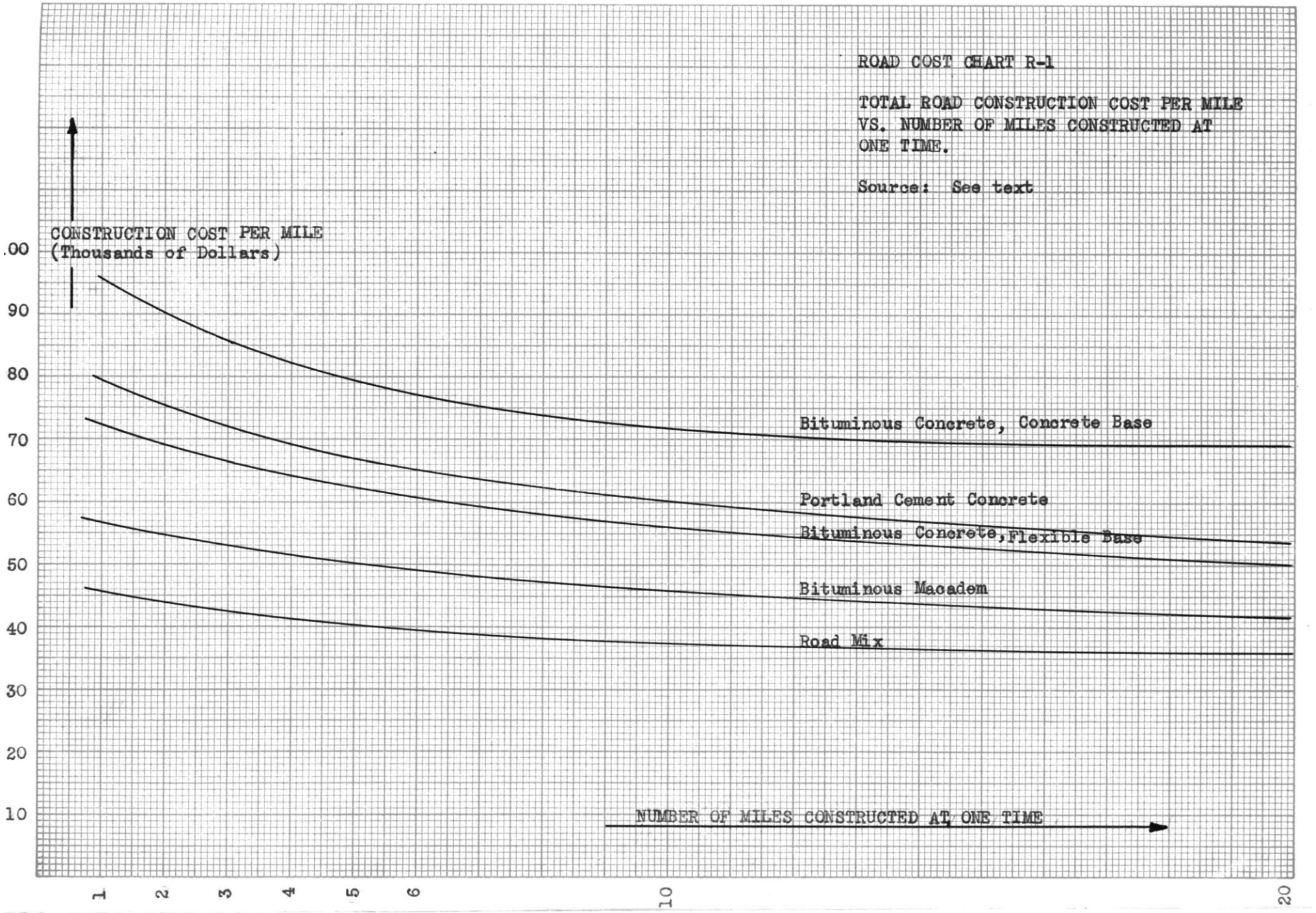
We have considered only the costs of concrete sidewalks for other types are not generally recommended by authorities (e.g., Lynch /13/, p. 7).

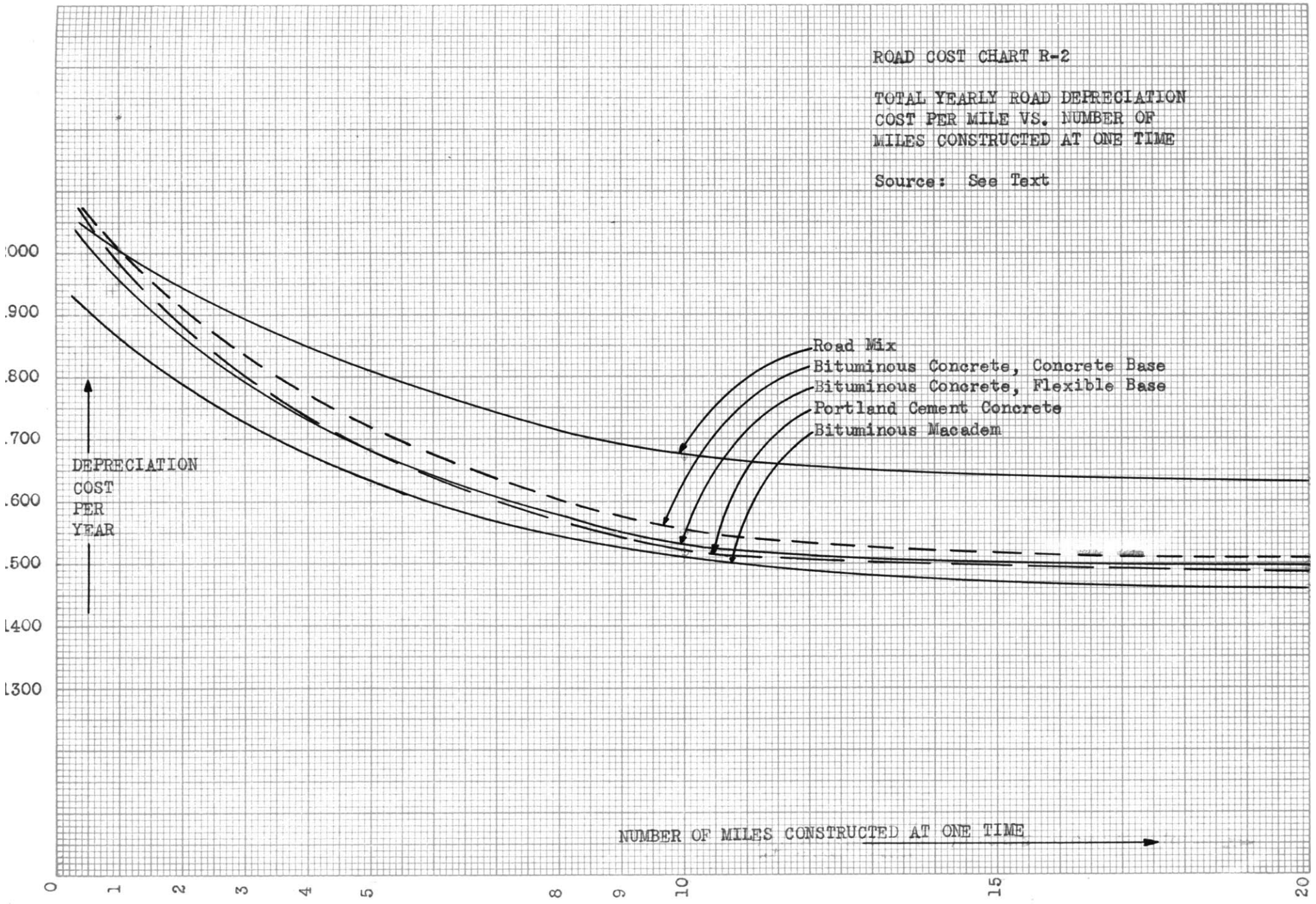
It is assumed that the developer will always choose the cheaper type of curb in his locality since both have long wearing properties. Therefore in all calculations, costs for concrete curbs are used.

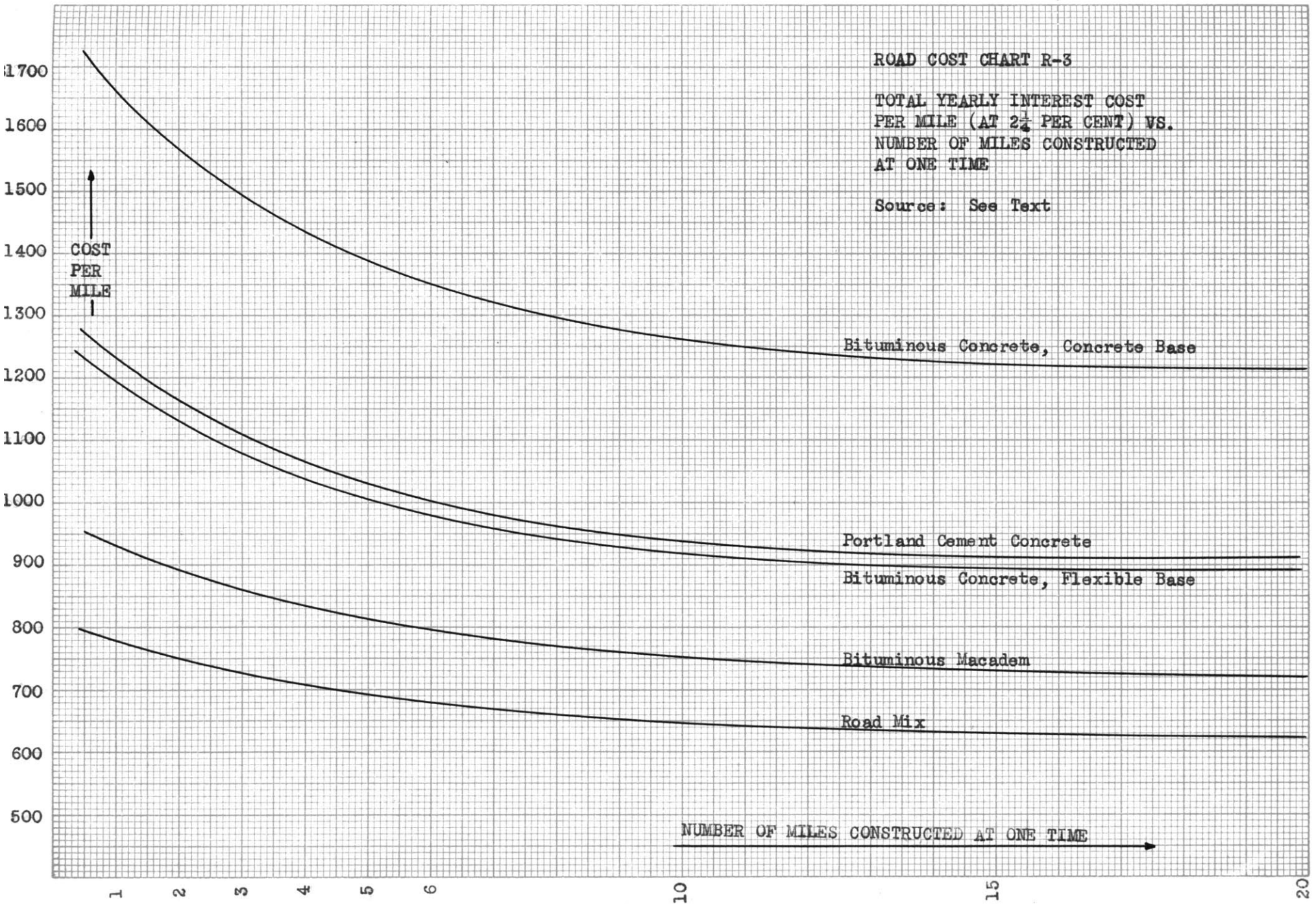
ROAD COST CHART R-1

TOTAL ROAD CONSTRUCTION COST PER MILE VS. NUMBER OF MILES CONSTRUCTED AT ONE TIME.

Source: See text



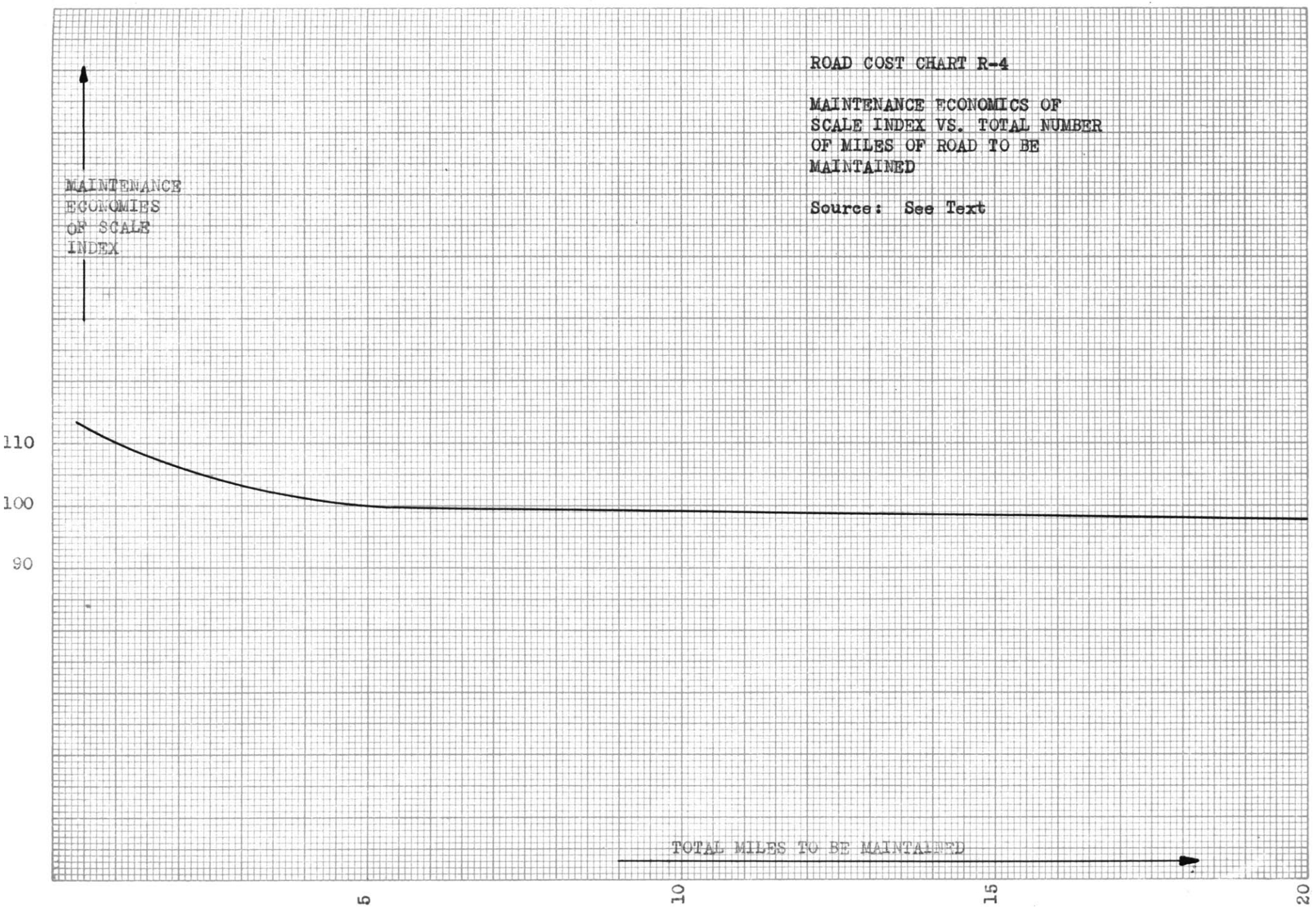

ROAD COST CHART R-2
TOTAL YEARLY ROAD DEPRECIATION COST PER MILE VS. NUMBER OF MILES CONSTRUCTED AT ONE TIME
Source: See Text
Road Mix
Bituminous Concrete, Concrete Base
Bituminous Concrete, Flexible Base
Portland Cement Concrete
Bituminous Macadem
DEPRECIATION COST PER YEAR
NUMBER OF MILES CONSTRUCTED AT ONE TIME
0
1
2
3
4
5
8
9
10
15
20


ROAD COST CHART R-3
TOTAL YEARLY INTEREST COST PER MILE (AT 2¼ PER CENT) VS. NUMBER OF MILES CONSTRUCTED AT ONE TIME
Source: See Text
COST PER MILE
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
Bituminous Concrete, Concrete Base
Portland Cement Concrete
Bituminous Concrete, Flexible Base
Bituminous Macadem
Road Mix
NUMBER OF MILES CONSTRUCTED AT ONE TIME
1
2
3
4
5
6
10
15
20

ROAD COST CHART R-4

MAINTENANCE ECONOMICS OF SCALE INDEX VS. TOTAL NUMBER OF MILES OF ROAD TO BE MAINTAINED

Source: See Text



5. School Costs

If he is to provide for the education of the children of a new population in a growing area the school planner must make several decisions. He must decide on the type of school system (e.g., K8-4 or K6-3-3).[1] He must decide whether to build one or a few large schools or several smaller ones. He must decide on the standard of education service the schools will offer. The desired standard not only affects the number and quality of teachers needed, but also the type and standard of building that must be provided.

What will it cost to provide a given standard of education service for our theoretical model? To answer this general question, we must investigate the magnitude and likely range of both capital costs and current costs. How do the capital costs of providing education service vary with capacity of school and the standard of service offered? How do the current costs vary with the size of school, size of school system, and standard of education service provided?

a. Total Capital Costs

The capital costs of schools are broken down into the capital costs of construction and the capital costs of equipment.

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[1] K8-4 refers to a school system in which kindergarten and the 8 elementary grades are in one school building. The 4 high school grades in another.

Total Construction Cost

Data on the cost of recently built schools is available in architectural journals and from state school building commissions. But there is no standard school. Requirements and specifications vary so widely that every school seems to be a unique set of classrooms, service rooms, and special purpose rooms. Efficiency of design varies widely. As far as we could determine, no adequate study has been carried out which makes it possible to estimate closely the cost of a school building when a few basic variables are known.

In order to make useful general cost estimates for schools, it was necessary to identify the key variables which describe school costs. Total area of the school was taken as the basic independent variable for all school capital cost estimates.[1] Other independent variables could have been chosen. For example, number of pupils is an often-used variable. However, construction costs are related to the number of pupils only if the number of square feet per pupil is known. Number of classrooms is another often used independent variable. It, too, must be qualified by more basic information: How many children to a classroom? How much floor space is to be allotted to each.

In order to judge the capital cost of a proposed school (if total area of the school is taken as the measure of the capital cost of

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[1] In conversation with the author in February, 1955, Dr. Basil Castaldi of the Massachusetts State School Building Commission expressed the opinion that the best single indicator of school cost is the school's total area.

the school), the school planner must be able to make a rough estimate of the floor area of school required to provide a given standard of education service to a given number of children. Of course, to do this he must know the floor area to be allotted per pupil. It turns out that the floor area to be allotted per pupil is itself a very good index of the standard of service the school building can provide.

Standard of service of school building can be measured by the type and quality of construction and by the diversity of education program which the building makes possible. The more general measure of the quality of a school building is the diversity of education program it makes possible. This diversity is the result of the inclusion of a number of varied special facilities, but it can be measured in a general way by the floor area provided per pupil using the school building.

A school which offers a traditional standard program for all students needs to provide but standard classrooms. Only a few rooms are necessary that are used only for special purposes, so one can expect nearly full utilization of all the school's space all of the time.[1] Therefore, the total floor area per pupil tends to be small.

A school planned for a diversified program must have special purpose rooms in addition to the basic classrooms. Not only will such a school be larger but it will show a lower per cent utilization of its

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[1]With 30 students to each standard classroom and no special classrooms, gymnasia or shops, one can theoretically expect utilization of total school area to approach the maximum. Of course, 100 per cent utilization can never be achieved for some common areas which are not used all the time are inevitable.

space. Division of classes into special groups which use special facilities in special rooms will always mean a smaller per cent utilization of space than would be found in the standard school with one 30-pupil capacity classroom for each 30 pupils. In effect, this means that in order to provide a more diversified program a school must provide more floor area per pupil.[1] Large floor area per pupil, of course, is but a necessary condition for a more diversified program. It is not a sufficient one.

Since square feet per pupil seems to be a very good general indicator of the level of service one can expect from a school building, we examined available data on schools constructed recently. From the range of data, we picked the median number of square feet per pupil as the medium level of service and picked representative values of square feet per pupil to represent high and low levels of service.[2] Chart S1, based on Table 23, relates the number of pupils to be provided for and the required total area of school for these levels of service.

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[1]In this argument we assume an equal level of design skill is displayed in all school buildings.

[2]We indicated in our discussion that high level of service school buildings have a large floor area per pupil and many specialized rooms; low level of service school buildings have smaller area per pupil and little more than basic classrooms. We were unable to get sufficiently detailed data to check this for the recently-built schools, but our failure to learn whether local experience bears out this contention is of little consequence. We are primarily concerned with general theoretical relationships. If an equal degree of design skill is exercised on each school building our contention can be expected to hold. However, the relationship between floor area per pupil and number of special facilities might well not be born out by a set of raw data, for the design skill exercised on each school building varies greatly.

TABLE 23

TOTAL FLOOR AREA PER PUPIL FOR BUILDINGS

OF VARIOUS LEVELS OF SERVICE

	Elementary Schools	Secondary Schools
High Level of Service	105 sq. ft.	145 sq. ft.
Medium Level of Service	85 sq. ft.	125 sq. ft.
Low Level of Service	65 sq. ft.	105 sq. ft.

Source: For Elementary Schools--based on published data of the Connecticut Public School Building Commission, in Connecticut Builds Schools. For Secondary Schools--based on unpublished data furnished by the Massachusetts State School Building Assistance Commission.

Given the total area of the school, we want to know its cost. Data was available for total construction cost and for total equipment cost so we examined these in turn.

Data[1] on construction cost per square foot of secondary schools showed no variation with total area of the school.[2] However, we felt

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[1]For secondary schools, data was examined which described the new secondary schools constructed in Massachusetts during the years 1950-1954. This data was furnished by the Massachusetts State School Building Assistance Commission, John E. Marshall, Administrator. For elementary schools, data was examined which described the new elementary schools constructed in Connecticut during the years 1947-9. This data was taken from Connecticut Builds Schools, Connecticut Public School Building Commission, 1950.

[2]Elementary school costs per square foot seemed to show a slight increase with increasing total area, but the spread of data was so great that we felt unjustified in assuming any trend.

the data not immediately comparable because many of the schools for which data was available were probably of different construction standards. It was necessary to develop a method of estimating this variation in construction standards. We looked for some rough way to measure the probable elaborateness of construction. It seemed that equipment cost per square foot and the number of square feet per pupil might indicate in a general way the expense lavished on the school building. Both these measures showed a definite increase with increase in total floor area. We expressed them as indexes--equipment index and area index.

We feel that if these measures of elaborateness or expensiveness are high, it is likely that the community also had the resources and inclination to call for more elaborate and expensive construction. The "construction expense index," is our measure of the elaborateness or expensiveness of construction the community is likely to have demanded.

We based our estimate of "construction expense index" on our derived "area index,"[1] but we felt the construction expense index is not likely to increase as rapidly as the "area index." In order not to overestimate variation in construction standard, we set the increase

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[1]Since construction costs per square foot are of the order of $14 per square foot and equipment costs are but of the order of $1 per square foot (for secondary schools) we felt that the area index rather than the equipment index gives a much better indication of the construction expense one would expect to find in the school. The meaning of the equipment index is further questionable because of the uncertainty of whether equipment has been bought just for the new school, or in a large lot. Equipment can be moved from an existing school to the new one or supplied in part after the new school is opened.

in the construction expense index at about one-half the increase in the area index. Our estimates for elementary and secondary schools are shown in Table 24.

The reciprocal of the construction expense index (the economies of scale index) given in Table 24 is the basis for a curve which describes the variation in cost per square foot for schools of comparable construction standard as total area increases. This was set up with 100 corresponding to the cost of the roughly median-sized building described by our data.

From the range of costs per square foot, we chose the median and considered it the cost of the (roughly) median sized building. From the same range of costs we picked cost levels to correspond to high and low levels of construction expense. All costs were brought up to 1954 levels by applying the Engineering News-Record Building Index. The same economies of scale curve was applied at all three expense levels. The resulting cost data are presented in Table 27A and 28A. They are the basis of School Cost Chart 2 (Chart S-2).

TABLE 24

SCHOOL EQUIPMENT INDEX, AREA INDEX,

AND CONSTRUCTION QUALITY INDEX

Elementary Schools	10,000 Square Feet	20,000 Square Feet	60,000 Square Feet
Equipment Index	100		450
Sq. Ft./Pupil Index (Area Index)	100		180
Construction Expense Index	100	109	136
Construction Expense Index (100 corresponding to quality levelfor median size school)	91.8	100	125
Reciprocal of Construction Expense Index of "Economies of Scale" Factor	1.08	1	0.80

Secondary Schools	20,000 Square Feet	100,000 Square Feet	180,000 Square Feet
Equipment Index	100		300
Sq. Ft./Pupil Index (Area Index)	100		170
Construction Expense Index	100	120	133
Construction Expense Index (100 corresponding to quality level of median size school)	83.4	100	111
Reciprocal of Construction Expense Index of "Economies of Scale" Factor	1.2	1	0.90

Source: Elementary Schools--derived from cost data of schools built in Connecticut 1948-1950, published in Connecticut Builds Schools. Connecticut School Building Commission, 1950.

Secondary School--derived from unpublished data furnished by the Massachusetts State School Building Assistance Commission.

It is interesting to compare Schussheim's school cost data with ours. He separates school cost into a fixed cost for the central plant of the school and a variable cost depending on the number of pupils.

TABLE 25

CAPITAL COSTS OF SCHOOLS PRESENTED BY SCHUSSHEIM IN RESIDENTIAL DEVELOPMENT AND MUNICIPAL SERVICE COSTS

	Cost of Central Plant	Variable Costs
Elementary Schools		
Natick	$115,000	40-45 pupils
Wayland	115,000	$33,300 per elementary classroom 25-30 pupils
Newton	115,000	$35,000 per kindergarten classroom 25-30 pupils
Junior High Schools		
Natick	290,000	$ 1,684 per pupil station
Wayland	Included in Variable Costs	2,700 per pupil station
Newton	290,000	45,000 per classroom (25-30 pupils)
Senior High Schools		
Natick	375,000	2,175 per pupil station
Wayland	Included in Variable Costs	2,700 per pupil station
Newton	375,000	2,175 per pupil station

Source: Schussheim, op. cit., Appendix Tables A-C, pp. 333-336.

In order to compare Schussheim's costs with ours it is necessary to bring them both to a per pupil basis. (It is not possible to bring Schussheim's data to a per square foot basis.) Table 26 shows costs from the two studies on a per pupil basis. Schussheim's data shows far greater economies of scale than does ours. His costs for various towns differ. He does not explain fully whether this implies a difference in product or whether the cost range among the three towns represents the range one would expect among many towns.

TABLE 26

COMPARISON OF PER PUPIL JUNIOR HIGH SCHOOL CAPITAL COSTS USED IN SCHUSSHEIM'S STUDY WITH THOSE USED IN THIS STUDY

	SCHUSSHEIM STUDY			THIS STUDY		
				Standard of Service		
Number of Pupils	Natick	Wayland	Newton	Low	Medium	High
100	$4,584	$2,320	$4,530	$1,990	$2,320	$2,660
200	3,130	2,320	3,080	1,990	2,160	2,540
300	2,650	2,320	2,600	1,880	2,180	2,460
500	2,260	2,320	2,210	1,790	2,050	2,310

Source: Schussheim costs computed from data in Schussheim /18 /; Tables A-C, Appendix. "This Study" costs computed from median construction expense curve, Chart S-2 Secondary Schools.

2. Total Equipment Cost

The school planner can provide various standards of equipment in a new school. Does the cost per square foot of providing a given quality of equipment vary with the total area of the school to be equipped?

From elementary school data and then from secondary school data, we plotted equipment costs per square foot against total area and fitted a curve to the data. We found that equipment costs per square foot increase with total area and in fact increase faster than does area per pupil.

We have no direct way of determining how much of the increase is due to a higher standard of equipment provided in the larger schools. However, we do know that the larger schools usually provide more area per pupil. It could be argued that a community which spends money on a more spatious school than average will also purchase more and better equipment than average. Following this assumption that the area index is a rough measure of the quality of equipment provided, we adjusted the curves representing equipment costs by dividing them point by point by the area index for various sizes of school. The equipment cost per square foot curves still showed an increase with increase in total area. We do not conclude that the resulting curves represent constant standards of equipment, for it is our experience that there are certainly not diseconomies of scale in providing equipment. On the contrary we expect

some economies. Therefore, we do not use area index as a measure of standard of equipment. Instead, we make the conservative estimate that the cost index per foot for a constant standard of equipment drops from 110 when a small 20,000 square foot school is to be equipped to 95 when a large school of 180,000 square feet is to be equipped. This same equipment economy of scale index is assumed to apply to both elementary and secondary schools. Note that with this assumption equipment cost per square foot drops only by about 15 per cent as we go from a very small school to a very large one.

From the equipment cost data of Connecticut elementary schools and Massachusetts secondary schools, we picked high, medium, and low cost levels and brought them up to 1954 price levels by applying the Bureau of Labor Statistics Commercial Furniture price index. These high, medium, and low cost levels correspond to the cost of high, medium, and low standards of equipment. We took these cost levels to apply to the roughly median sized schools, and by using our "equipment economy of scale index" we derived the equipment cost per square foot data of Table 27B and 28B. Charts S-3 also present this data.

b. Total Yearly Capital Cost

The capital cost of a school is not paid off all at once by a community but is spread out (theoretically) over the life of the school. We assume that this is paid as a constant annual depreciation charge and a

constant annual interest charge. The reasons for doing this on a constant annual basis are the same as those discussed in the section on road costs. Maintenance costs should in theory and do in fact increase with the age of the building. We also will consider maintenance costs constant over the life of the building. This serves to balance our bias in interest charges.

We estimate the average life of a school building to be 50 years, and estimate that at the end of that time 20 per cent of the building's value remains and can be utilized if extensive modernization and refurnishing is carried out.[1] We calculated the annual depreciation cost of the school building as follows:

$$\text{annual depreciation cost} = \frac{\text{(replacement value) minus (value at end of life)}}{\text{50 years}}$$

The annual depreciation cost per square foot varies with total area just as the total capital cost per square foot does.

Annual depreciation cost of equipment was calculated on the assumption that equipment depreciates to zero value in 25 years. Yearly depreciation cost was first calculated separately for the building and equipment. Total yearly depreciation cost per square foot (including that of both building and equipment) is presented in Table 27C and 28C and Chart S-4.

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[1] Estimates in line with our judgment were given by W. Muldowney, Building Superintendent of the Brookline School System, who estimated from studies he is now doing of replacement or remodeling of old schools that the average life of a school is 50 years and that at that time generally less than ¾ of its value remains.

We computed annual interest cost separately on the value of the building at half life and on the value of the equipment at half life. We used an interest rate of $2\frac{1}{4}$ per cent as we did for roads. The total yearly interest costs per square foot (including that of both building and equipment), are presented in Table 27D and 28D and in Chart S-5. Total yearly capital cost is the sum of depreciation cost and interest cost, but in order to keep explicit the effect of the interest rate, we have not combined these costs into one curve.

School capital costs which wewill use in the cost estimates of our theoretical models are derived from School Cost Charts S-4 and S-5.

TABLE 27

CAPITAL COSTS PER SQUARE FOOT OF SECONDARY SCHOOLS

ACCORDING TO SIZE OF SCHOOL

(1954 Prices)

	20,000 sq. ft.	100,000 sq. ft.	180,000 sq. ft.
A. Total Construction Cost Per Sq. Ft. (Construction Economy of Scale Index)	(120)	(100)	(90)
at high standard	$18.00	$15.00	$13.50
at medium standard	16.80	14.00	12.60
at low standard	15.60	13.00	11.70
B. Total Equipment Cost Per Sq. Ft. (Equipment Economy of Scale Index)	(110)	(100)	(95)
at high standard	2.09	1.90	1.80
at medium standard	1.76	1.60	1.52
at low standard	1.10	1.00	.95
C. Total Yearly Depreciation Cost Per Sq. Ft. (Including both Construction and Equipment)			
at high standard	.372	.316	.288
at medium standard	.339	.288	.263
at low standard	.294	.248	.225
D. Total Yearly Interest Cost Per Sq. Ft. (On both Construction and Equipment @2¼ per cent)			
at high standard	.264	.222	.201
at medium standard	.248	.207	.187
at low standard	.222	.186	.167

Source: Derived from unpublished data furnished by the Massachusetts State School Building Assistance Commission.

TABLE 28

CAPITAL COSTS PER SQUARE FOOT OF ELEMENTARY SCHOOLS

ACCORDING TO SIZE OF SCHOOL

(1954 Prices)

	10,000 sq. ft.	20,000 sq. ft.	60,000 sq. ft.
A. Total Construction Cost Per Sq. Ft. (Construction Economy of Scale Index)	(108)	(100)	(80)
at high standard	$21.60	$20.00	$16.00
at medium standard	18.30	16.90	13.50
at low standard	14.90	13.80	11.00
B. Total Equipment Cost Per Sq. Ft. (Equipment Economy of Scale Index)	(102)	(100)	(95.5)
at high standard	1.45	1.42	1.36
at medium standard	.92	.90	.86
at low standard	.40	.39	.37
C. Total Yearly Depreciation Cost Per Sq. Ft. (Including both Construction and Equipment)			
at high standard	.404	.377	.312
at medium standard	.329	.307	.251
at low standard	.253	.236	.191
D. Total Yearly Interest Cost Per Sq. Ft. (On both Construction and Equipment at 2¼ per cent)			
at high standard	.304	.286	.231
at medium standard	.256	.238	.193
at low standard	.205	.190	.153

Source: Derived from cost data of schools built in Connecticut 1948-50 published in Connecticut Builds Schools, Connecticut School Building Commission 1950.

c. Yearly Noncapital Cost for Secondary Schools

In constrast with the few studies that have been made of school capital costs, many studies have been made of current costs.[1] The conclusion is firm in all of these studies that substantial economies of scale are realized in the current costs of schools.

The inefficiency of very small school districts was recognized in the early 30's and their reorganization became an issue. A pioneering but unsophisticated study by W. A. Gaumnitz /35/ made it evident that for schools of less than 70-80 pupils, costs rise steeply.

Soon studies of costs in larger school units (characteristic of urban rather than rural places) were made. In 1931, S. P. Nanniga /48/ found that current cost per high school pupil declines up to an enrollment of 500-600 pupils, and then remains constant in high schools of 600-1,000 pupils. In 1934, H. A. Dawson /32/ made a study which showed that substantial savings in current costs per pupil are made in large schools. He concluded that (in elementary schools) "the cost per pupil tends to decrease rather rapidly up to an enrollment of 100 pupils and to a less marked degree to 200 pupils. In high schools, cost per pupil decreases rapidly up to 200 pupils and continues to decrease but not so rapidly up to 500 pupils." This finding was still considered valid by the National

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[1] We use the term current costs to include all noncapital costs: costs of instruction (salaries and supplies), costs of administration (salaries and supplies), general operating costs (utilities, fuel, custodian's salary), costs of routine maintenance (salaries and supplies).

Committee on School District Reorganization /49/ in 1948. H. A. Little /42/ found that the cost per pupil declined rapidly until an enrollment of 200-300 was reached. The Washington State Planning Council /57/ p. 57 found a decline in per pupil cost up to an enrollment of 1,500. Brewton /29/ found that per pupil cost was considerably less in larger schools even when the cost for pupil transportation was included.

Most of these studies considered only the total cost of instruction or teachers' salaries. Total current costs also include the cost of janitorial service, utilities, and clerical service. One would expect that these costs per pupil would decrease considerably in larger schools. If the studies had included them, the economies of scale found might well have been even larger.

These studies did not take into consideration the relative quality of education obtained in the schools they studied. However, other studies have shown a definite increase in quality of education with increase in size of school.[1] Pupils in large schools, in general, are actually getting more education service than those in small schools. So once again, these size-cost studies have underestimated the economies of scale achieved by larger schools.

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[1]Every major study of school district reorganization agrees on the effect of size of school on per pupil cost and on educational opportunities available to the pupil. See Dawson /32/ p. 30, Shannon /55/ p. 28, Illinois Legislative Council /39/, Fowlkes /34/ p. 8, Georgia State Department of Education /36/ p. 9, Seyfert /54/ p. 232, Pillsbury /51/ p.14, Grace and Moe /37/.

A 1946 New Hampshire Study /50/ p. 55-63 showed that in secondary schools expenditures per pupil decreased rapidly as size increased up to a size of 200-300 pupils. For larger schools, expenditure rose slowly. The number of services provided increased rapidly as school size increased from a few pupils up to 100-150 pupils. For the larger schools considered, the number of services provided continued to increase with size but at a slightly slower rate. Schools of over 76 pupils always provided more services than those of less than 76 pupils for the same expenditure. For large expenditures the increase in services for small schools was much less than for large schools. Similar results were found for elementary schools where per pupil expenditures decreased until a size of 220-230 pupils was reached.

The Division of Research and Field Studies, Indiana University /40/ made a study of how current per pupil expenditures in Indiana high schools varied with size. Costs in this study were more complete. They included the costs of administration, instruction, coordinate activities, operation, maintenance, fixed costs and auxiliary activities. Excluded were costs of transportation, transfer tuition payments to other school corporations and lease-rental payments to school building holding corporations. The large high schools studied (those of greater than 200 enrollment) all had first-class commissions, so even though it is known that some of the larger schools in this group presented a wider educational offering, no extremely low variations in educational product distort the results of the

study. Decrease in cost per pupil with increase in size of school enrollment was found in these schools. (See Column 1, Table 29)

Data was also given for smaller schools, but it was pointed out that many of these schools were of inferior quality and that they should not be compared with the larger high schools. However, although their quality was worse, per pupil expenditures for these schools were higher than for the larger, better schools and the expenditure decreased as the size of school increased. (See Column 1, Table 29). We were unable to check these economies of scale against Massachusetts experience since there is no certification of high schools in Massachusetts, and as far as we know, there exists no independent evaluation of their educational offerings.[1] However, there is no reason to believe that Massachusetts high schools do not experience the same economies of scale as do the high schools of other states.

Therefore, our assumptions of economies of scale in school operating costs are based on the Indiana data. Judgment of the variation in

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[1] When, for Massachusetts data, current expenses per pupil were plotted against size of school no correlation was evident. In an attempt to determine the quality of Massachusetts High Schools, we made the admittedly shaky assumption that the first term records of Freshmen at MIT are a measure of the quality of the high schools from which they came. First term averages of MIT Freshmen from each high school were ranked, from them an index was constructed and the current expenses per pupil for each high school were divided by the school's index. If the indexes describe the quality of their schools, the resulting expense per pupil should represent the expense which would have been incurred had each school provided an equal educational service. These expenses per pupil were plotted against size of school. Again no correlation was evident. Until some better evaluation of the variation in quality of Massachusetts high schools is made, it is impossible to determine directly the effect of size on operating costs in Massachusetts high schools.

standard of service with size of Indiana high schools was made based on the qualitative evaluations in the Indiana report (see column 3 of Table 29). The cost index (column 2 Table 29) was divided by the standard of service index. The result is the cost index for equal level of education service (column 4 Table 29).[1]

After this determination of the cost index for equal educational service had been completed, we had the opportunity to examine the unpublished doctoral dissertation of W. J. Woodham, Jr. /59/. His study, done at the University of Florida in 1951 and based on Florida data, investigated "The Relationship between the Size of Secondary Schools, the Per Pupil Cost, and the Breadth of Educational Opportunity." This very important study is the first attempt to apply an objective measure of educational opportunity and then study how cost per pupil for unit educational

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[1] It is possible that the pupil cannot take full advantage of the increased level of education service offered by the larger school for, as psychologists remind us, a child finds it difficult to make social adjustments to a large group.

The set of psychological considerations affecting the education of the child lies outside the scope of this study, but arguments based on it may be of enough importance so that educators would feel justified in incurring larger costs in smaller schools in which the school child can make more happy social adjustment. The importance of small size and social adjustment might be considered especially important for the elementary school child. However, as seen in column 4, Table 29, although there is a sizeable difference in cost between very large and very small schools, it is only when school size is reduced considerably below 200 that costs mount rapidly. For larger schools, size can be varied considerably with only a small change in costs.

opportunity varies with size of school.[1] His results show that for the same educational offering, the larger schools show far greater economies in operation than they do when costs have not been corrected for variation in breadth of educational offering. An index of the expenditure per pupil per unit of educational opportunity (columns 6 and 8, Table 29) was computed from Woodham's data (columns 5 and 7, Table 29) so that his findings could be compared with our findings based on Indiana data. Woodham's data show far greater economies of scale than do our data.

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[1]Woodham points out that the quality of a school program is not determined directly by the breadth of offering but by the training of the teachers. However, he argues, additional subjects are not usually added because there is available a teacher who can teach them. Rather, qualified teachers are employed on the basis of a previously adopted program.

TABLE 29

ECONOMIES OF SCALE IN CURRENT COSTS OF SECONDARY SCHOOLS

FROM DATA OF INDIANA STUDY AND FROM DATA OF WOODHAM'S STUDY

	FROM DATA OF INDIANA STUDY[1]				FROM DATA OF WOODHAM'S FLORIDA STUDY[4]			
	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8
					3 & 4 Year High School		6-Year High School	
Number of Pupils	Median Current Expenditure Per Pupil	Cost Index	Assumed Standard of Service Index[2]	Cost Index for Equal Service[3]	Actual Expenditure	Index	Actual Expenditure	Index
1 - 49	$392	1.46	80	180	No data		$8.07	343
50 - 99	358							
100 - 149	375							
150 - 199	272							
200 - 299	280	1.12	90	124	$4.75	150	3.68	157
300 - 399	271							
400 - 499	245	98.5						
500 - 999	249	100	100	100	3.15	100	2.35	100
1,000 - over	242	97.3	110					

[1] Indiana University, Division of Research and Field Studies, "Analysis of Current Expenditure of Selected Indiana High Schools." Indiana University School of Education Bulletin. 30:1-28 My 1954.

[2] Based on statement in study that many of schools smaller than 200 enrollment were inferior and should not be compared with schools of greater than 200 enrollment all of which had first-class commissions and many of the larger of which were known to present exceptionally wide educational opportunities.

[3] Derived by dividing Cost Index by Assumed Quality Index.

[4] Woodham, W. J. Jr., The Relationship between the Size of Secondary Schools, the Per Pupil Cost, and the Breadth of Educational Opportunity. Unpublished Doctoral Thesis, University of Florida, 1951.

Expenditure and Quality of Education

In schools of a given size, what is the relationship between the quality of education provided and the cost per pupil? What returns can be expected if more is spent per pupil? This general question has concerned school administrators and has prompted several studies. It is indeed difficult to judge the effect on pupils of the education service provided. Instead of trying to judge the ultimate effect on the pupil, these studies have related the number and type of services provided to the amount spent per pupil. All the studies which we examined showed that when one spends more one gets more.

In his 1933 analysis, Mort /47/ pp. 76-112 separated New York elementary school districts into groups with high, median, and low cost per pupil. He found that many services increase when expenditure is increased. Health, library, and dental services become progressively better. When more money is spent for clerical help, the superintendent can spend more time on the improvement of instruction. Teachers' salaries (and presumably their abilities also) increase when expenditure per pupil increases. No low expenditure level districts provided special classes for children of low ability; but 15 per cent of median expenditure level districts and 45 per cent of high level districts did provide them. High level districts provided special teachers or supervisors in art, music, manual training, home visitation, remedial work, physical education, sewing and nature study. In low level districts special teachers or

supervisors were found only in music. Intelligence and achievement tests were found in 40 per cent more high level districts than median level districts. They were found in no low level districts. In low level districts the curriculum slavishly followed the state courses of study. Sixty-nine per cent of median level districts supplemented the state courses of study. The high level districts often had specially prepared courses developed by the teachers themselves. Mort found similar relations in junior and senior high schools, but he found that low expenditure level schools managed to equal median level schools in scores on teaching methods and techniques, directed or supervised study, and extra curricular activities.

A study with similar procedures and similar findings was carried out by the Maine School Finance Commission in 1934 /44/. Grimm /38/ found that in tests of achievement pupils from low expenditure schools never exceeded pupils from median or high level schools. Those from high level schools were only slightly above those from median level schools. O. E. Powell /52/ showed how expenditures and pupil achievement rose and fell together. Ferrell /33/ turned to a statistical approach to show the correlation between current expenditure per pupil and six measures of educational efficiency. Length of school term, training of teachers, holding power of school gave the highest correlations with per pupil expenditure (coefficients of correlation: 0.79, 0.78, and 0.76

respectively). Experience of teacher, pupil-teacher ratio and per cent of census children in average daily attendance correlated less well.

Wollatt /58/ studied the relationship between expenditure per pupil and "the teaching of basic skills, the teaching of areas of knowledge, the discovery and development of special aptitudes of individuals through test and tryout and the discovery and development of gross behavior patterns like citizenship, character, and thinking." He found a nearly straight line relationship between expenditure per pupil and a school's average scores for these four measures. At higher expenditure levels, increased expenditure does not seem to bring quite as large an improvement in score as it does at lower expenditure levels. Wollatt (p. 65) sums up: "Just as we have seen that there is a general increase in the quality of schools as cost increases, so it is evident that there is a general increase in skills, knowledge fields, special aptitudes, and behavior patterns. In these specific phases there are variations between intermediate critical points of expenditure, but the general picture is one of increasing expenditure accompanied by increasing quality. Spending more to get more is established as an axiom in preparing school budgets."

In choosing our cost levels for different standards of education service, we recognized the general relationship between increase in quality of service and increase in cost. We do not hold that every additional dollar spent will bring a unit increase in the quality of education.

In fact, we recognize that at higher levels, diminishing returns will be experienced. We envisage no formal relationship between our high standard and our low standard of education service (e.g. high standard service is not two or three or n times as good as low standard). With the results of the cost-quality studies in mind, we simply picked typical high median and low levels from recent data.

Note that the standards of service have no absolute meaning outside of the set of data they interpret. They say relative to present high schools in Massachusetts a certain expenditure represents a high standard of service. Relative to present junior high schools in Massachusetts a certain expenditure represents a high standard of service. These two high standards of service are not necessarily equal.

We took cost levels from 1953-1954 Massachusetts current expenditure per pupil data[1] /45/ for junior high schools, senior high schools and high schools in turn. These cost levels are given in Table 30 column 3. To these cost levels we applied the cost index for equal level of education service (an economy of scale index) which we derived from Indiana data. These results are given as Table 30. They form the basis of curve S-6. Values from these curves are used in the cost calculations for our theoretical models.

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[1] Total current expenditure for support including cost of general control.

TABLE 30

TOTAL YEARLY NONCAPITAL COSTS PER PUPIL

FOR SECONDARY SCHOOLS

Number of Pupils	75	250	550	1000
Cost Index for Equal Level of Education Service	(180)	(124)	(100)	(92)
High School (4 years)				
high level of service	$720	$495	$400	$368
medium level of service	585	403	325	299
low level of service	450	310	250	230
Junior High Schools (3 years)				
high level of service	640	440	355	326
medium level of service	485	335	270	248
low level of service	330	230	185	170
Senior High Schools (3 years)				
high level of service	765	527	425	391
medium level of service	620	433	350	322
low level of service	495	340	275	253

This data is also presented as Charts S-6 for the three types of secondary school.

Source: Cost levels for 550 pupil school computed from cost levels taken from Massachusetts data /45/. Economy of Scale index computed from Indiana Study /40/.

d. Yearly Non-capital Cost Per Pupil For Elementary Schools

We were unable to find a conclusive recent study of the variation of non-capital costs with size of elementary school. A study of "The Cost-Size Relationships in Illinois Public Schools "/56/ is nearly as comprehensive but not nearly so conclusive as is the Indiana study for secondary schools. Per capita current costs vary quite widely and on the average actually rise by about 10 per cent as size of school increases to 500. However, the study goes on to state on page 15: "Subjective observation of public elementary schools indicates conclusively that larger schools furnish better physical surroundings and a greater quantity and variety of teaching materials and equipment, pay better salaries, and incur greater 'overhead' costs for administrative and supervisory services than do the small schools. It would seem, therefor, that the larger elementary schools are more efficient educational enterprises, at a per capita cost not appreciably greater than that found in their small contemporaries. Thus, though the data of this section may at first seem inconclusive, further consideration would seem to indicate that larger schools are more economical and more efficient." Therefor, it is not unreasonable to suppose that the cost per unit of educational opportunity or service might well go down with increasing size of school.

A Providence, Rhode Island study /53/ indicates that overhead costs per pupil in elementary school buildings drop substantially as size of school increases from below 150 pupils (where average overhead costs were

$40.90 per pupil) to over 300 pupils (where average overhead costs were $29.90 per pupil).

We felt that while these studies were useful, they were not sufficiently conclusive. Therefor, we studied the current costs for each elementary school in three local school systems: Belmont, Waltham and Cambridge. We assumed that all the schools in any one system offer about the same standard of education service. Officials of the three school systems stated that to the best of their knowledge this is so.

Working from the unpublished financial records of these school systems, we summed all current costs for each school for the fiscal year 1953-1954. Because maintenance costs for a particular school in a particular year are not likely to be typical, we allocated all maintenance costs to schools on a per pupil basis. Costs of special services which were enjoyed by all the schools were also allocated on a per pupil basis (for example, the salaries of school committeemen, superintendent, supervisors, health service, etc.).

Per pupil current costs in Belmont and Waltham schools show a definite decrease with increasing size of school. Per pupil current costs in Cambridge schools showed no trend with size of school. Table 31A summarizes the Belmont and Waltham data.

The Belmont data shows that current cost per pupil in a 200-pupil school is roughly 1.27 times that in a 700-pupil school. In Waltham schools the cost in a 200-pupil school is roughly 1.18 times that in a

700-pupil school. From these two sets of data and the general conclusions of the Illinois and Providence studies we estimate conservatively that in general the current cost per pupil in a 200-pupil school is 1.20 times that in a 700-pupil school which provides the same level of education service. The economy of scale index, then, drops from 120 to 100 as size of school increases from 200 to 700 pupils.

With the results of published cost-quality studies in mind, we examined the current costs per pupil in all Massachusetts public elementary school systems. From the range of costs we picked high, median and low cost levels to correspond with high, median and low levels of education service. To these cost levels we applied our economy of scale index. The resulting price levels are presented in Table 31. They are the basis for the curves of Chart S-6. Values from these curves are used in the cost calculations for our theoretical models.

TABLE 30A

NONCAPITAL COSTS PER PUPIL IN BELMONT AND WALTHAM ELEMENTARY SCHOOLS DURING SCHOOL YEAR 1953-1954

Belmont		Waltham	
Size School (pupils ADA[1])	Total Current Expenditures/per pupil	Size School (pupils ADA)	Total Current Expenditures/per Pupil
501	$241	1,085	$207
488	267	616	149
470	236	551	203
380	267	493	206
342	290	340	192
176	281	308	194
		304	176
		298	244
		288	248
		260	238

[1]ADA = Average Daily Attendance

Source: Computed from data furnished by Belmont and Waltham School Superintendents.

TABLE 31

TOTAL YEARLY NONCAPITAL COSTS PER PUPIL FOR ELEMENTARY SCHOOLS

	School of 200 Pupils (Economy of Scale Index = 120)	School of 700 Pupils (Economy of Scale Index = 100)
Grade 1-6 Schools		
High level of service	$306	$255
Medium level of service	252	210
Low level of service	198	165
Grade 1-8 Schools		
High level of service	355	280
Medium level of service	264	220
Low level of service	192	160

Source: Cost levels for 700 pupil school computed from cost levels taken from Massachusetts data /45/. Economy of scale index computed from our studies of Newton and Waltham schools.

e. Size of School System

We are not concerned with the total size of the school system in this study, but it is interesting to note that school administration authorities agree that a rather large minimum school population is necessary if a school system with high level of service is to operate efficiently.

Dawson /32/ p. 51-55 sets up a list of special functions which good school systems should perform. If 12,000 pupils are under instruction a staff of 31 can perform all the special functions effectively. There will be no need for any one individual to perform two or more special services. If the student body is but 6,000, a median downward revision of the standard organization is necessary. By doubling up on duties a staff of forteen could perform most of the special duties listed. It would require a maximum modification of organization to serve a student body of 1,750 pupils. Four persons would be necessary to perform the minimum special services necessary. The National Committee on School District Reorganization /49/ p. 87 follows Dawson's conclusions with slight modifications.

f. School Costs Summary Charts

The school cost data which we will use in the cost calculations for our models are summarized as a set of curves or cost functions. Six basic charts are presented for elementary schools and secondary schools.

1. Chart S-1 is used to determine the total area of school required, given the number of pupils to be planned for and the desired general level of service expressed in square feet per pupil.

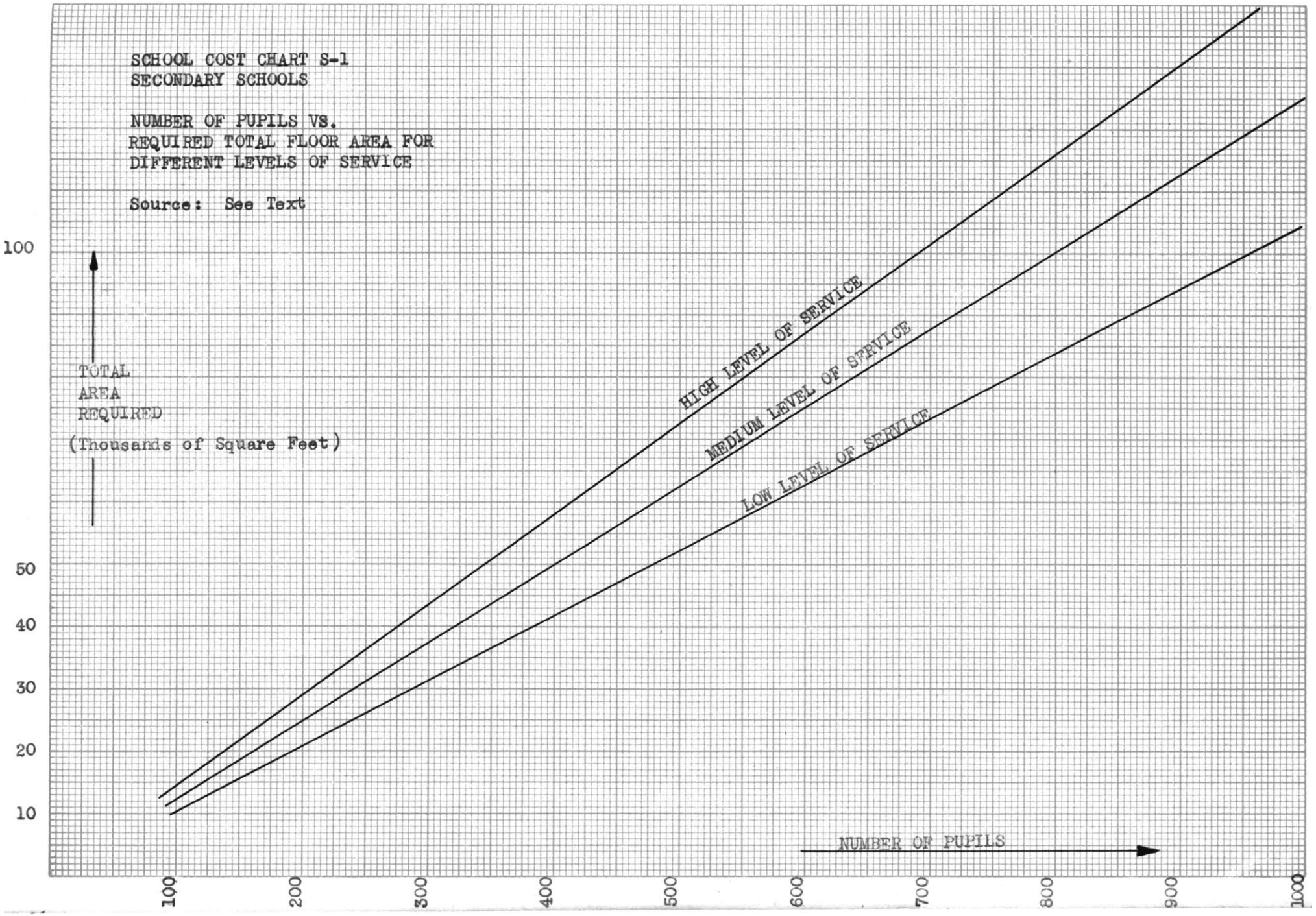
2. Chart S-2 is used to determine the construction cost per square foot, given the total area (in square feet) to be constructed and the desired standard of construction (high, medium, or low).

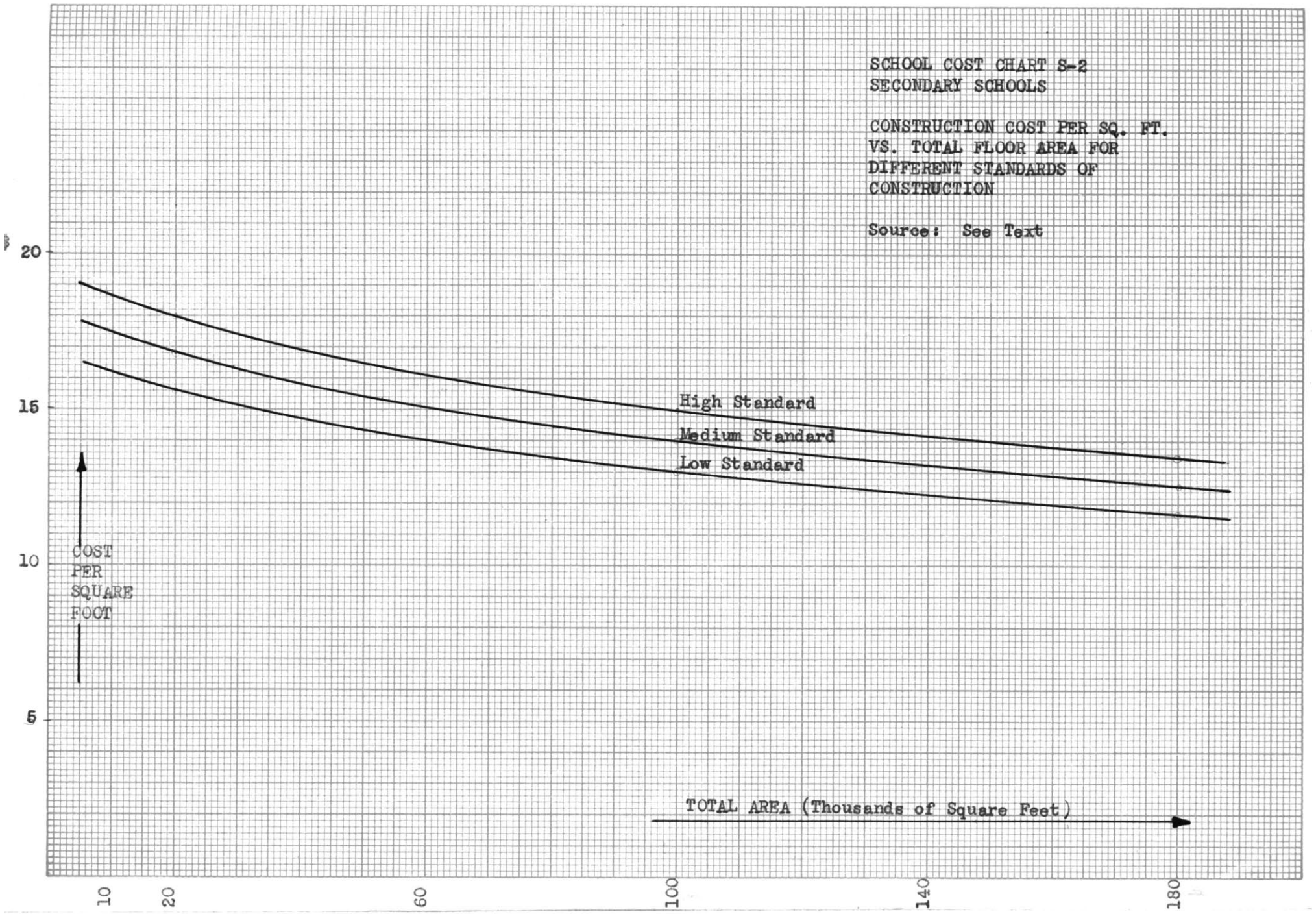
3. Chart S-3 is used to determine the equipment cost per square foot, given the total area (in square feet) of the building to be equipped and the desired standard of equipment (high, medium, or low).

4. Chart S-4 is used to determine the yearly depreciation cost per square foot of building and equipment given the total area of the building and the standard of construction and equipment (high, medium, or low). The assumption is made that high standard of construction is always found with high standard of equipment; medium with medium, low with low.

5. Chart S-5 is used to determine the yearly interest cost per square foot of building and equipment given the total area of the building and the standard of construction and equipment. The curves presented are based on an interest rate of $2\frac{1}{4}$ per cent.

6. Chart S-6 is used to determine the total yearly noncapital expenditures per pupil given the number of pupils in the school and the level of educational service offered (high, medium, or low).

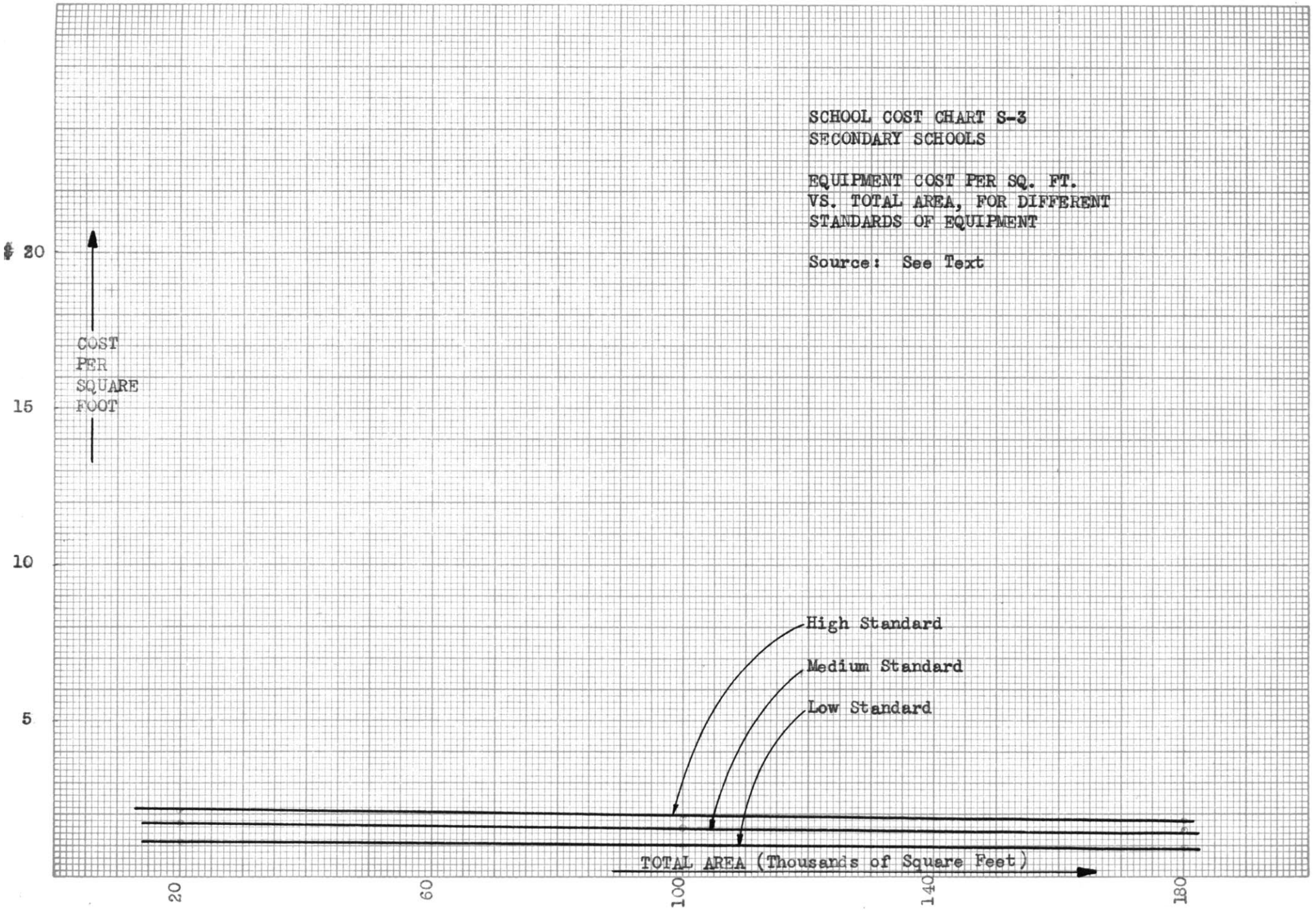

SCHOOL COST CHART S-1
SECONDARY SCHOOLS
NUMBER OF PUPILS VS.
REQUIRED TOTAL FLOOR AREA FOR
DIFFERENT LEVELS OF SERVICE
Source: See Text
100
TOTAL
AREA
REQUIRED
(Thousands of Square Feet)
50
40
30
20
10
HIGH LEVEL OF SERVICE
MEDIUM LEVEL OF SERVICE
LOW LEVEL OF SERVICE
NUMBER OF PUPILS
100
200
300
400
500
600
700
800
900
1000

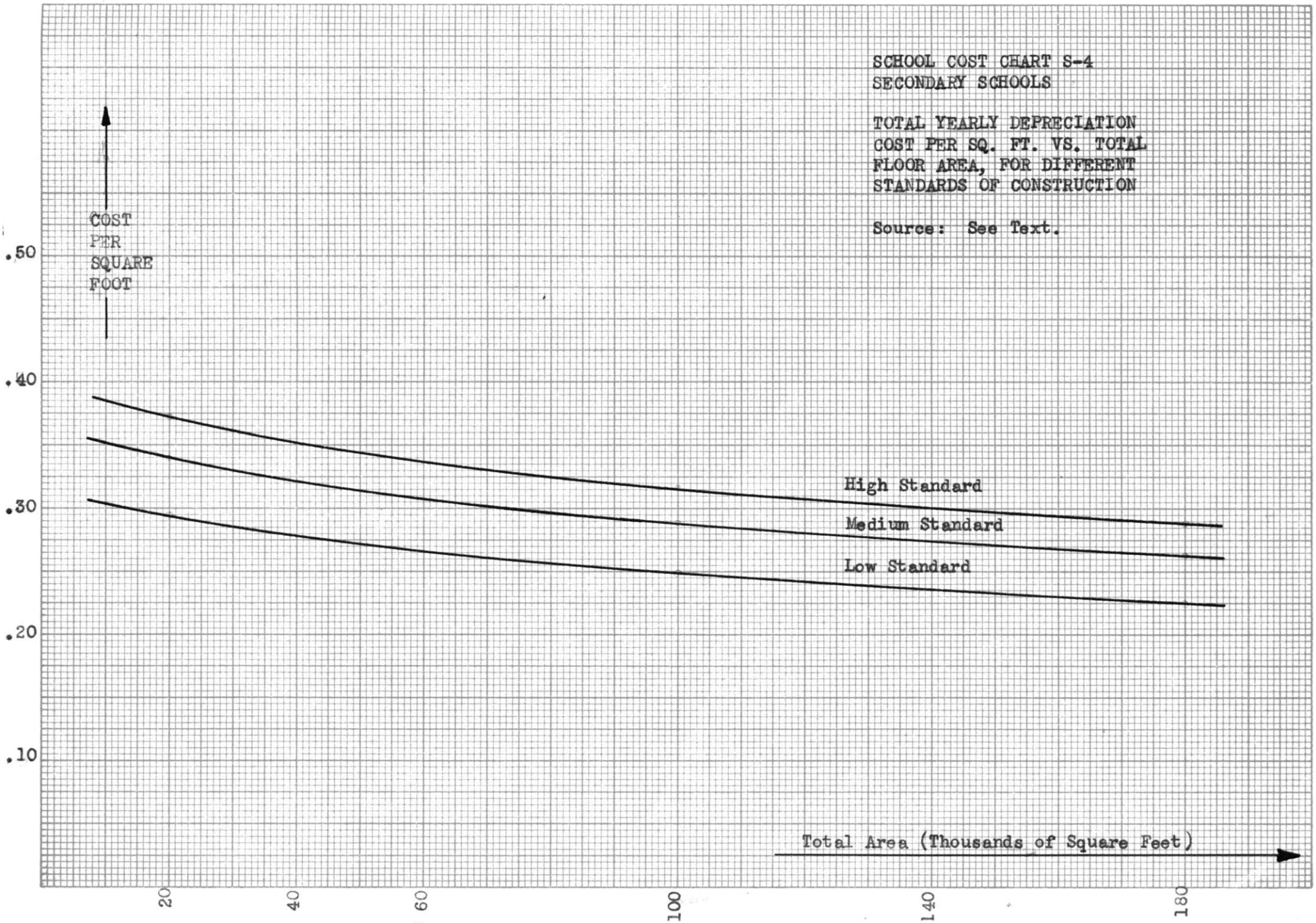

SCHOOL COST CHART S-2
SECONDARY SCHOOLS
CONSTRUCTION COST PER SQ. FT. VS. TOTAL FLOOR AREA FOR DIFFERENT STANDARDS OF CONSTRUCTION
Source: See Text
20
15
10
5
COST PER SQUARE FOOT
High Standard
Medium Standard
Low Standard
TOTAL AREA (Thousands of Square Feet)
10
20
60
100
140
180

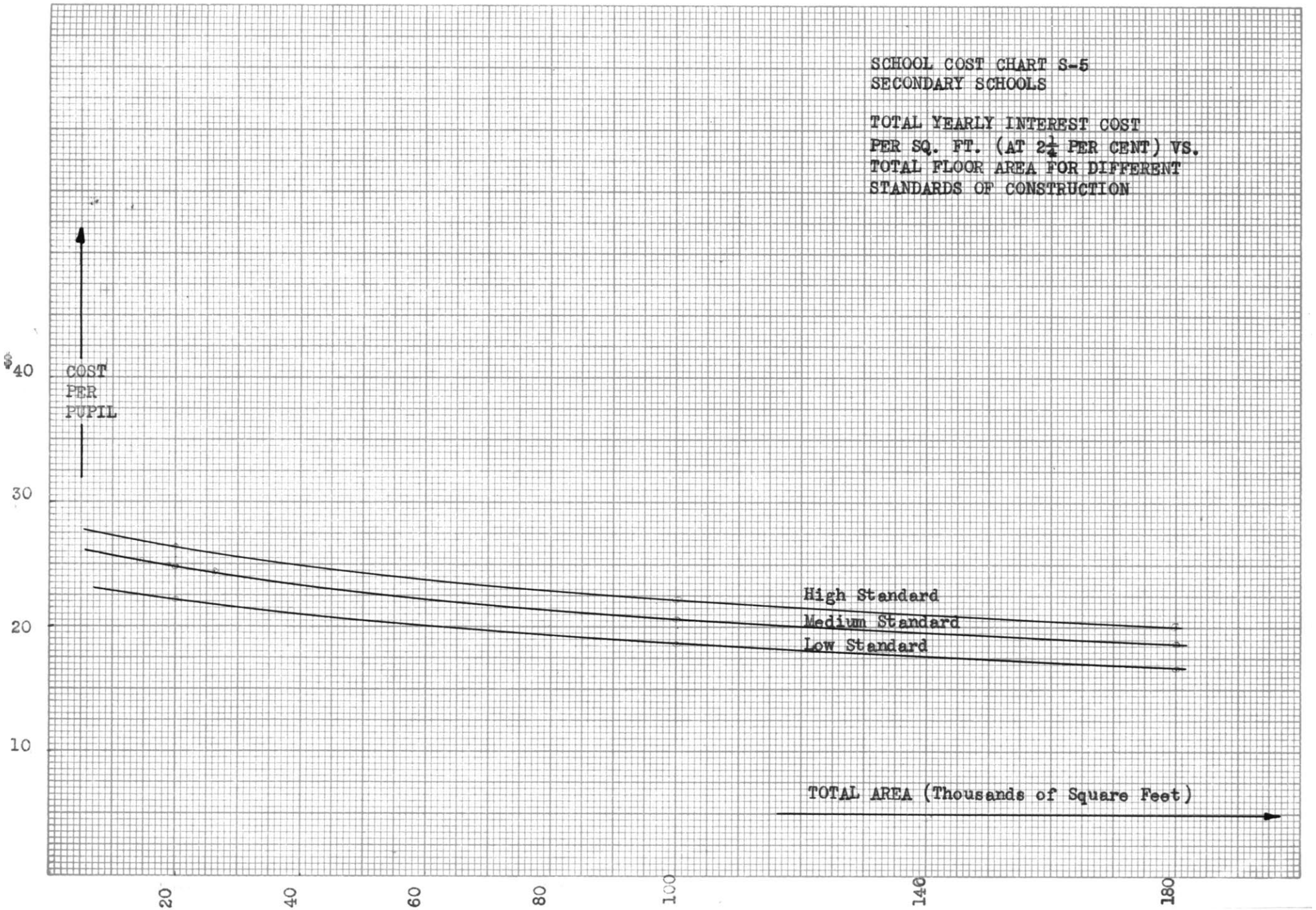
SCHOOL COST CHART S-3
SECONDARY SCHOOLS

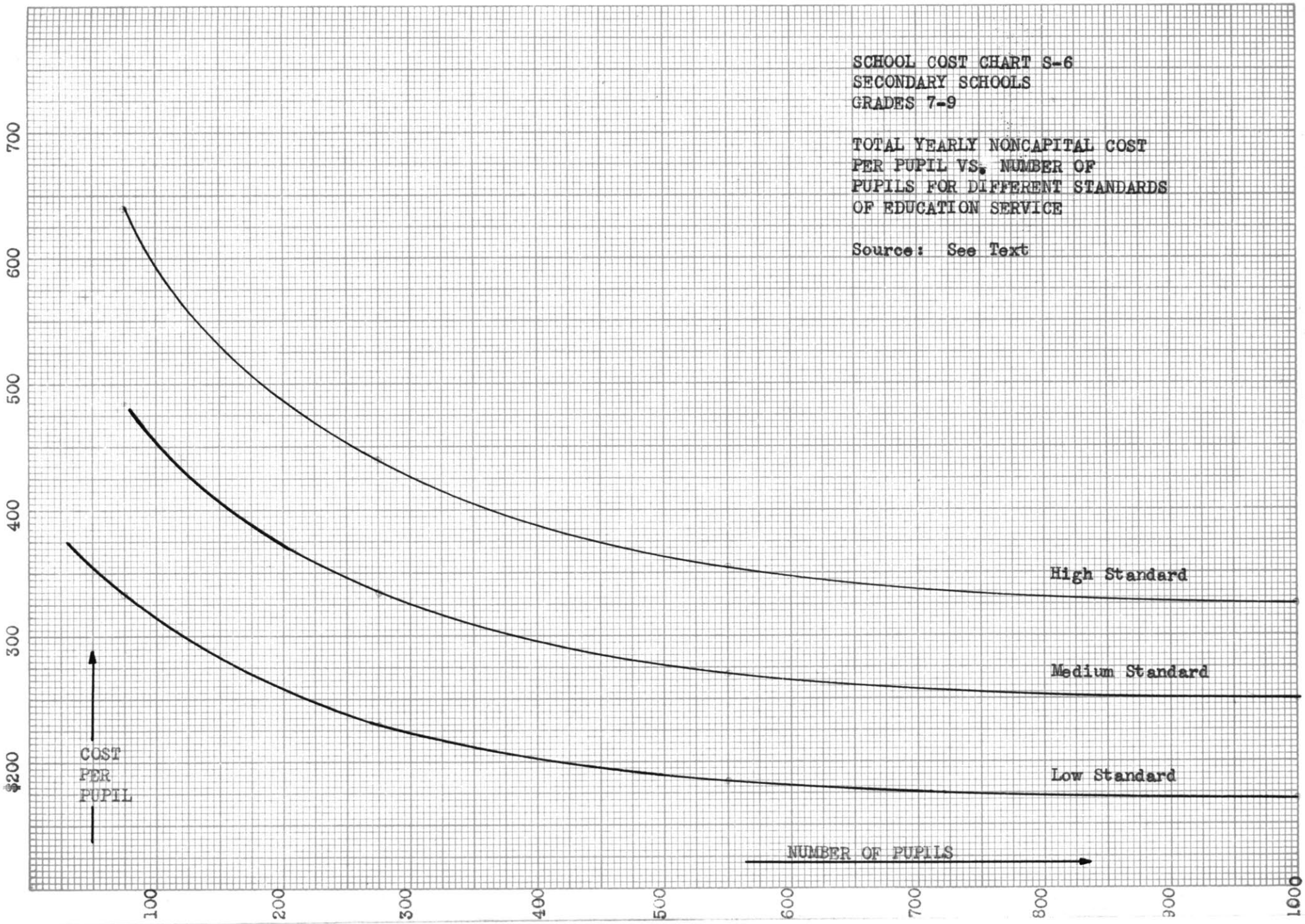
EQUIPMENT COST PER SQ. FT.
VS. TOTAL AREA, FOR DIFFERENT
STANDARDS OF EQUIPMENT

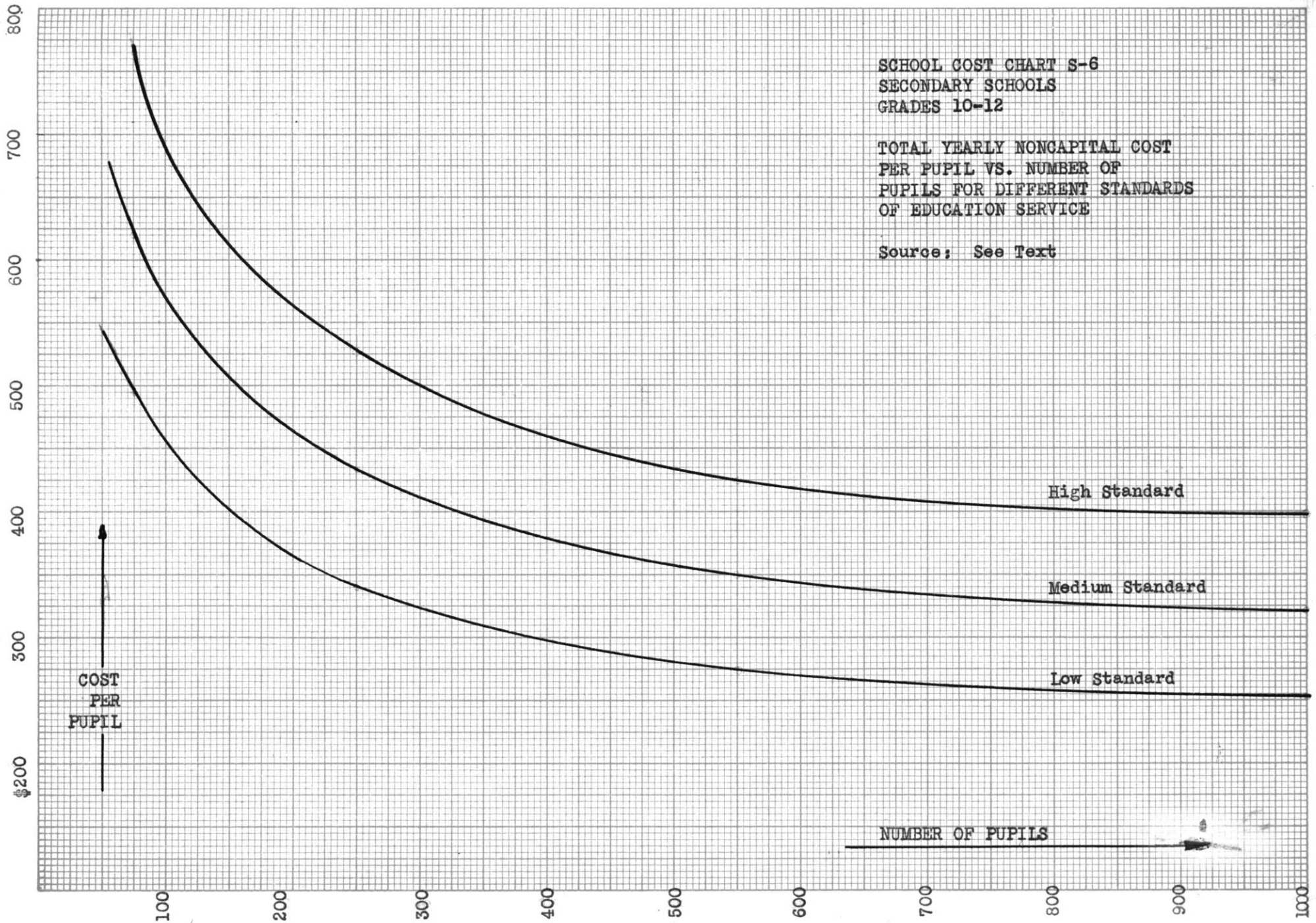
Source: See Text

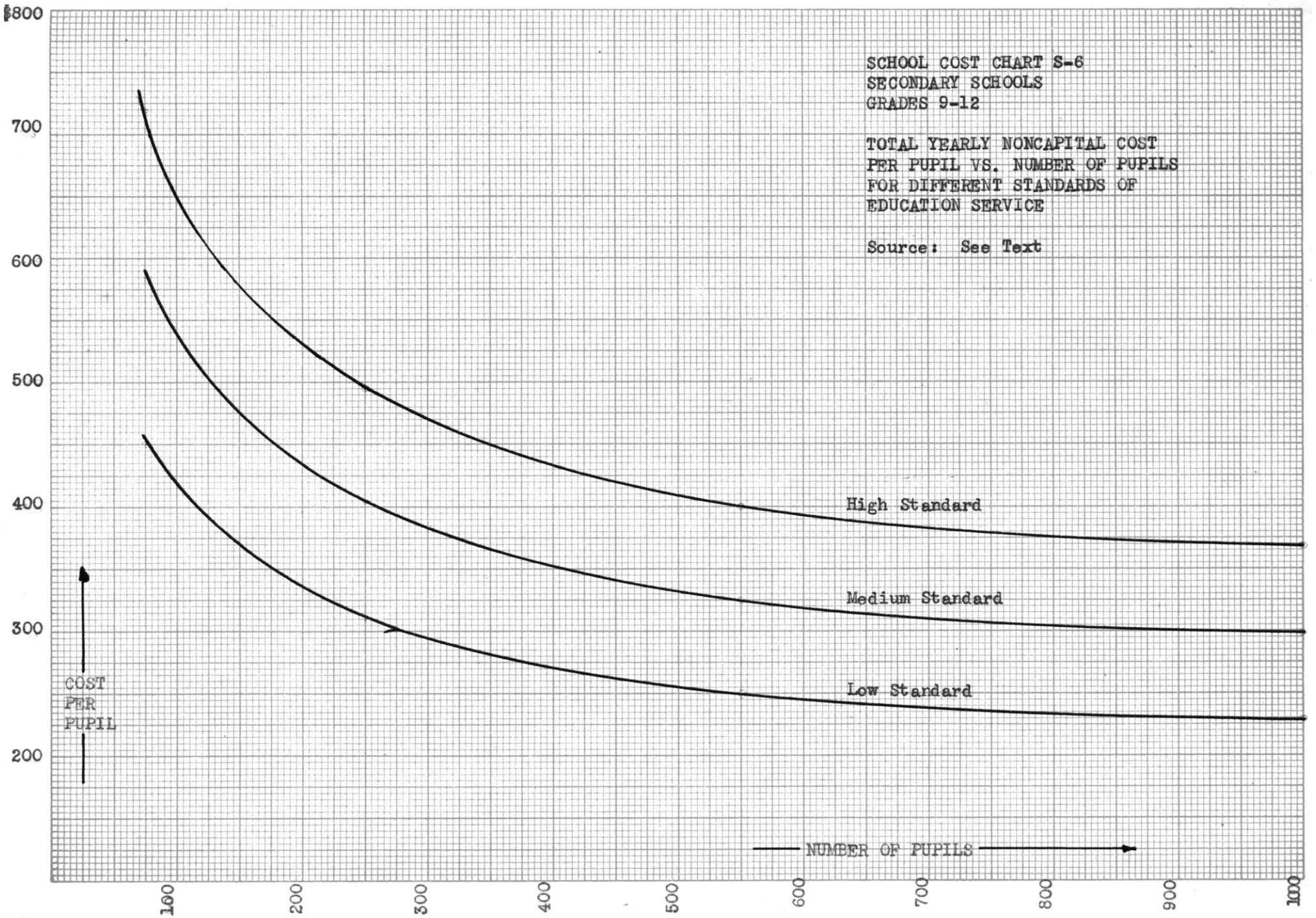


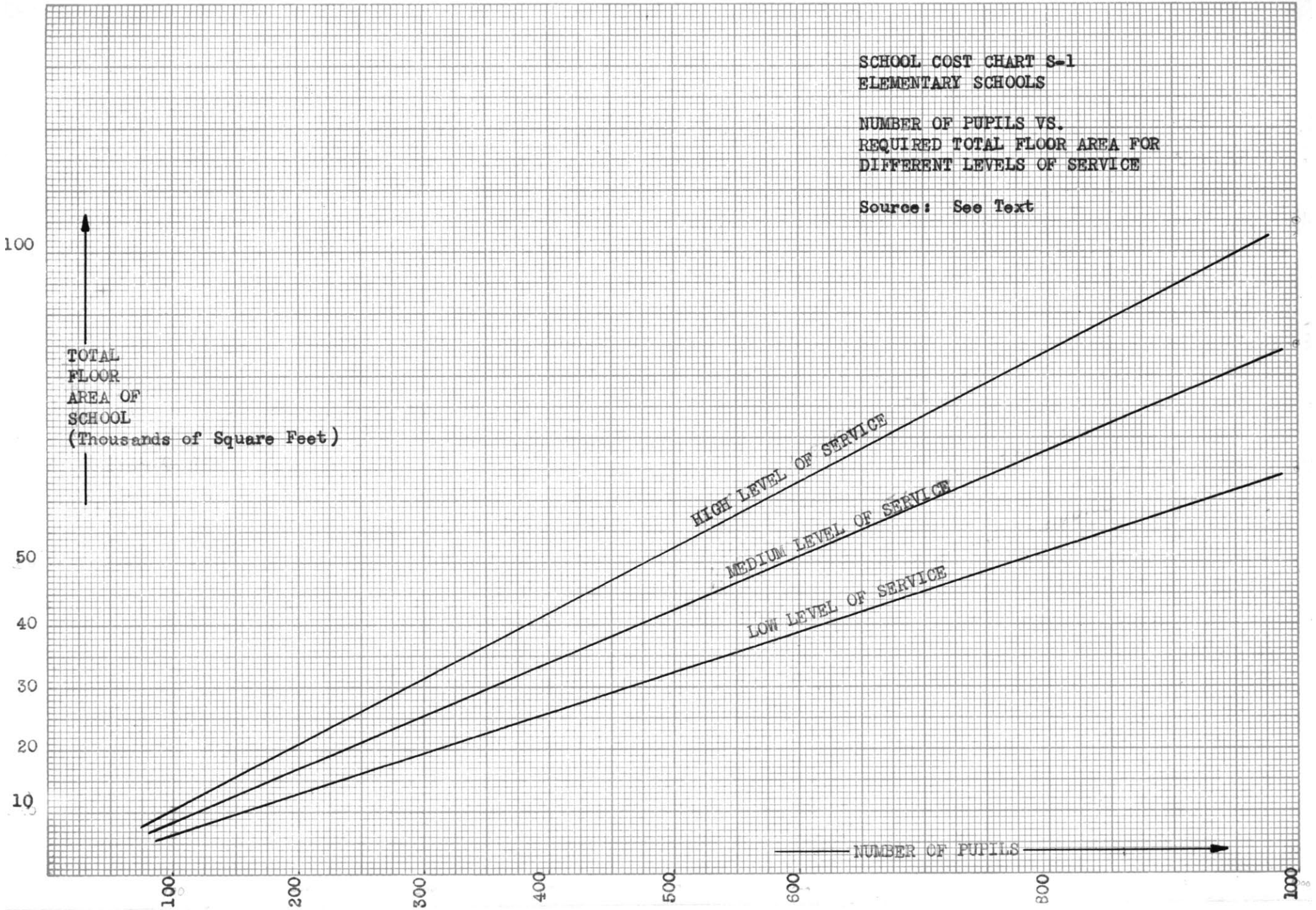

SCHOOL COST CHART S-4
SECONDARY SCHOOLS
TOTAL YEARLY DEPRECIATION COST PER SQ. FT. VS. TOTAL FLOOR AREA, FOR DIFFERENT STANDARDS OF CONSTRUCTION
Source: See Text.
COST PER SQUARE FOOT
.50
.40
.30
.20
.10
High Standard
Medium Standard
Low Standard
Total Area (Thousands of Square Feet)
20
40
60
100
140
180

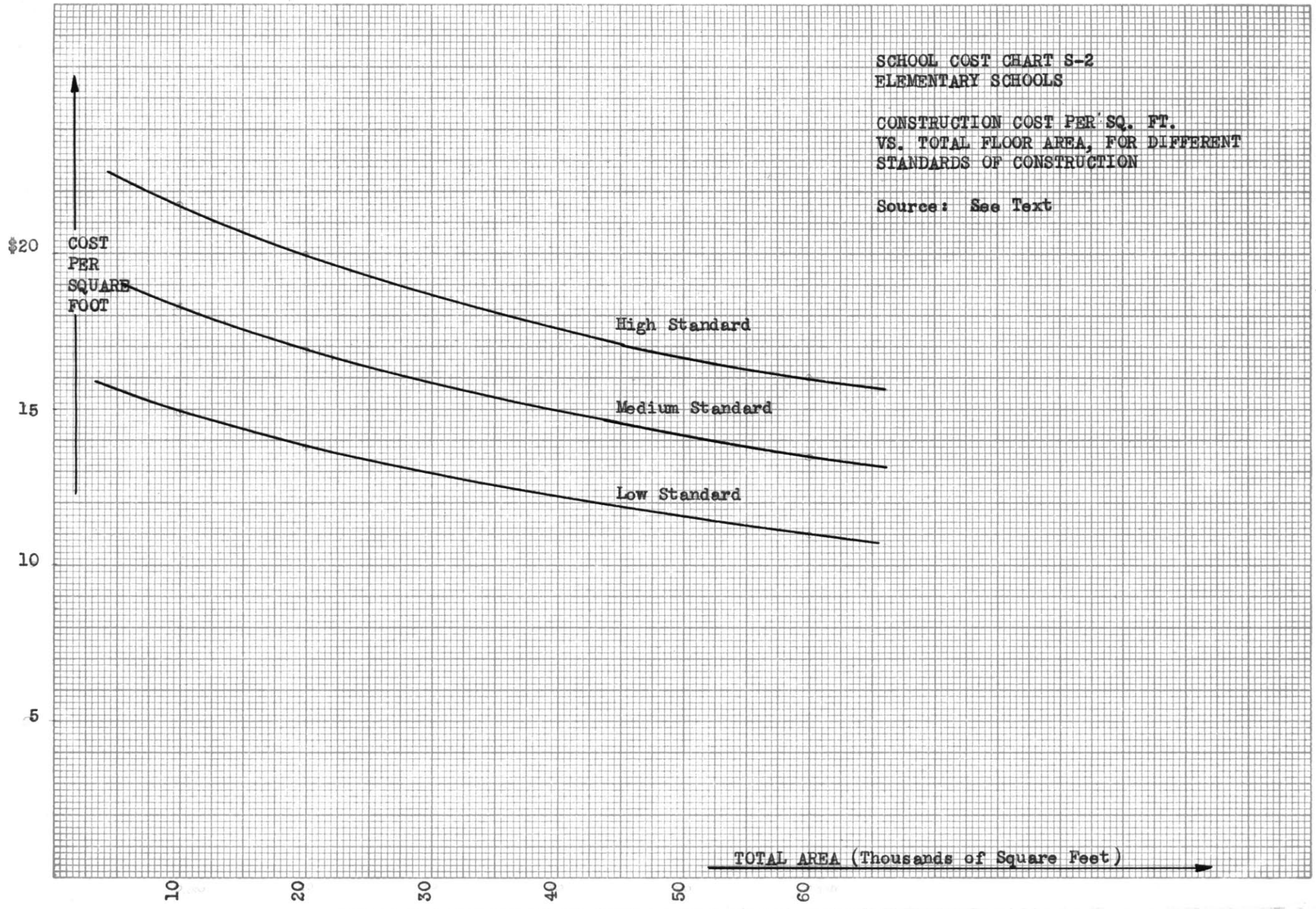

SCHOOL COST CHART S-5
SECONDARY SCHOOLS
TOTAL YEARLY INTEREST COST PER SQ. FT. (AT 2¼ PER CENT) VS. TOTAL FLOOR AREA FOR DIFFERENT STANDARDS OF CONSTRUCTION
$40
COST PER PUPIL
30
20
10
High Standard
Medium Standard
Low Standard
TOTAL AREA (Thousands of Square Feet)
20
40
60
80
100
140
180


SCHOOL COST CHART S-6
SECONDARY SCHOOLS
GRADES 7-9
TOTAL YEARLY NONCAPITAL COST PER PUPIL VS. NUMBER OF PUPILS FOR DIFFERENT STANDARDS OF EDUCATION SERVICE
Source: See Text
High Standard
Medium Standard
Low Standard
COST PER PUPIL
NUMBER OF PUPILS
$200
300
400
500
600
700
100
200
300
400
500
600
700
800
900
1000


SCHOOL COST CHART S-6
SECONDARY SCHOOLS
GRADES 10-12
TOTAL YEARLY NONCAPITAL COST PER PUPIL VS. NUMBER OF PUPILS FOR DIFFERENT STANDARDS OF EDUCATION SERVICE
Source: See Text
High Standard
Medium Standard
Low Standard
COST PER PUPIL
$200
300
400
500
600
700
800
NUMBER OF PUPILS
100
200
300
400
500
600
700
800
900
1000


SCHOOL COST CHART S-6
SECONDARY SCHOOLS
GRADES 9-12
TOTAL YEARLY NONCAPITAL COST PER PUPIL VS. NUMBER OF PUPILS FOR DIFFERENT STANDARDS OF EDUCATION SERVICE
Source: See Text
$800
700
600
500
400
300
200
COST PER PUPIL
High Standard
Medium Standard
Low Standard
NUMBER OF PUPILS
100
200
300
400
500
600
700
800
900
1000

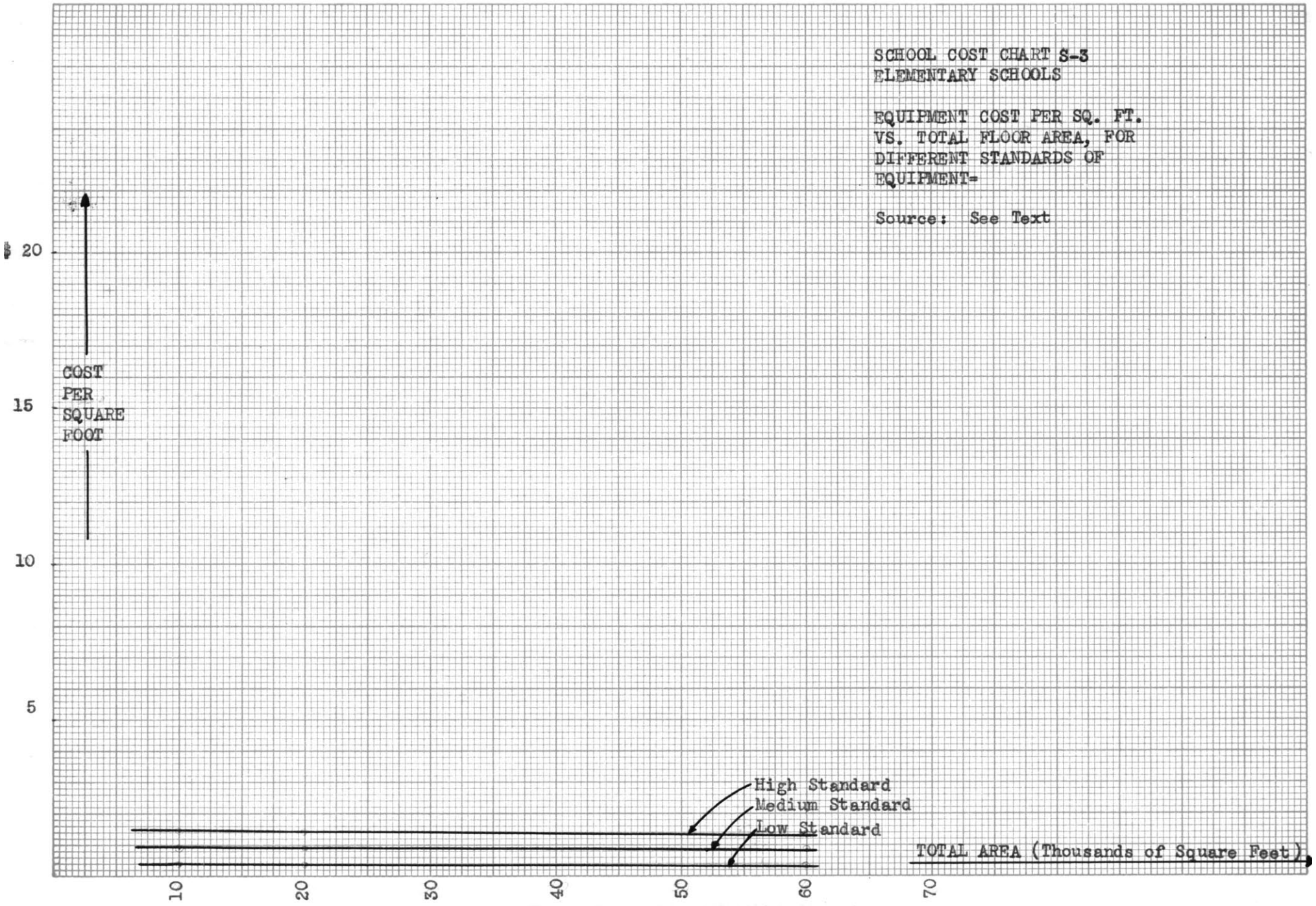

SCHOOL COST CHART S-1
ELEMENTARY SCHOOLS
NUMBER OF PUPILS VS.
REQUIRED TOTAL FLOOR AREA FOR
DIFFERENT LEVELS OF SERVICE
Source: See Text
TOTAL
FLOOR
AREA OF
SCHOOL
(Thousands of Square Feet)
100
50
40
30
20
10
HIGH LEVEL OF SERVICE
MEDIUM LEVEL OF SERVICE
LOW LEVEL OF SERVICE
NUMBER OF PUPILS
100
200
300
400
500
600
800
1000

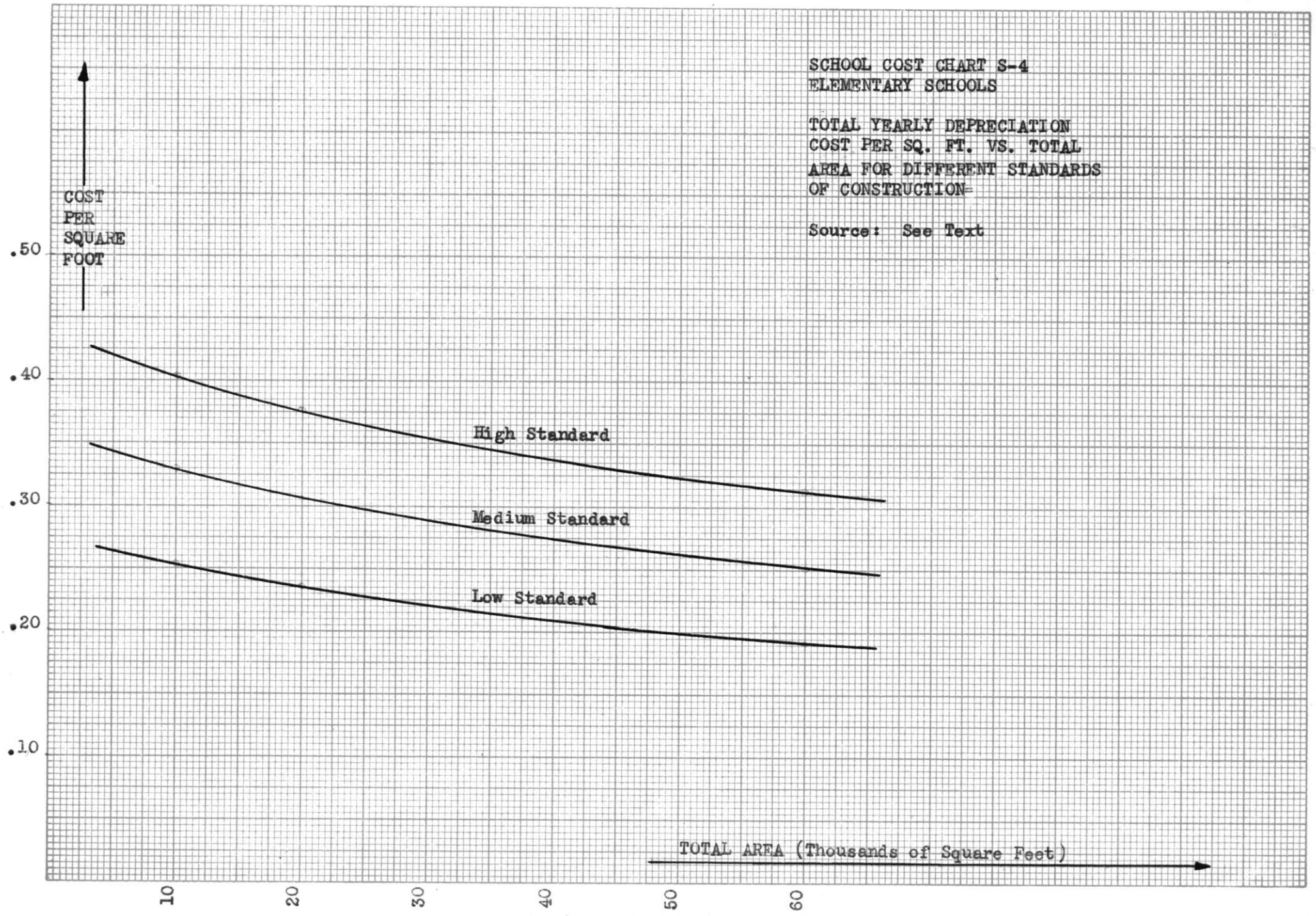

SCHOOL COST CHART S-2
ELEMENTARY SCHOOLS
CONSTRUCTION COST PER SQ. FT.
VS. TOTAL FLOOR AREA, FOR DIFFERENT
STANDARDS OF CONSTRUCTION
Source: See Text
$20
COST
PER
SQUARE
FOOT
15
10
5
High Standard
Medium Standard
Low Standard
TOTAL AREA (Thousands of Square Feet)
10
20
30
40
50
60

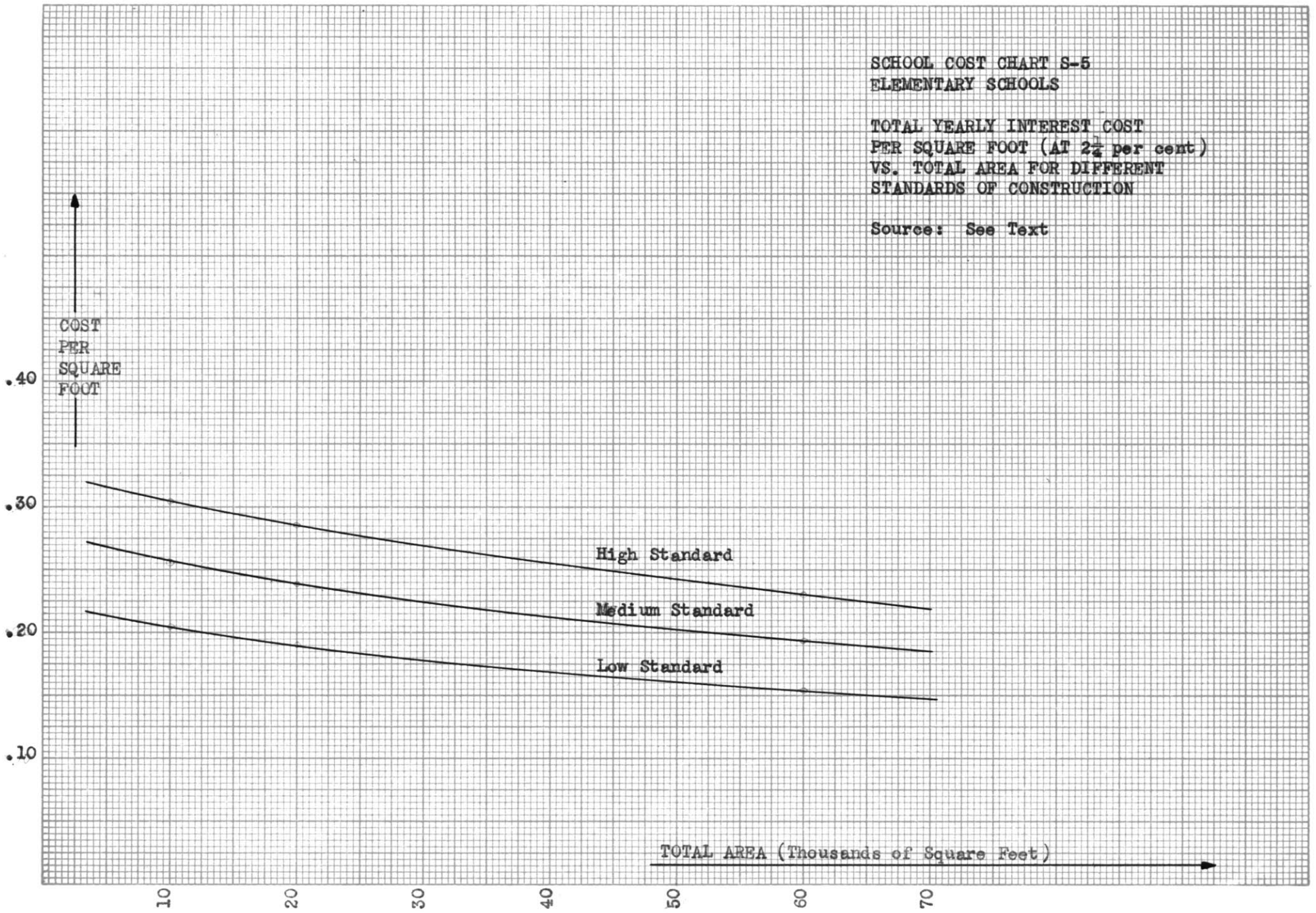
SCHOOL COST CHART S-3
ELEMENTARY SCHOOLS

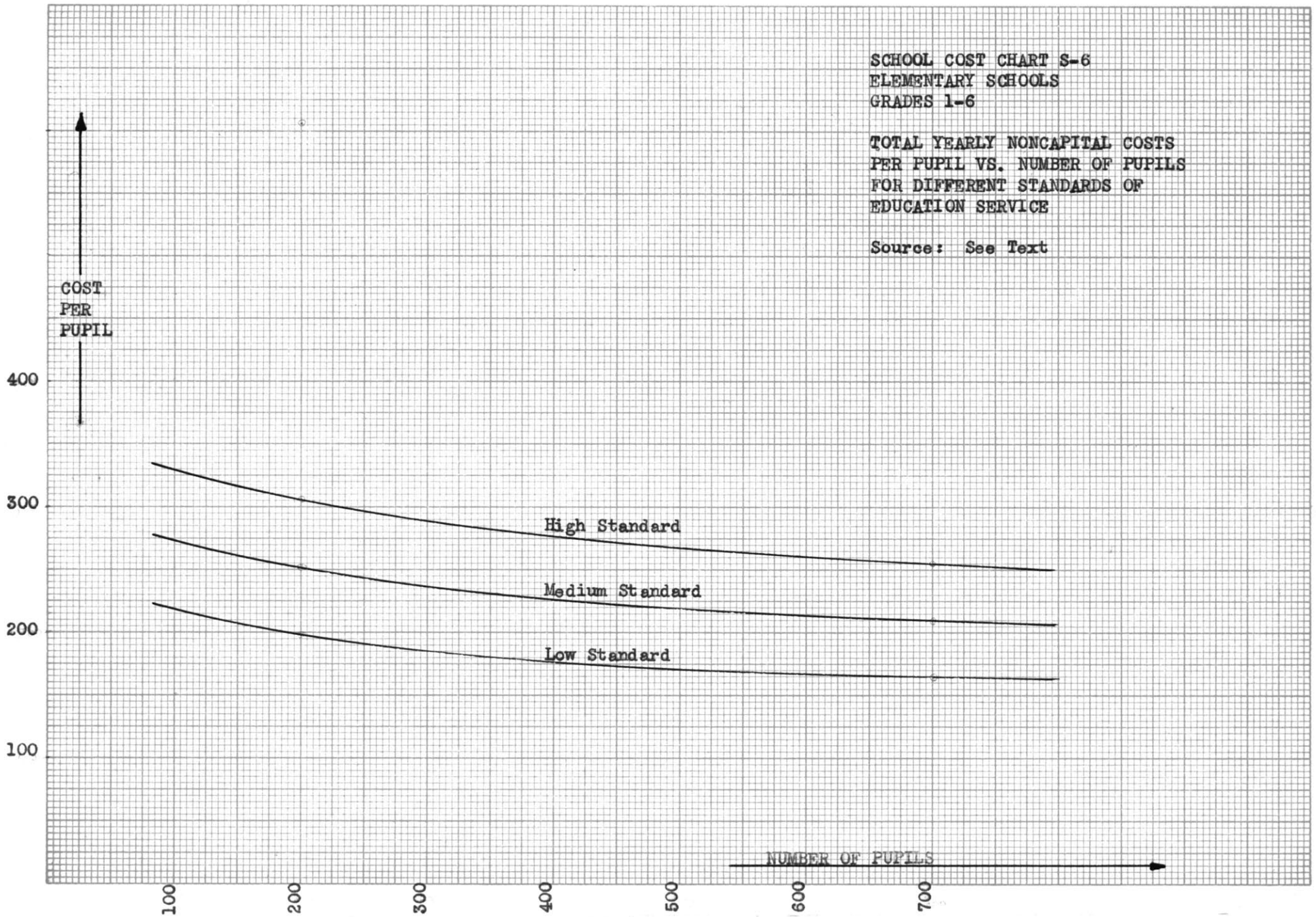
EQUIPMENT COST PER SQ. FT. VS. TOTAL FLOOR AREA, FOR DIFFERENT STANDARDS OF EQUIPMENT=

Source: See Text




SCHOOL COST CHART S-4
ELEMENTARY SCHOOLS
TOTAL YEARLY DEPRECIATION COST PER SQ. FT. VS. TOTAL AREA FOR DIFFERENT STANDARDS OF CONSTRUCTION=
Source: See Text
COST PER SQUARE FOOT
.50
.40
.30
.20
.10
High Standard
Medium Standard
Low Standard
TOTAL AREA (Thousands of Square Feet)
10
20
30
40
50
60

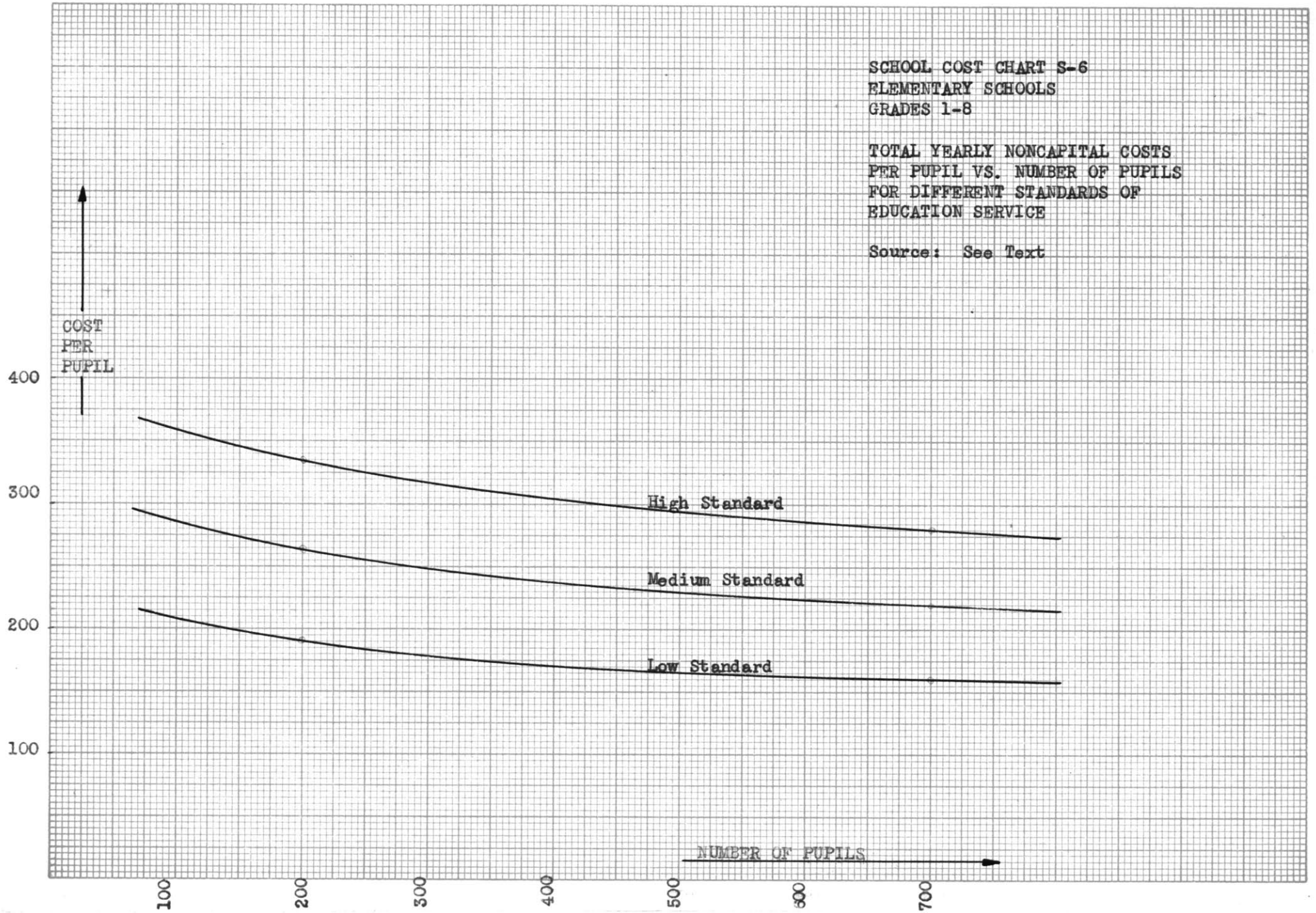

SCHOOL COST CHART S-5
ELEMENTARY SCHOOLS
TOTAL YEARLY INTEREST COST
PER SQUARE FOOT (AT 2¾ per cent)
VS. TOTAL AREA FOR DIFFERENT
STANDARDS OF CONSTRUCTION
Source: See Text
COST
PER
SQUARE
FOOT
.40
.30
.20
.10
High Standard
Medium Standard
Low Standard
TOTAL AREA (Thousands of Square Feet)
10
20
30
40
50
60
70


SCHOOL COST CHART S-6
ELEMENTARY SCHOOLS
GRADES 1-6
TOTAL YEARLY NONCAPITAL COSTS PER PUPIL VS. NUMBER OF PUPILS FOR DIFFERENT STANDARDS OF EDUCATION SERVICE
Source: See Text
COST PER PUPIL
400
300
200
100
High Standard
Medium Standard
Low Standard
NUMBER OF PUPILS
100
200
300
400
500
600
700

SCHOOL COST CHART S-6
ELEMENTARY SCHOOLS
GRADES 1-8

TOTAL YEARLY NONCAPITAL COSTS PER PUPIL VS. NUMBER OF PUPILS FOR DIFFERENT STANDARDS OF EDUCATION SERVICE

Source: See Text



6. Sanitation Costs

a. Capital Costs

Capital costs for sanitary sewerage were broken down into the cost of treatment plant and the cost of sewer lines.

Capital Cost of Sanitary Sewerage Treatment Plant

Sanitary sewage treatment plants, like schools and roads, answer many descriptions. Engineers are quick to make it clear that no two plants are alike, that the complex set of specifications for each plant must be studied by itself. Various degrees of primary and secondary treatment can be combined and several engineering methods can be used to attain each degree of treatment. For our study it was necessary to find the general factors which influence cost and to estimate general cost functions from a number of individual cases.

From our reading and discussions with sanitary engineers[1] it became evident that it is sensible to classify treatment plants by capacity (in million gallons per day), that distinct degrees of treatment can be identified, and that very great economies of scale can be expected.

From brief descriptions in the Engineering News-Record /64/, /65/, /66/, and /67/ we assembled total costs for fifteen sewerage treatment plants of various capacities which were built during the past two or

---

[1] Particularly with W. E. Stanley, Professor of Sanitary Engineering, M. I. T.

three years. These were separated roughly into two groups: those plants which were designed to perform nearly full treatment of sewage and those plants which were designed for primary treatment or little more. The total capital costs per million gallons per day capacity for these two groups of plants were plotted against their capacity in millions of gallons per day (see Chart SW-1). A curve was estimated to fit the data for nearly complete treatment plants and one was estimated to fit the data for primary treatment plants. These two curves are our basic cost functions for the capital cost of sewage treatment plants.[1]

It is unreasonable to suppose that a town in a metropolitan area would build a small inefficient plant of its own since it is most likely that it would be possible for the town along with other towns of the area to make use of a large efficient plant. Therefore, we assume that our theoretical development makes use of an efficient high capacity plant. From our chart we see that for such a plant, say a 150 mgd capacity complete treatment plant, the capital cost per mgd is $150,000.

---

[1]From a study done in 1929 (by Pearse, Greeley, and Housen, Chicago Hydraulic and Sanitary Engineers) we learn that economies of scale for sewage pumping stations follow those of sewage treatment plants. Although the costs of the 1929 data are of no use to us, the findings of economies of scale are valid today for there have been no major changes in the design of sewage pumping stations. The necessity of providing pumping stations depends on the natural drainage slope of the land. For many situations no pumping facilities are necessary. In any case, the cost of pumping facilities compared with that of treatment plant is small. Rather than work out the necessary pumping station capacity for various capacity sewer systems on land of various slopes, we disregard the additional possible cost for pumping facilities and assume that pumping cost is included in treatment plant cost.

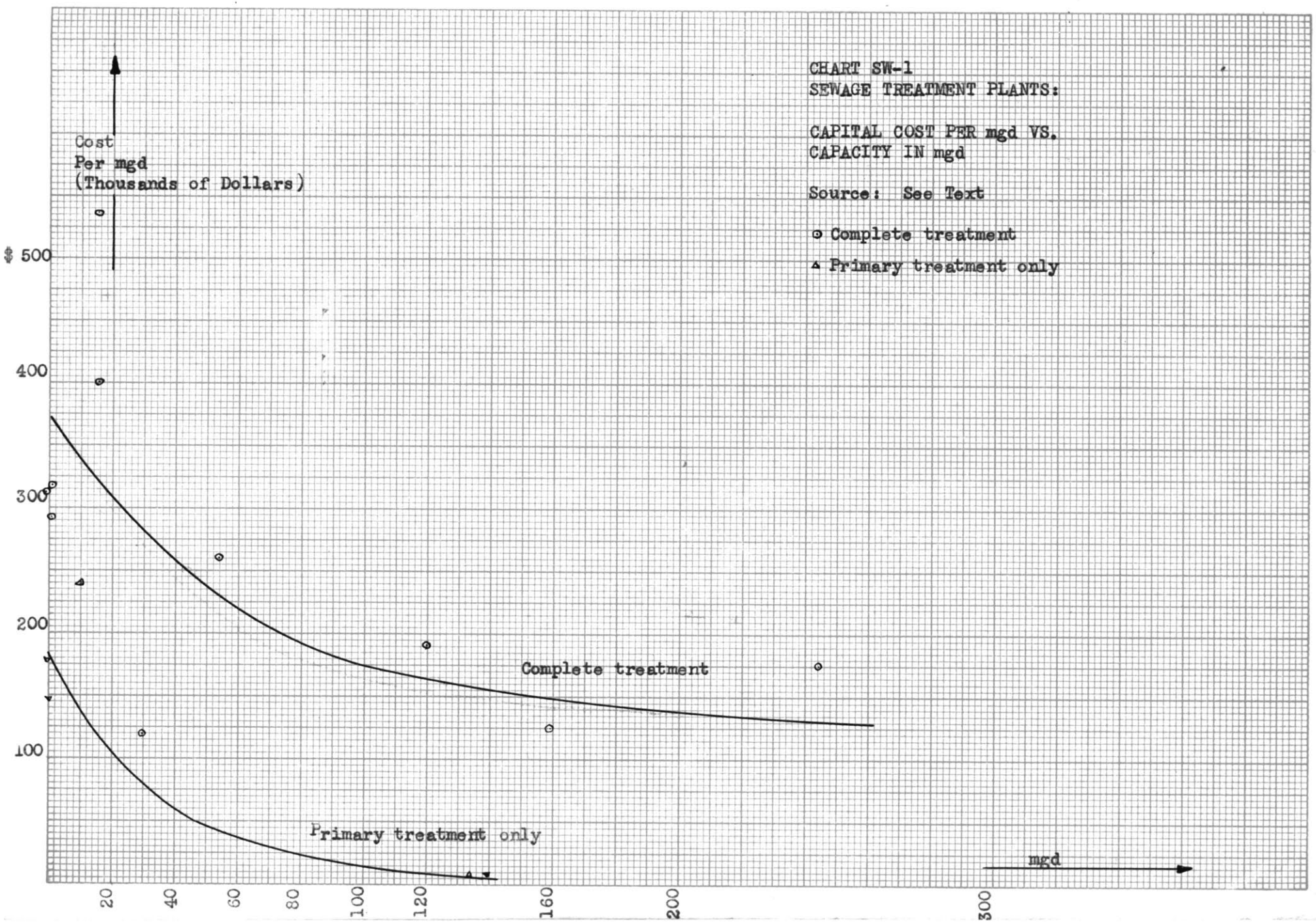


CHART SW-1
SEWAGE TREATMENT PLANTS:
CAPITAL COST PER mgd VS.
CAPACITY IN mgd
Source: See Text
Complete treatment
Primary treatment only
Cost
Per mgd
(Thousands of Dollars)
$ 500
400
300
200
100
Complete treatment
Primary treatment only
20
40
60
80
100
120
160
200
300
mgd

In order to determine the yearly capital cost of sewage treatment plants, we assume as with School Buildings that after a depreciation period of 50 years the plant reaches its end of life, but that at the same time 20 per cent of its value remains. Interest cost is computed as before at $2\frac{1}{4}$ per cent on the value of the plant at half life. For example:

Capital cost of treatment plant	$150,000/mgd
Depreciation over 50 years (80 per cent)	120,000/mgd
Depreciation cost per year	2,400/mgd
Interest cost per year @ $2\frac{1}{4}$ per cent	2,030/mgd
Total yearly cost	4,430/mgd

The total yearly cost is actually 2.95 per cent of the total capital cost.

$$\text{Yearly depreciation cost} = \frac{80\%}{50 \text{ years}} \times \text{capital cost} = 1.6\% \times \text{capital cost.}$$

Yearly interest cost = $2\frac{1}{4}\%$ x value at half life

$$2\frac{1}{4}\% \times 0.6 \text{ capital cost} = \underline{1.35}\ \% \times \text{capital cost}$$

$$2.95\ \% \times \text{capital cost}$$

Capital Cost of Sewer Lines

Sanitary engineers classify their estimates for the total cost of sewer pipe in place by depth of pipe and diameter of pipe. Current estimates of W. E. Stanley /69/ were used as the basis for our cost data. Since his estimates did not describe pipe larger than 24" diameter, we were forced to extrapolate his estimates to obtain estimates for larger sizes of pipe. This cost data is presented as Table 32.

TABLE 32

ESTIMATED COST OF SEWER PIPE

IN PLACE FOR AVERAGE GROUND CONDITIONS

Sewer Pipe Diameter in Inches	0-6' Depth	6-12' Depth
8	$ 4.50	$ 6.00
10	5.25	6.50
12	6.00	7.00
15	7.00	8.50
18	8.30	9.75
21	9.50	11.00
24	11.00	12.50
27	12.25	14.00
30	13.50	15.50
33	14.75	17.00
36	16.00	18.50

Source: For 8"-24" diameter, estimates furnished by W. E. Stanley, Professor of Sanitary Engineering, M.I.T. /69/ Estimates for 27-36" diameter extrapolated directly from data for smaller diameter.

It is the opinion of W. E. Stanley that few economies of scale will be realized by laying large lengths of sewer line at one time. This judgment is based on the fact that sewer lines are usually laid by small contractors who possess a minimum of specialized equipment. Since these

contractors are able to operate at close to their maximum efficiency at small jobs and since contractors with large force and specialized equipment are not available, no savings can be expected by letting a large job rather than several smaller jobs.

b. Noncapital Costs

Costs for the operation of sewer systems were avilable on a per capita basis but were not readily available on a plant capacity or sewerage volume basis. Per capita costs throw little light on how the operating cost of sewerage systems varies, for per capita costs are the result of a great many unidentifiable factors--for example, for the same degree of treatment by equally efficient plants in equal sized communities there can be great differences in per capita costs if there are differing amounts and types of industry contributing wastes.

Therefore, we see no special advantage in presenting per capita operating costs for sewerage systems. Instead, we present noncapital per capita costs for sanitation--a wider category which includes cost of street cleaning, waste collection, and disposal as well as operating costs of the sanitary sewerage system. Costs for Massachusetts cities of population 25-50,000 tabulated under this head in the Compendium of City Government Finances 1953 were analyzed. (See Table 43 in Appendix I.) As might be expected, highly industrialized cities showed high noncapital per capita sanitation costs. These cities are also densely populated and probably are forced to make more frequent waste collections, and probably are unable simply to dump waste in a convenient town dump.

The sort of development we envisage in our model will not have such extreme costs. Nor will it have unusually low noncapital sanitation costs, for considerable industry is envisaged. Therefore, we take the median noncapital cost ($4,31 per capita) from Table 43 in Appendix I for use in calculations on our model.

There are disadvantages in using the readily available all-inclusive sanitation cost figure. It is impossible to investigate the saving in municipal waste collection and disposal that a low density development can make by providing a town dump to which residents can bring their own waste.

7. Fire Protection Costs

We were unable to break down the cost of fire protection into capital and operating costs, and could not identify any economies of scale. However, we were able to show variation in cost due to level of service provided.

The National Board of Fire Underwriters grades cities according to their ability to cope with fire and according to the fire hazard present. The Board's Grading Schedule lists eight basic categories: water supply, fire alarm, police, building laws, hazards, structural conditions, climatic conditions and fire department. The fire department itself is graded in deficiency points from 1 to 1500. We have arbitrarily simplified this rating system to three levels of service: good (0-550 deficiency points), average (551-900 deficiency points) and poor (901-1500 deficiency points).

Per capita expenses for fire protection (from data published in the Municipal Year Book 1954) were then analyzed by level of service for towns of 25,000-50,000. A definite increase in cost was found to be associated with increase in level of service. (See Table 33)

Fire protection cost for average level of service was then analyzed for towns of 10,000-25,000 population and for towns of 50,000-100,000 population. Median costs for each of these size groups were significantly less than for the size group 25,000-50,000. It is not our opinion that this indicates diseconomies of scale and then economies of scale with increasing size of city. As size of city increases we would expect constant or

decreasing costs per capita for providing the same level of fire protection. We would expect decreasing costs per capita especially going from very small towns to medium sized towns (going from 10,000-50,000 population). The small town would need the same fire fighting equipment as the larger town but would be called upon to use it less frequently. The true cost of fire protection in small towns probably is higher than the statistics indicate for two reasons. First, it is well known that towns of less than 25,000 make extensive use of volunteer firemen. Their services are rendered but no money cost is incurred by the town. Second, the fire departments of cities over 25,000 population are graded by engineers of the National Board of Fire Underwriters, but those of the towns of less than 25,000 are determined by engineers of state rating organizations. It is possible that the ratings of these private agencies are not comparable with those of the National Board. State agencies may tend to over-estimate the level of service rendered by individual fire departments.

Because of these uncertainties, median per capita cost of fire protection at different levels of service for cities 25,000-50,000 population was used for all cost calculations in our theoretical models.

TABLE 33

MEDIAN PER CAPITA FIRE DEPARTMENT EXPENDITURES

BY SIZE OF CITY AND LEVEL OF SERVICE PROVIDED IN 1954

	High Level of Service	Average Level of Service	Low Level of Service
Cities 10-24,000 population		5.22	
Cities 24-49,999 population[1]	9.04	6.16	3.79
Cities 50-99,999 population		5.52	

[1]Note: Per capita costs from this line are used for calculations of costs in our theoretical models.

Source: The Municipal Year Book 1954, The International City Manager's Association, Chicago 1954 for total expenditures. U. S. Census of Population, 1950 for population.

CHAPTER V

THE COST ESTIMATES OF THE MODELS

1. Estimation of Total Yearly Costs

In the previous sections we developed some theoretical models and then investigated the costs of providing various services which communities require. In this chapter we bring together the models and the costs.

For the following situations we computed total yearly costs during four representative years spaced throughout the period of growth:

1.a. Low Density Model, Continuous development, low standard of services.
c. Continuous development, high standard of services.

2.a. Medium Density Model, Continuous development, low standard of services.
b. Jump development, low standard of services
c. Continuous development, high standard of services.
d. Jump development, high standard of services

3.a. High Density Model, Continuous development, low standard of services.
c. Continuous development, high standard of services.

The total yearly costs for each model are presented in Table 34 and are shown graphically on Chart A. Detailed costs for each model are given in Tables 53-60 in Appendix IV. As an example of how the yearly costs for each model were arrived at, an outline of the calculations for model 2a is presented in Appendix III.

For all these situations we assumed average "social model" requirements, e.g., average number of school children per dwelling unit, average

sewage requirements, average traffic requirements. Of these variables, variation only in the number of school children is likely to produce significant cost differences. For each density model, we investigated the situations where all municipal services provided were at a low standard or all at a high standard. In any real situation a combination of high and low standard services would be provided. Therefore the cost of any real situation would fall within the extremes we have investigated.[1]

TABLE 34

SUMMARY OF TOTAL YEARLY COSTS FOR VARIOUS MODELS

Density Model	Pattern of Growth	Level of Service	Year 5	Year 10	Year 15	Year 20
1.a. Low	Continuous	Low	$292,570	$539,860	$800,750	$1,040,850
c. Low	Continuous	High	367,090	674,000	993,190	1,291,310
2.a. Medium	Continuous	Low	299,250	554,760	822,070	1,071,250
b.	Jump	Low	306,370	564,750	821,160	1,064,630
c.	Continuous	High	373,770	688,880	1014,530	1,320,710
d.	Jump	High	380,890	698,890	1013,620	1,314,950
3.a. High	Continuous	Low	271,110	504,700	733,780	957,470
c.	Continuous	High	345,630	638,840	922,240	1,199,930

Source: See text.

2. Cost Variation with Standard of Service Provided

A glance at Chart A shows that the cost curves fall into two major groups depending on the standard of service provided. For each density

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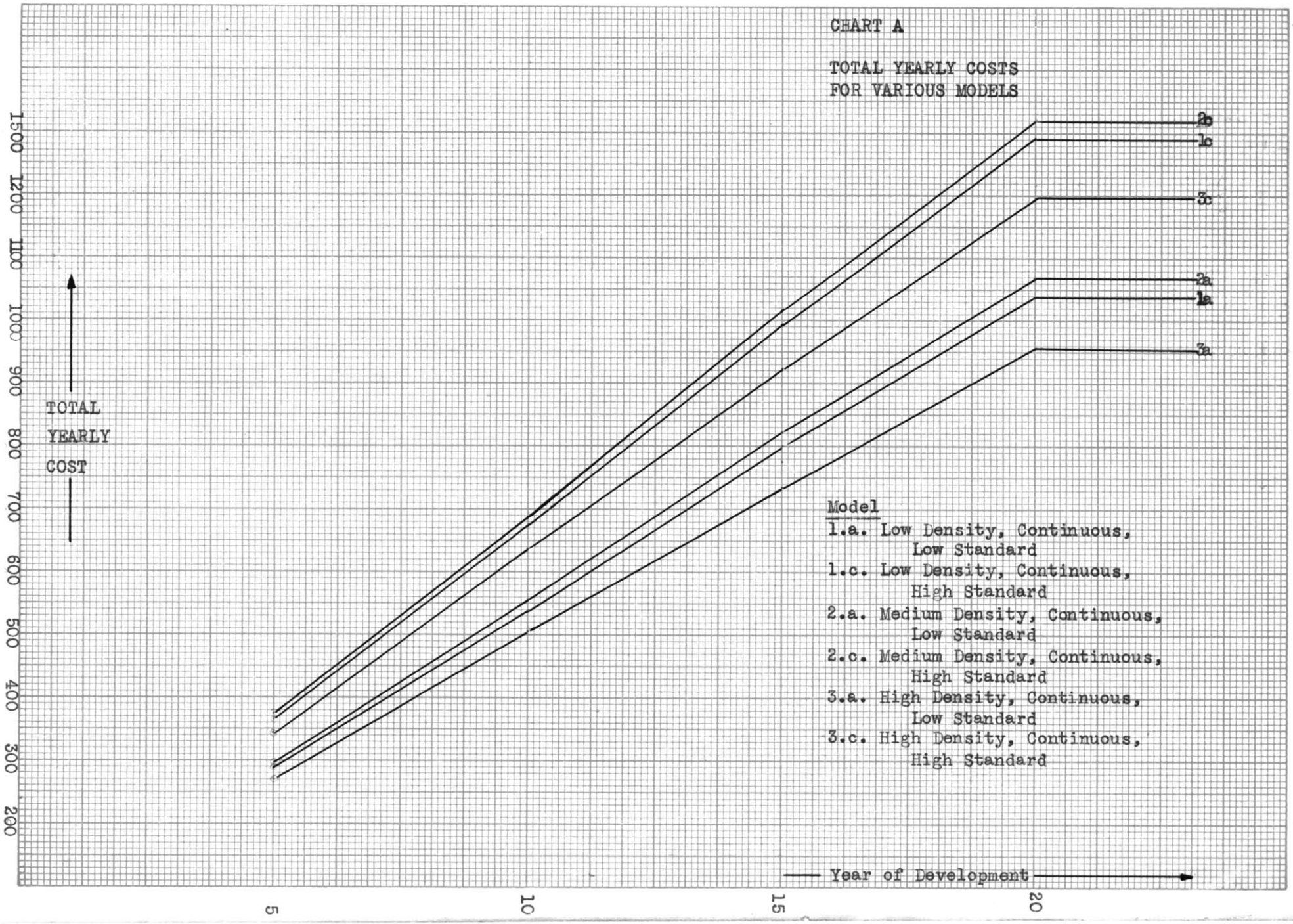
[1]This is true only insofar as our cost data is graded according to quality of facility or service. Over 50 per cent of costs are so graded.

CHART A

TOTAL YEARLY COSTS
FOR VARIOUS MODELS



model the costs at high standard of service are about 1.2 times those at low standard of service. Standard of service causes a greater cost differential than any other single factor. This cost differential would be even greater if all services had been graded according to standard of service.

3. Cost Variation with Density

The cost differential between curves of equal level of service but different density is not so great. For each level of service the costs of the most expensive density model is about 1.1 times that of the least expensive.[1] Within the low level of service group and the high level of

---

[1]Schussheim /18/ found that variation in density makes more difference in yearly capital costs than in yearly noncapital costs but causes only a small difference in total yearly costs. He investigated the total yearly costs precipitated by the development of a specific area in Natick and found that the public costs would be only about 3% greater if it was developed at four dwelling units per acre than at two dwelling units per acre. The cost of a public sewer system in the higher density development more than off set the cost of longer roads in the lower density development where no public sewers were necessary.

TABLE 35

TOTAL ANNUAL PRECIPITATED MUNICIPAL COSTS PER DWELLING UNIT

FOR THEORETICAL DEVELOPMENT OF A SPECIFIC AREA IN NATICK DERIVED BY SCHUSSHEIM

	Yearly Costs per Dwelling Unit	
	Residential Development	
	500 DU at 2 DU/Acre	500 DU at 4 DU/Acre
Capital Costs	$ 86.97	$ 93.70
Noncapital Costs	294.71	298.36
Total	$381.68	$392.06

Source: Schussheim /18/, Table 20, p. 111.

service group, the high density model is the cheapest, the medium density model the most expensive.

As density increases, less roadway, less sidewalk, and less sewer line must be provided for the same number of dwelling units. Larger schools are possible and these tend to be less costly per pupil.[1] On the other hand, as densities increase and private yards shrink, more land must be acquired as public open space for recreation. However the increased cost of public open space is not great enough to outbalance the decreased cost of roads and utilities. This is especially so if land is acquired in advance of its need and before adjacent development has caused its price to rise.[2] Since the main cost variables which are affected by density decrease with increase in density, one would expect the public costs to decrease as density rises. This appears to be true, for densities greater than two dwelling units per acre but just below that density municipal costs drop, because it is possible to remove public sanitary sewerage service from the complement of services provided. At lower densities sidewalks and rubbish collection are often not provided. As density is

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[1] In the low and medium density models, two medium-sized elementary schools are provided. In the high density model one large elementary school is provided.

[2] The cost data we have used in our models does not show how the cost of land and services for recreation varies with density. We assumed in our model that the town acquires all public open spaces by gift of the developer or at a very low price before development makes the land assessible and increases its usefulness and market value. It seems plausible, too, that when at higher densities public playgounds replace private yards recreation costs will rise but we were unable to develop recreation cost data that reflected changes in density.

lowered one must measure the increasing costs due to longer (though narrower) roads against the savings from not providing municipal sanitary sewerage rubbish collection, or sidewalks. The increasing cost of roads with decreasing densities cannot be avoided even though the roads are narrower, of less heavy construction, and often without curbs and sidewalks. This increasing cost can be offset if the complement of municipal services is decreased.

If the same complement and standard of services is provided for each model, the low density models will be the more costly. If sewer and sanitation services comparable to those of the medium density model were provided in the low density model, its ultimate total yearly cost would increase by some $78,000. The low density model rather than the medium density model would then be the more costly per year by approximately $49,000.

4. Cost Variation with Pattern of Growth

Total yearly costs for jump growth models are greater in the early years but less in the later years than for corresponding continuous growth models. The cost difference,[1] however, is small and the eventual

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[1] When growth is by jump instead of continuous, capacity must be built into the main road and the main sewer line at the outset. This capacity will not be fully utilized for many years. This tends to make jump growth more expensive than continuous growth during the first years. But since larger stretches of road are built at one time than in continuous growth, larger economies of scale in road construction are realized. Since the resulting unit costs of road are less, when the road system is completed and its capacity is fully utilized, ultimate road costs for jump growth are less than for continuous growth. Since the ultimate physical development is the same for each type of growth, when growth is complete total yearly costs for the jump growth models are less than for continuous growth models.

cost advantage of the jump model depends on economies of scale achieved in road construction and the ultimate complete utilization of roads which during the early years are sharply underutilized. If for some reason development does not continue as rapidly as expected, these savings are deferred. If it is not completed as first envisioned, unused capacity will always remain and savings will never be utilized.

5. Cost per Dwelling Unit

Table 36 is the result of dividing the total yearly costs (capital and noncapital) the developing area precipitates by the number of dwelling units in the developing area during each of four key years.

TABLE 36

TOTAL YEARLY COSTS PER DWELLING UNIT

FOR VARIOUS MODELS

Density Model	Pattern of Growth	Level of Service	Year 5	Year 10	Year 15	Year 20
1a. Low	Continuous	Low	$473	$434	$430	$420
c. Low	Continuous	High	593	543	534	522
2a. Medium	Continuous	Low	483	446	442	432
b. Medium	Jump	Low	495	455	441	429
c. Medium	Continuous	High	603	555	546	533
d. Medium	Jump	High	615	563	545	530
3a. High	Continuous	Low	437	407	394	386
c. High	Continuous	Low	557	514	495	483

Source: See text.

In all models studied, costs per dwelling unit are high at first and fall as the number of dwelling units increases. In the first years, costs per dwelling unit in continuous growth models are about 1.13 times costs in the later years. Early costs per dwelling unit in jump growth models are about 1.15 times greater than in later years.[1] Higher per capita costs in the early years are a result of the construction of capital facilities which will not be fully utilized until the sector has grown. (For example, main roads, main sewers, secondary schools.) That part of total yearly per capita costs due to current costs is constant, for current costs are all on a constant per capita basis.

Our basic analysis considers four key years during the development of the sector. Each of these years is at the completion of a five-year stage of growth. So far it has not been made clear how per capita costs behave throughout each five-year stage. Because we have conceived of this growth in separate stages and since (particularly in roads) we have based our costs on economies of scale due to large construction at one time, it follows that capital facilities for each stage must be

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[1] Schussheim /18/ Table 13 p. 89 found decreasing total public capital costs per dwelling unit in a specific area in Natick when the size of development increased from 500 to 1000. The per dwelling unit costs dropped by 8% when the area was developed at 2 DU/Acre, and by 10% when developed at 4 DU/Acre. For this range of increase, per dwelling unit costs in our model dropped by about 9% in the low density model (1 DU/Acre) and by about 8% in the medium density continuous growth model (4 DU/Acre).

constructed during the first years of each stage. This means that in the first years of each stage, the new facilities will be underutilized and per capita costs will be high.

In order to get some idea of the variation of per capita costs during each stage of development we have made the assumption that during each stage half the new capital costs of the stage were incurred during the first year of the period, half during the second. New current costs increase by an equal amount each year. For model 1a, the yearly costs resulting from these assumptions are presented in Table 37 and Chart B.

TABLE 37

TOTAL YEARLY COSTS FOR EACH YEAR DURING THE PERIOD OF GROWTH OF LOW DENSITY MODEL

(CONTINUOUS GROWTH, LOW STANDARD)[1]

	Year of Development																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Capital Costs	$30,740	$61,480	$61,480	$61,480	$61,480	$87,040	$112,600	$112,600	$112,600	$112,600	$142,600	$172,600	$172,600	$172,600	$172,600	$196,775	$220,950	$220,950	$220,950	$220,950
Current Costs	46,200	92,440	138,660	184,880	231,090	270,320	309,550	348,780	388,100	427,260	467,440	507,620	547,800	587,980	628,140	666,490	704,840	743,190	781,540	819,870
Total	76,940	153,920	200,140	246,320	292,570	357,360	422,150	461,380	500,700	539,860	610,040	680,220	720,400	760,580	800,740	863,265	925,790	964,140	1,002,490	1,040,820
Number of Dwelling Units	124	248	372	496	620	744	868	992	1,116	1,240	1,364	1,488	1,612	1,736	1,860	1,984	2,108	2,232	2,356	2,480
Average Cost Per D.U.	620	620	538	498	473	481	486	465	448	435	447	457	447	438	430	434	438	432	425	420

[1]Computed under the following assumptions:

a. Fifty per cent capital cost of each stage is in first year of each stage, 50 per cent in second year of each stage.

b. Current costs increase at constant rate during each stage.

Source: See text.

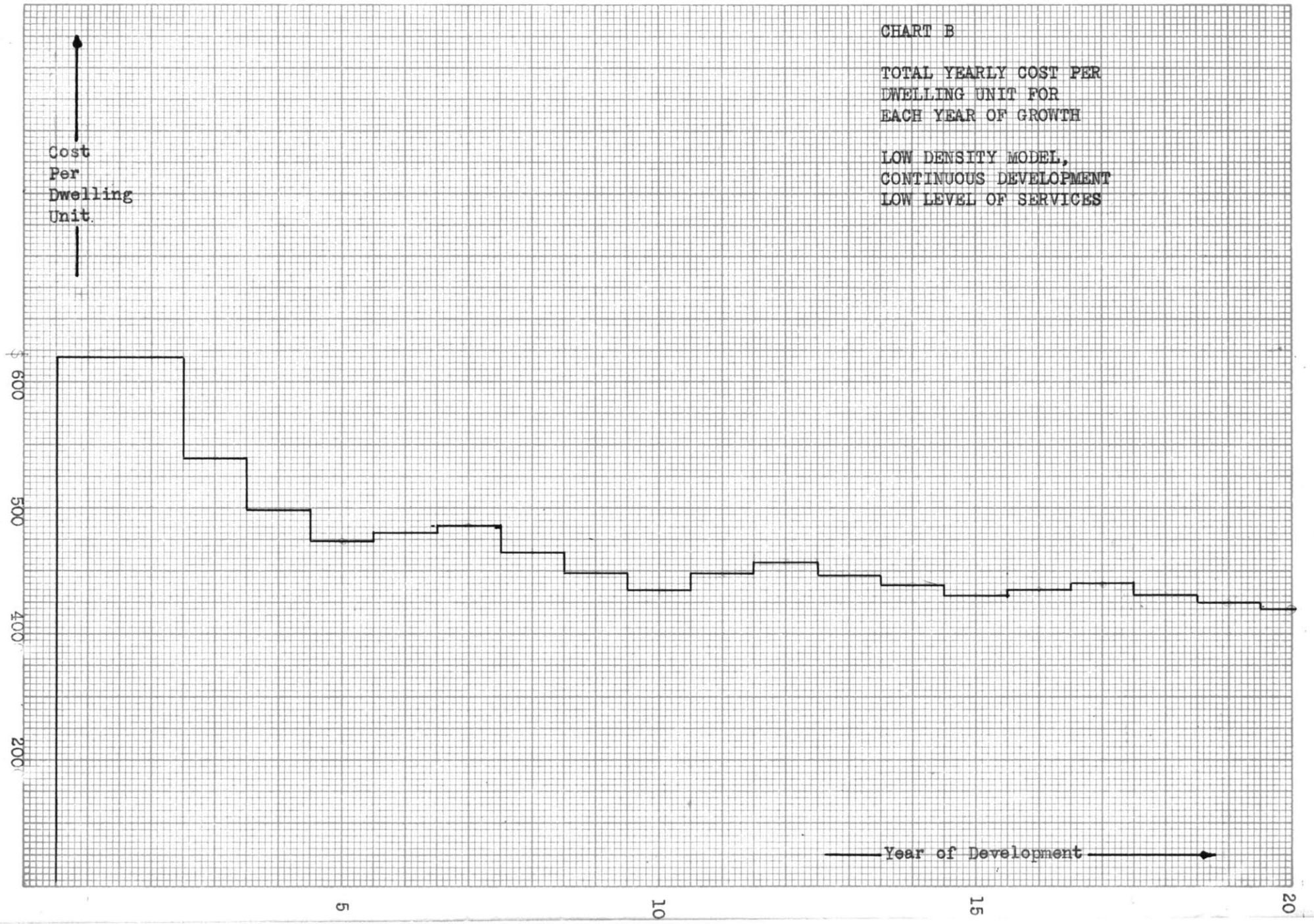


CHART B
TOTAL YEARLY COST PER DWELLING UNIT FOR EACH YEAR OF GROWTH
LOW DENSITY MODEL, CONTINUOUS DEVELOPMENT LOW LEVEL OF SERVICES
Cost Per Dwelling Unit
600
500
400
200
Year of Development
5
10
15
20

The trend of the cost per capita curve is downward with growth, but bumps occur at the beginning of each stage. This curve can be thought of as a picture of the unused capacity in the model at any time. It is evident that if growth were to slow down after the construction of the facilities, per capita costs would remain high for a longer period. However, if growth were to speed up after their construction, the cost per capita would fall more rapidly during the stage of development. A sudden spurt of growth will cause costs to increase suddenly, but if the new facilities are fully utilized immediately, per capita costs will not increase appreciably if the level of services remains unchanged.

Our analysis has not considered whether the standard and complement of services must increase because major growth has occurred in a town. When a town's population and economic activity grow, activity intensifies within it. Especially in the central area it is likely that a higher standard of police protection, and traffic control will be required. Perhaps special facilities such as parking areas will be required.

The general relationships between size of town, intensity of activity and resulting standard of services required deserve thorough study.

6. Community Costs When the Developer Bears the Primary Costs of Development

We have assumed so far that all the costs we have considered are borne directly by the municipality. In fact, many municipalities today

require the developer to bear the cost of many primary facilities. Local roads, sidewalks, and sewers are often constructed or paid for by the developer who then shifts the cost to the people who move into the new area.

The cost of these facilities is the same whether they are paid for out of city taxes or out of rental or capital payments by the individual who comes to live in the Sector. However, when primary facilities are paid for privately the municipal costs look altogether different from when all facilities were paid for by the municipality. Table 38 shows municipal costs under a fiscal policy which requires the developer to provide all primary facilities--local roads, sewers and sidewalks.

TABLE 38

TOTAL YEARLY COSTS (NOT INCLUDING COST OF LOCAL STREETS, SIDEWALKS, AND SEWERS) FOR VARIOUS MODELS

Density Model	Pattern of Growth	Level of Service	Year 5	Year 10	Year 15	Year 20
1.a. Low	Continuous	Low	257,820	473,250	699,990	908,430
c. Low	Continuous	High	332,340	607,390	892,430	1,158,890
2.a. Medium	Continuous	Low	265,790	489,250	722,660	939,290
b. Medium	Jump	Low	272,910	499,240	721,750	932,670
c. Medium	Continuous	High	340,310	623,370	915,120	1,188,750
d. Medium	Jump	High	347,430	633,330	914,210	1,182,990
3.a. High	Continuous	Low	257,930	478,340	694,240	904,750
c. High	Continuous	Low	332,450	612,480	882,700	1,147,210

Source: See text.

Under this policy the total municipal cost is obviously less, but at the same time the relative cost difference is greater between high and low service standards of any one density model. The high standard of service model always costs about 1.28 times as much as the low standard of service model.

Difference in cost between various density models is sharply reduced. The most costly density model is never more than 1.04 times as costly as the least expensive at the same standard of service. The ranking of the models by cost is unchanged. The low density model is slightly more expensive than the high density model. The medium density model remains the most expensive.

With this sort of fiscal practice, it makes little difference to community out-of-pocket costs whether the development proceeds at high or low density, but it makes relatively larger difference whether its services are at a high or low standard.

7. The Effect on Costs of Existing Unused Municipal Facilities

The cost variations shown by our models are small. The most expensive is but 1.2 times as costly as the least expensive. In actual situations, the variation could well prove to be considerably greater. In our model we assumed no excess capacity in any municipal facilities or services at the beginning of growth. In an actual partly-developed town it is likely that underdeveloped locations can be found which can be served by existing

schools, roads, and sewers. The existence of these facilities can have a major effect on the cost precipitated by the development of land within their service areas. Both McHugh /14/ and Schussheim /18/ found that locating within the service area of existing underutilized municipal facilities and services is the way to make the largest cost reductions.

Schussheim concludes that when underutilized municipal facilities and services are available, "density is not a determining factor so far as municipal expenses are concerned. The proper choice of the location of a new development area is the principal method of effecting substantial savings in a community such as Natick" (a partly developed community with unused capacity in various services and facilities). When underutilized facilities are not available, (this can happen in either relatively underdeveloped towns or built up extensively serviced towns) choice of location has little effect on costs.

This paper is not concerned with estimating the amount and type of unused municipal services in any situation but it is worth nothing that these considerations fit into our conceptual scheme. A survey of unused facilities would tell us how much more service could be produced before it becomes necessary to provide new facilities. It also would tell us at what point on the cost function curve we are when we begin to operate. In general, existing underused facilities mean both lower capital costs and lower operating costs. Capital costs are lower, for fewer new capital

facilities need be provided for the same standard of service and those needed can be deferred until a later date. Operating costs are less from the outset for many fixed costs have been incurred already. Only variable costs need be incurred to produce more service.

CHAPTER VI

CONCLUSION

Certain general decisions about growth must be faced by any town. How much development? At what densities? In what pattern? At what level of community service? The analysis of Chapter V explored the implications of extreme choices in each decision. Some general conclusions were reached:

1. Variation in level of services offered has a major effect on the community costs resulting from growth. Although only a little over half of the costs had been graded according to level of service, high level of service models were about 1.2 times the cost of low level of service models.

2. Variation in density has a less important but still a major effect on community costs. The most expensive density model was about 1.1 times the cost of the least expensive density model. If each model were provided with exactly the same level of services as well as the same standard of service, the less densely developed models would be most expensive, the most dense models cheapest. But since only a limited public sanitation system is provided in the low density model, its cost falls below that of the medium density model. If, as commonly happens, the developer is required to bear the primary costs of development, the remaining community costs differ little for developments of different density.

3. Jump pattern of growth is definitely at least 2-3% more expensive than continuous growth at medium density during the first years. When road and sewer systems become fully utilized in the later years of development the jump model may prove less expensive than the corresponding continuous growth model, if the anticipated economies in road construction had been realized when the initial long lengths of main road were constructed.

4. As growth increases from 5-600 new dwelling units to 24-2600 dwelling units, yearly cost per dwelling unit decreases. It is about 1.13 times greater in the early years than in the later years when all facilities are fully utilized. With jump growth the difference is slightly greater. But cost per dwelling unit does not decrease constantly. It rises slightly whenever additional major new capital investments are made.

It should be remembered that these general conclusions are based on a specific set of assumptions and on cost data which was often crude. Since we attempted to choose the most general possible assumptions and variables affecting growth, these assumptions and variables cannot describe the pecularities of terrain and needed special facilities of any one town. We were able to classify according to the standard of service provided only a little over half the costs incurred. In any town local availability of materials and skills will affect costs in a way this analysis cannot predict.

Because of these limitations, the study's results cannot be applied directly to any town, but the study has developed a set of cost data generalized from theoretical and engineering calculations and the experience of many towns. This can be used along with our analytical framework for a rough analysis of the community costs of growth in any town. One should always realize that such an initial analysis is not a substitute for a more thorough-going engineering analysis which takes into account all conditions and requirements of the local environment.

Data that can be used for a rough analysis of the cost of growth in many cities and towns cannot at the same time provide a precise measure of the cost of growth in any one particular town. But because the cost data is generalized and the treatment of growth requirements is generalized, the analysis has relevance for all towns. By contrast a case study of a particular town based on a specific pattern of development over certain terrain, and developed with cost data from the specific experience of the town would present findings which could be applied to other towns only with difficulty.

The sets of assumptions in our growth models and the cost data for particular services are spelled out as explicitly as was possible. Should future investigation prove any of these unsuitable, they can be replaced readily. The effects of each major variable acting alone is made explicit in our analysis.

Although we believe that this study presents a more comprehensive framework for analysis than any other known studies of community costs resulting from growth, it does not explore many intricate questions. The analysis does not treat the costs of expanding facilities in the center of town which must be expanded because they become used more intensively when new growth occurs. Still largely uncharted is the general answer to the question of how much the level of services must be increased to meet the demands of congestion caused by intensified activity following growth.

If in a future study, the cost models of this study are analysed along with the revenue models of J. H. Larson's study /11/, it is likely that more complete understanding than we have now will be gained of the range and magnitude of fiscal problems facing growing communities.

APPENDIX I

TABLE 39

PERSONS PER DWELLING UNIT IN TOWNS OF OVER 25,000 IN MASSACHUSETTS, RHODE ISLAND, AND CONNECTICUT WHOSE POPULATION INCREASED BY OVER 10 PER CENT BETWEEN 1940 AND 1950

	Persons per Dwelling Unit
Revere	3.5
Chicopee	3.4
Newton	3.4
Bristol	3.3.
Stamford	3.3
Waltham	3.3
Worcester	3.2
Middletown	3.2
Cranston	3.2
Quincy	3.2
Warwick	3.2
Beverly	3.1
Norwalk	3.1
Taunton	3.1
Northampton	3.0
Springfield	3.0
Meriden	3.0
Newport	3.0
Median	3.2

Source: County and City Data Book, 1952.

TABLE 40

EMPLOYED PERSONS PER DWELLING UNIT IN TOWNS OF OVER 25,000

IN MASSACHUSETTS, RHODE ISLAND, AND CONNECTICUT

WHOSE POPULATION INCREASED BY OVER 10 PER CENT BETWEEN 1940 AND 1950

Newton	2.12
Warwick	1.60
Chicopee	1.55
Middletown	1.53
Stamford	1.52
Norwalk	1.51
Bristol	1.48
Springfield	1.46
Waltham	1.43
Worcester	1.43
Cranston	1.41
Meriden	1.41
Taunton	1.38
Revere	1.37
Quincy	1.35
Newport	0.99
Median	1.43

Source: County and City Data Book, 1952, U. S. Bureau of the Census. Government Printing Office, Washington, D. C. 1953.

TABLE 41

ROADCOST DATA COMPILED BY A. J. BONE

APPROXIMATE COST OF CONSTRUCTION AND MAINTENANCE

FOR DIFFERENT TYPES OF PAVEMENT[1]

(Surface only - excluding grading and drainage)

Type	Construction Cost		Maintenance Cost		Approx. Traffic Limit Per Day	Probable Life Years
	Per Mile 2-lane (24' wide)	Per Sq. Yd.	Per Mile 2-lane (24' wide)	Per Sq. Yd.		
Gravel	$10,000 to 17,000	$ .80 to 1.30	$350 to 800	$.025 to .057	300	5+
Bit. surface treated gravel	14,000 to 25,000	1.10 to 2.00	350 to 550	.025 to .039	500	8+
Road mix	17,000 to 25,000	1.30 to 2.00	300 to 500	.021 to .035	800	10
Bituminous macadam	24,000 to 35,000	1.90 to 2.70	180 to 350	.013 to .025	3000	17
Bit. conc. on flexible base	35,000 to 45,000	2.70 to 3.50	140 to 350	.010 to .025	Full capacity	20
Bit. conc. on conc. base	50,000 to 60,000	3.90 to 4.70	100 to 200	.007 to .014	"	20
Portland cem. concrete	36,000 to 55,000	2.80 to 4.30	100 to 300	.007 to .021	"	25
Brick on conc. base	70,000 to 130,000	5.50 to 10.00	200 to 300	.014 to .021	"	30
Stone block on conc. base	100,000 to 150,000	8.00 to 12.00	50 to 200	.004 to .014	"	35

Grading and drainage costs range from $15,000 to $150,000 per mile (2-lane) depending upon nature of terrain.

Maintenance costs for other than surface range from $100 for local roads to $600 for trunk highways (2-lane).

Snow removal and sanding costs range from $150 to $750 (2-lane) depending upon climate.

[1] Cost ranges are for 1952 when Engineering News-Record cost index was 575 (1913 base), and U.S. Bureau of Public Roads index for composite mile was 172 (base 1925-29).

Source: Data compiled by Professor A. J. Bone, M.I.T.

TABLE 42

CALCULATION OF DEPRECIATION OF ROADS WITH VARIOUS TYPES OF PAVEMENT

(24' pavement--costs for 1 mile when built in stretch of 5 miles)

	Original Construction Cost	Value at End of Life	Depreciation on Life of Pavement	Life of Pavement
Bituminous Concrete, Concrete Base				
Subbase	$25,000 x $\frac{20}{40}$	$12,500		
Pavement	54,000[1] - 22000[2]	32,000		
Total	$79,000	$44,500	$34,500	20 years
Portland Cement Concrete				
Subbase	$25,000 x $\frac{15}{40}$	$ 9,400		
Pavement	42,000 - 26400	15,600		
Total	$67,000	$25,000	42,000[3]	25
Bituminous Concrete, Flexible Base				
Subbase	$23,500 x $\frac{20}{40}$	$11,800		
Pavement	38,500 -22,000	16,500		
Total	$62,000	$28,300	33,700	20
Bituminous Macadam				
Subbase	$22,500 x $\frac{23}{40}$	$13,000		
Pavement	27,500 - 18300	9,200		
Total	$50,000	$22,200	27,800	17
Road Mix				
Subbase	$20,000 x $\frac{30}{40}$	$15,000		
Pavement	20,000 - 13,100	6,900		
Total	$40,000	$21,900	18,100	10

Footnotes for Table 42

[1]Total cost of original construction of pavement.

[2]Total cost of resurfacing. It is assumed that the new surface will last as long as the original one. Estimates of the cost of resurfacing are based on discussions with Professor A. J. Bone, M.I.T., and Mr. Parker, Massachusetts Public Works Commission:

Bituminous Concrete, Concrete Base and Bituminous Concrete Flexible Base roads resurfaced with Bituminous Concrete $2\frac{1}{2}$" thick at $1.56 per square yard or $22,000 per lineal mile (24' pavement).

Portland Cement Concrete road resurfaced with Bituminous Concrete 3" thick at $26,400 per lineal mile.

Bituminous Macadam road resurfaced with Bituminous Macadam $2\frac{1}{2}$" thick at $18,300 per lineal mile.

Road Mix road resurfaced with Road Mix at $0.92 per square yard or $13,100 per lineal mile.

Estimates based on discussion with A. J. Bone, M.I.T., and Mr. Parker of Massachusetts Public Works Commission.

[3]In this case, the depreciation is understated for with present technology no resurfacing will last as long as the original cement concrete. Average life of resurfacing is but 10-12 years due to transverse reflection cracks over the joints between concrete slabs.

TABLE 42A

ROAD SURFACE MAINTENANCE COST TRENDS WITH AGE

1934 PRICES

	Annual Surface Maintenance Costs per Square Yard in Cents when Age of Pavement Is:					
	2 Years	5 Years	10 Years	15 Years	20 Years	25 Years
Plain Concrete	0.60	2.5	3.0	2.6	2.3	
Asphalt Macadam	0.50	2.80	1.4	2.4	2.6	1.8
Asphaltic Concrete	0.40	0.60	1.4	1.9	1.8	
Reinforced Concrete	0.50	0.60	0.8	1.0		

Note: This data reflects the price levels and technology of 1930-1934. They are presented for information only and should not be used for present-day analysis.

Source: Based on Chart "Massachusetts State Highways Surface Maintenance Cost Trends with Age" from a study prepared under the direction of Professor A. J. Bone, M.I.T. in 1934.

TABLE 43

NONCAPITAL COSTS FOR SANITATION IN MASSACHUSETTS CITIES OF 25-50,000 POPULATION

Waltham	$8.95
Melrose	6.80
Everett	6.48
Chelsea	6.00
Salem	5.70
Beverly	4.78
Taunton	3.84
Chicopee	3.76
Fitchburg	3.50
Gloucester	3.02
Northampton	2.65
Haverhill	2.60

Median Cost: $4.31

"Sanitation" includes street cleaning, sewers, and sewage and waste collection and disposal.

Source: U. S. Bureau of the Census, Compendium of City Government Finances in 1953.

APPENDIX II

Calculation of expected peak traffic load on main road at the intersection of the main road with the subsidiary road.

1. We made the following assumptions:

a. Traffic in sector X is just that traffic caused by the households, industries, and businesses located in the sector. We do not analyze outside traffic passing through our sector.

b. Fifty per cent of the workers who live within a half mile of their employment will walk to work. Ninety per cent of all others will go to work by automobile, the remaining 10 per cent by bus.

c. Each automobile will carry 1.2 workers.

d. During the peak afternoon hours, the total of shopping traffic, traffic due to the transport of goods, and random traffic are assumed to be 20 per cent of all home-work traffic.[1] That is, the total number of trips is equal to 1.2 times the number of work trips.

e. All industrial workers begin their work day at 8 a.m. and end it at 4 p.m. One-third of all other workers begin their work day at 8 a.m. and end at 5 p.m. Two-thirds of all other workers begin their work

---

[1] This, of course, is but a rough general estimate. The proportion between home-work traffic and all traffic at peak traffic hour differs greatly from location to location. Our ratio 1:1.20, is within the range of actual observations. For example the Philadelphia-Camden Area Traffic Survey, 1950, showed that during the peak hour, the total number of trips from a downtown section was 1.12 times the number of work trips. (See Mitchell & Rapkin /26/ p. 33.)

day at 9 a.m. and end at 5 p.m.

The number of busses is neglibible. As a consequence when we calculate the number of vehicles expected assumption 3 and assumption 4 cancel each other. Therefore, in our calculations we disregard the reduction in number of vehicles due to ride-sharing (assumption 3) and also disregard the number of nonwork trips (assumption 4).

2. We analyzed the traffic at ultimate development for two situations:

a. "Normal" home-work pattern (i.e. 350 industrial district workers come from sector X. The rest come from the town.)

Of the workers returning home to sector X:

350 come from the industrial district--all at 4 p.m.-- 40 walk, 310 by auto (310 autos)

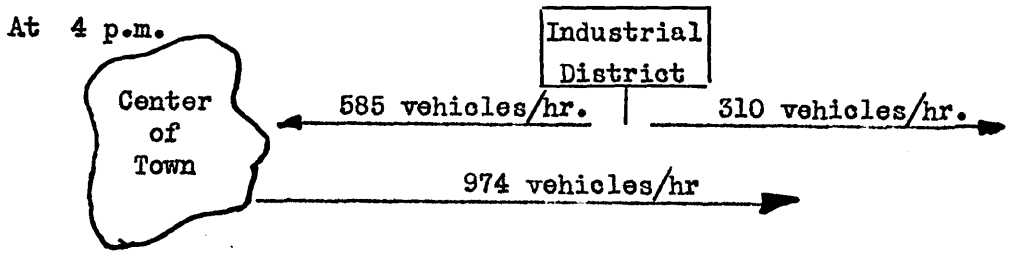
3,190 come from the town--of these 1,080 come at 4 p.m., 970 by auto (970 autos)
110 by bus (4 busses)

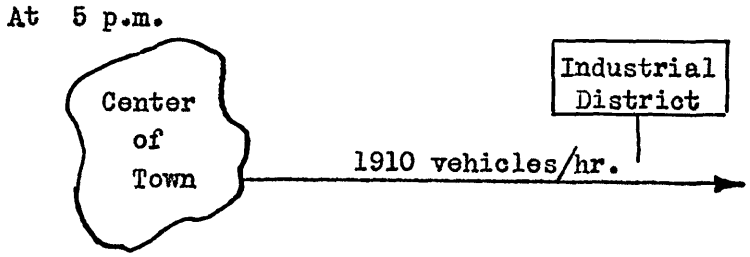
2,110 come at 5 p.m. 1,900 by auto (1,900 autos)
210 by bus (8 busses)

Of the workers going to the central town:

650 come from the industrial district--of these 650 come at 4 p.m.
585 by auto (585 autos)
65 by bus (3 busses)

Therefore, the resulting traffic patterns on the main road are:





b. No workers in the industrial district live in Sector X.

Of the workers returning home to sector X:

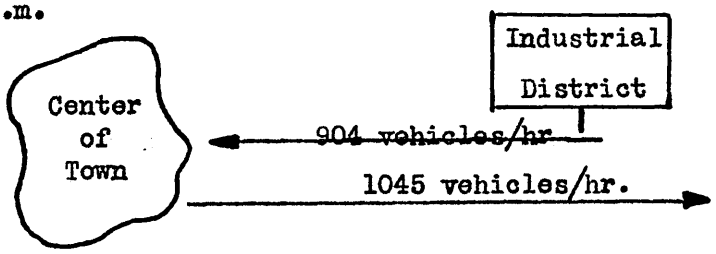
all 3,480 come from the town--of these 1,160 come at 4 p.m.
1,040 by auto (1,040 autos)
120 by bus (5 busses)
of these 2,320 come at 5 p.m.
2,090 by auto (2,090 autos)
230 by bus (9 busses)

Of the workers going to the central town:

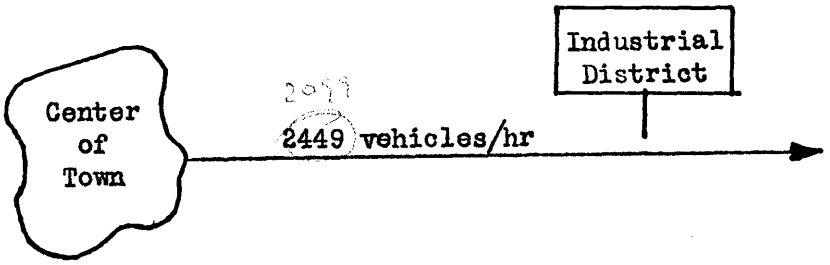
all 1,000 come from the industrial district--of these all 1,000 come at 4 p.m.
900 by auto
(900 autos)
100 by bus
(4 busses)

Therefore, the resulting traffic patterns are:

At 4 p.m.



At 5 p.m.



APPENDIX III

CALCULATIONS OF YEARLY COSTS FOR MODEL 2a-- MEDIUM DENSITY MODEL, CONTINUOUS DEVELOPMENT, LOW STANDARD OF SERVICE

As an example of how we arrived at the yearly costs during the four key years for various models, we present a brief outline of the calculations we made to determine the costs of the medium density model for continuous development (model 2a) with a low standard of services provided.

Reference should be made to Figure 2 and Table 9. Note the sequence of stages of continuous development.

Table 44 outlines the cost calculations for highway right-of-way and for construction of all roads. It is assumed that developers deed to the community the right-of-way for secondary and local roads.

A generous right-of-way (88 feet wide) is allowed for the highway on the principle that undeveloped land is extremely cheap and is good insurance against the demands which may be brought by now predictable future traffic. Land is considered a non-depreciable capital asset, the cost of owning which is the yearly interest cost on its value. As we stipulated in Table 5, secondary roads provide two lanes for moving traffic and two lanes for parking. Local roads provide two lanes for moving traffic, and one lane for parking.

All road lengths were converted to equivalent lengths of 24 foot wide roadway. We assume that all the roads for each stage of development are built at once. Therefor, with the sum of the equivalent lengths of each type of surface for each stage we go to our road cost functions (Charts R 1,2,3) and determine the costs per mile. (Note that economies of scale are achieved from the construction at one time of increased width as well as increased length.) The total construction, yearly depreciation, and yearly interest costs per mile of 24 foot width are listed in columns 3, 5, 6, of Table 44. Total yearly capital cost (Column 8) for each stretch of road is calculated by multiplying the length of road (Column 2) by the sums of the yearly capital costs per mile (Col. 7). These yearly costs are then listed in the table of Detailed Total Yearly Costs, Table 55, lines 2-6.

Maintenance cost of roads is calculated on the total equivalent length of road. Economies of scale index for this length is got from Chart R-4; basic maintenance costs per mile from Table 19. Yearly maintenance costs are calculated in Table 45 and listed on line 51 of the Table of Detailed Total Yearly Costs Table 55.

Four and one-half foot cement sidewalks are constructed on both sides of all roads. Yearly Capital Costs are derived in Table 46 from unit cost data taken from Table 22. Yearly capital costs are listed in lines 7-10 of the Table of Detailed Total Yearly Costs, Table 55.

Requirements for sewerage treatment plant are calculated assuming average requirements of residential, commercial and industrial areas. (See Table 47) We assume that cost of a large efficient plant described on page 106 are applicable. Yearly costs are listed in line 11, of the Table of Detailed Total Yearly Costs, Table 55.

Table 48 summarizes the calculations of sewer pipe capacity. Requirements for sewer pipe are calculated using normal requirements from Table 8. Capacity required is calculated roughly at the four points in the developing area shown in figure 2. Size of pipe required for these capacities is derived from Nutter's equation assuming N = 0.13, slope = 2/1000.

Calculations of the detailed requirements for sewer pipe are shown in Table 49. Calculations of the cost of sewer pipe are shown in Table 50. Units Costs are taken from Table 32.

The schedule of expected school children (Table 4) is the starting point for the determination of school requirements. To satisfy its requirements a construction schedule was developed (Table 51). The floor area of school required for its stipulated pupil capacities is determined from Chart S-1. For this model, low level of service is stipulated (65 sq. ft. per pupil for elementary schools, 105 sq. ft. per pupil for secondary schools). Depreciation and interest costs per square foot per year for these schools are derived from Charts S-4 and S-5. These costs and the total yearly capital cost are summarized in Table 52. Yearly school

capital costs for model 2a are listed in lines 16-21 in the Table of Detailed Total Yearly Costs, Table 55.

Noncapital costs for schools are derived for each school from the low-level of service curve of Chart S-6. The S-6 chart for senior high school costs was used to derive all combined secondary school costs. For example, in year 15, 495 pupils can be educated in one secondary school for $280 apiece according to the low level of service line of Chart S-6 for senior high schools. This is a total cost of $139,000. Similarly, in year 20, 658 students can be educated in one secondary school for $175,000 or for only $265 apiece. These costs are listed on line 57 of the Table of Detailed Total Yearly Costs, Table 55.

Fire protection cost is calculated for a low level of service from the per capita data of Table 33.

All other costs (lines 52, 59-65 of Table 55) are got by multiplying the per capita costs of Table 12 by the number of people who we posit will be linving in sector x during the year we analyze.

These costs are the same for all our models. For convenience in computing the costs of other models, we have summarized the standard cost items #58-65:

	Year 5	Year 10	Year 15	Year 20
Cost items #58-65	$109,220	$218,440	$327,650	$436,800

All costs listed in the Table of Detailed Total Yearly Costs, Table 55 are then totaled.

TABLE 44

CALCULATION OF YEARLY CAPITAL COST OF ROADS FOR MODEL 2a

(Continuous Development, low standard of service)

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	
	Equivalent Length	Total Construction Cost Per Mile	Total	Yearly Depreciation Per Mile	Yearly Interest Per Mile @ 2¼ Per Cent	Total Yearly Capital Costs Per Mile	Total Yearly Capital Costs	
STAGE I								
Buy Right of Way 64' x 5800' = 371,000 sq.ft or 8.51A	(8.51A)	($300/A)			($7/A)			(60)
Construct 2900' highway 44' pavement, Port. Cem. Conc.	1.01	$79,000	$ 80,000	$1,980	$1,220	$3,200	$3,230	
6180' secondary road, 38' pavement, Bit. Mac.	1.81	47,000	85,000	1,550	770	2,320	4,200	
25,290' local road, 30' pavement, Bit. Mac.	5.98		282,000				13,900	$21,330
STAGE II								
Construct 6180' secondary road 38' pavement, Bit. Mac.	1.81	47,000	85,000	1,550	770	2,320	4,200	
25,290' local road, 30' pavement, Bit. Mac.	5.98		282,000				13,900	18,100
STAGE III								
Construct 2900' highway 44' pavement Port. Cem.	1.01	79,000	80,000	1,980	1,220	3,200	3,230	
6180' secondary road, 38' Bit. Mac.	1.81	47,000	85,000	1,550	770	2,320	4,200	
25900' local road, 30' pavement, Bit. Mac.	6.12		287,000				14,200	21,630
STAGE IV								
Construct 6180' secondary road, 38' pavement, Bit. Mac.	1.81	47,000	85,000	1,550	770		4,200	
25980' local road, 30' pavement, Bit. Mac.	6.12		287,000				14,200	18,400

TABLE 45

CALCULATION OF YEARLY MAINTENANCE COST OF ROADS FOR MODEL 2a

(CONTINUOUS DEVELOPMENT, LOW STANDARD OF SERVICE)

	Total Equiv. Miles	Economy of Scale Index	Cost per Mile	Total Cost	
Year 5					
Portland Cement	1.01	.99	$550[1]	$ 550	
Bituminous Macadam	7.79	.99	520	4,000	
	8.80			4,550	
Year 10					
Portland Cement	1.01	.98	550[1]	545	
Bituminous Macadam	15.58	.98	520	7,930	
	16.59			8,475	or 8,480
Year 15					
Portland Cement	2.02	.98	550[1]	1,090	
Bituminous Macadam	23.51	.98	520	12,000	
	25.53			13,090	or 13,100
Year 20					
Portland Cement	2.02	.98	550[1]	1,090	
Bituminous Macadam	31.44	.98	520	16,000	
	33.46			17,090	or 17,100

[1]Main road.

TABLE 46

CALCULATION OF YEARLY CAPITAL COST OF SIDEWALKS AND CURBS

FOR MODEL 2a

(CONTINUOUS DEVELOPMENT, LOW STANDARD OF SERVICES)

	Yearly Interest and Depreciation per Mile
Sidewalks--4½ feet wide	$344
Curbs (cement)	328
	$672

Sidewalks and curbs to be constructed on both sides of all roads.

Year	Miles of New Sidewalk and Curb	Yearly Cost per Mile	Total New Cost
5	8.80 x 2	$672	$11,800
10	7.79 x 2	672	10,500
15	9.03 x 2	672	12,100
20	7.93 x 2	672	10,700

TABLE 47

CALCULATION OF CAPITAL COST OF SEWAGE TREATMENT PLANT FOR MODEL 2a

(Continuous Development, Low Standard of Service)

	Sewerage Requirement			Yearly Capital Cost @ $4430/mgd
Year 5				
Domestic	620 DU x 3.2 P/DU	x 250 gpcpd	= 496,000 mgd	
Commercial		x 14000 gad	=	
Industrial	57A x .4	x 10000 gad	= 224,000	
			720,000	$ 3,180
Year 10				
Domestic	1,240 x 3.2 x 250		= 992,000	
Commercial	2.5 x 14,000		= 35,000	
Industrial	57 x .6 x 10,000		= 342,000	
			1,369,000	6,070
Year 15				
Domestic	1,860 x 3.2 x 250		=1,490,000	
Commercial	.5 x 14,000		= 70,000	
Industrial	57 x .8 x 10,000		= 456,000	
			2,016,000	8,920
Year 20				
Domestic	2,480 x 3.2 x 250		=1,980,000	
Commercial	5 x 14,000		70,000	
Industrial	57 x 1.0 x 10,000		570,000	
			2,620,000	11,150

TABLE 48

CALCULATION OF SEWER PIPE REQUIREMENTS FOR COMBINED SEWER SYSTEM FOR MODEL 2a AT FULL DEVELOPMENT

Assume High Sewerage Requirements (i.e. Domestic = 330 gcd; commercial = 20,000 gad; industrial = 16,000 gad).
For Use in Kutters Formula, Assume n = 0.013, average slope = 2/1000.
For Location of Points S_1, S_2, S_3, see figure 2.

	At Point S_1		At Point S_2		At Point S_3	
Sanitary Sewage						
Domestic	2480 DU x 3.2p/DU x 330 gcd	= 2.62 mgd	1240 x 3.2 x 330	= 1.31	1860 x 3.2 x 330	= 1.96
Industrial	57A x 16,000 gad	= 0.9				
Commercial	5A x 20,000 gad	= 0.1	5A x 20,000	= 0.1	5 x 20,000	= 0.1
Storm Sewage	Q^1 = ACi = 672 x 1.2 x .55x 2.5 x 30 x 60 x 7.48	=15.0		11.2		7.5
		18.63 mgd		15.26 mgd		8.9 mgd
Therefore according to Kutter's formula,	30" pipe necessary		27" pipe necessary		22" pipe necessary	

l_A = Total Area including streets = 672 A x 1.2
C = runoff coefficient = .55
i = intensity = 2.5 inches/hour

TABLE 49

CALCULATION OF SEWER PIPE REQUIREMENTS FOR COMBINED SEWER SYSTEM FOR MODEL 2a

Assume low requirements (i.e. domestic = 200 gcd, commercial = 8000 gad, industrial = 6000 gad).
For use in Kutters formula, assume n = 0.013, average slope = 2/1000.
For location of Points S_1, S_2, S_3 see Figure 2.

	At Point S_1	At Point S_2	At Point S_3
Sanitary Sewage			
Domestic	2480 DU x 3.2 p/DU x 200 gcd = 1.59 mgd	1860 x 3.2 x 200 = 1.19	1240 x 3.2 x 200 = 0.79
Industrial	57A x 6000 gad = 0.34 mgd		
Commercial	5A x 8000 gad = 0.04 mgd	5A x 8000 gad = 0.04	5A x 8000 gad = .04
Storm Sewage	(as in Table 48) =15.0 mgd	11.20	7.5
	16.97mgd	12.43	8.33
Therefore according to Kutter's formula,	30" pipe required	27" pipe required	22" pipe required

TABLE 50

CALCULATION OF YEARLY CAPITAL COST

OF SEWER PIPE MODEL 2a (CONTINUOUS DEVELOPMENT)

Diameter	Length	Depth	Cost/Foot	Total Cost	Yearly Cost
STAGE I					
36"	2,900'	10'	$18.50	$ 53,600	
33"	2,000'	10'	17.00	34,000	
27"	1,000'	8'	14.00	14,000	
10"	8,500'	6'	5.25	44,600	
8"	17,400'	6'	4.50	78,300	
				$224,500 x 2.95%	$6,620
STAGE II					
27"	1,500'	8'	14.00	21,000	
10"	1,500'	8'	6.50	9,800	
10"	8,500'	6'	5.25	44,600	
8"	17,400'	6'	4.50	78,200	
				153,600	4,520
STAGE III					
8"	26,100'	6'	4.50	117,000	3,450
STAGE IV					
8"	26,100'	6'	4.50	117,000	3,450

TABLE 51

SCHOOL CONSTRUCTION SCHEDULE FOR MODEL 2a

Number of School Children Expected (from Table 5)		Construction Schedule	
Year 5			
Kindergarten and Elementary	206	1 Elementary	210 Pupil Capacity
Secondary School			
Junior High	86	1 Secondary	180 Pupil Capacity
High School	79		
Year 10			
Kindergarten and Elementary	412	1 Elementary (addition)	210 Pupil Capacity
Secondary School			
Junior High	172		
High School	158	1 Secondary (addition)	180 Pupil Capacity
Year 15			
Kindergarten and Elementary	618	1 Elementary	210 Pupil Capacity
Secondary School			
Junior High	258	1 Secondary	
High School	237	(addition)	180 Pupil Capacity
Year 20			
Kindergarten and Elementary	824	1 Elementary (addition)	210 Pupil Capacity
Secondary School			
Junior High	342	1 Secondary	140 Pupil Capacity
High School	315	(addition)	

TABLE 52

CALCULATION OF CAPITAL COSTS OF SCHOOLS FOR MODEL 2a

(Continuous Development, Low Standard of Service)

	Capacity (Pupils)	Total Area[1] (Sq.Ft.)	Yearly Depreciation[2]		Yearly Interest at 2¼ Per Cent[3]		Total Yearly Capital Cost
Elementary School	210	13,600	$.322	$4,400	$.250	$3,400	$7,800
Secondary School	180	18,800	.340	6,400	.248	4,670	11,070
Secondary School Addition[4]	140	14,500	.344	4,990	.252	3,660	8,650

[1]At low level of service from Chart S-1

[2]From Chart S-4

[3]From Chart S-5

[4]It is likely that an addition would cost less per square foot than a complete school building. Although our data is not sensitive enough to show this differential, it is the best data we have. Therefore, we use it but realize that the cost is probably overstated.

TABLE 53

DETAILED TOTAL YEARLY COSTS FOR LOW DENSITY MODEL CONTINUOUS DEVELOPMENT (Model 1a) AT LOW STANDARD OF SERVICE

	CAPITAL COSTS	Year 5	10	15	20
1.	Interest on right of way	$ 200	$ 200	$ 200	$ 200
2.	Main Road	5,740	5,740	11,480	11,480
3.	Subsidiary Road Stage 1	24,600	24,600	24,600	24,600
4.	" " " 2	0	24,000	24,000	24,000
5.	" " " 3	0	0	24,000	24,000
6.	" " " 4	0	0	0	24,000
7.	Sidewalks Stage 1	9,750	9,750	9,750	9,750
8.	" " 2	0	7,460	7,460	7,460
9.	Sidewalks Stage 3	0	0	9,750	9,750
10.	" " 4	0	0	0	7,260
11.	Sewerage Plant	1,160	2,000	2,820	3,480
12.	Sewers Stage 1	1,110	1,110	1,110	1,110
13.	" " 2	0	0	0	0
14.	" " 3	0	0	830	830
15.	" " 4	0	0	0	0
16.	Elementary Schools Stage 1	7,800	7,800	7,800	7,800
17.	" " " 2	0	7,800	7,800	7,800
18.	" " " 3	0	0	7,800	7,800
19.	" " " 4	0	0	0	7,800
20.	Secondary School A	11,070	22,140	22,140	22,140
21.	" " B			11,070	19,720
	TOTAL	61,480	112,600	172,600	220,950
	Sum of items #1-#15	42,610	74,860	116,000	147,920

OPERATING COSTS[1]

51. Roads		$ 6,510	12,210	18,720	24,220
52. Sanitation		3,260	5,650	7,970	9,850
53. Elementary School Stage	1	40,200	72,000	72,000	72,000
54. " " " "	2	0			
55. " " " "	3	0	0	40,200	72,000
56. " " " "	4	0	0	0	
57. Secondary Schools		64,400	104,000	139,000	175,000
58. Fire Protection		7,500	15,000	22,600	30,000
59-65 Standard Cost Items[2]		109,220	218,400	327,650	436,800
TOTAL		231,090	427,260	628,140	819,870
TOTAL YEARLY COSTS		292,570	539,860	800,750	1,040,850

[1] Capital costs are included in items 52, 58, and 59-65.

[2] See Table 55

TABLE 54

DETAILED TOTAL YEARLY COSTS FOR LOW DENSITY CONTINUOUS DEVELOPMENT MODEL (Model 1b) AT HIGH STANDARD OF SERVICE

Capital costs	Year 5	10	15	20
1-15 Standard Cost items	$ 42,610	74,860	116,000	148,920
16. Elementary Sch. Stage 1	11,830	11,830	11,830	11,830
17. " " " 2	0	11,830	11,830	11,830
18. " " " 3	0	0	11,830	11,830
19. " " " 4	0	0	0	11,830
20. Secondary School A	15,160	30,320	30,320	30,320
21. " " B	0	0	15,160	27,180
TOTAL	69,600	128,840	196,950	253,740
Operating costs				
51. Roads	6,510	12,210	18,720	24,220
52. Sanitation	3,260	5,650	7,970	9,850
53. El. Sch. Stage 1	62,200	113,000	113,000	113,000
54. " " " 2	0			
55. " " " 3	0	0	62,200	113,000
56. " " " 4	0	0		
57. Secondary Schools	98,300	160,000	213,000	270,000
58. Fire Protection	18,000	35,900	53,700	71,700
59-65 Standard Cost Items	109,220	218,400	327,650	436,800
TOTAL	297,490	545,160	796,240	1,038,570
TOTAL YEARLY COSTS	367,090	674,000	993,190	1,291,310

TABLE 55

DETAILED TOTAL YEARLY COSTS FOR MEDIUM DENSITY CONTINUOUS DEVELOPMENT MODEL (Model 2a) AT LOW STANDARD OF SERVICE

CAPITAL COSTS	Year 5	10	15	20
1. Interest on Land and Right of Way for Main Road	$ 60	$ 60	$ 60	$ 60
2. Main Road	3,240	3,240	6,480	6,480
3. Subsidiary Road Stage 1	21,330	21,330	21,330	21,330
4. " " " 2	0	18,100	18,100	18,100
5. " " " 3	0	0	21,630	21,630
6. " " " 4	0	0	0	18,400
7. Sidewalks Stage 1	11,880	11,880	11,800	11,800
8. " " 2	0	10,500	10,500	10,500
9. " " 3	0	0	12,100	12,100
10. Sidewalks Stage 4	0	0	0	10,700
11. Sewage Treatment Plant	3,180	6,070	8,920	11,150
12. Sewers Stage 1	6,220	6,220	6,220	6,220
13. " " 2	0	4,520	4,520	4,520
14. " " 3	0	0	3,450	3,450
15. " " 4	0	0	0	3,450
16. Elementary Schools Stage 1	7,800	7,800	7,800	7,800
17. " " " 2	0	7,800	7,800	7,800
18. " " " 3	0	0	7,800	7,800
19. " " " 4	0	0	0	7,800[1]
20. Secondary School A	11,070	22,140	22,140	22,140
21. Secondary School B	0	0	11,070	19,720
TOTAL	64,780	119,680	181,720	233,950
Sum of Items #1-#15	45,910	81,920	125,110	160,890

[1] Since this item represents an addition to existing building, its cost would probably be less than shown.

OPERATING COSTS

51. Roads	$ 4,550	8,480	13,100	17,100
52. Sanitation	8,600	17,200	25,800	34,400
53. El. Sch. Stage 1	40,200	72,000	72,000	72,000
54. " " " 2	0			
55. " " " 3	0	0	40,200	72,000
56. " " " 4	0	0	0	0
57. Secondary Schools	64,400	104,000	139,000	175,000
58. Fire Protection	7,500	15,000	22,600	30,000
59. Police Protection	15,300	30,600	45,900	61,200
60. General Government Cost	8,500	17,000	25,500	34,000
61. Recreation	6,550	13,100	19,650	26,200
62. Health and Hospitals	6,000	12,000	18,000	24,000
63. Welfare	53,000	106,000	159,000	212,000
64. Libraries and Gen'l Public Bldgs.	5,570	11,100	16,700	22,200
65. Other [1]	14,300	28,600	42,900	57,200
TOTAL	234,470	435,080	640,350	837,300
TOTAL YEARLY COSTS	299,250	554,760	822,070	1,071,250
Sum of Items #59-#65 (Standard Cost Items)	109,220	218,400	327,650	436,800

[1] See page 46

TABLE 56

DETAILED TOTAL YEARLY COSTS FOR MEDIUM DENSITY JUMP DEVELOPMENT MODEL (Model 2b)

AT LOW STANDARD OF SERVICE

CAPITAL COSTS	Year 5	10	15	20
1. Interest on Land and Right of Way for Main Road	$ 60	$ 60	$ 60	$ 60
2. Main Road	6,140	6,140	6,140	6,140
3. Subsidiary Road Stage 1	22,050	22,050	22,050	22,050
4. " " " 2	0	21,700	21,700	21,700
5. " " " 3	0	0	14,600	14,600
6. " " " 4	0	0	0	14,400
7. Sidewalks Stage 1	11,800	11,800	11,800	11,800
8. " " 2	0	10,500	10,500	10,500
9. " " 3	0	0	12,100	12,100
10. " " 4	0	0	0	10,700
11. Sewage treatment plant	3,180	6,070	8,920	11,150
12. Sewers Stage 1	8,250	8,250	8,250	8,250
13. " " 2	0	2,740	2,740	2,740
14. " " 3	0	0	4,340	4,340
15. " " 4	0	0	0	2,740
16. Elementary Schools Stage 1	7,800	7,800	7,800	7,800
17. " " " 2	0	7,800	7,800	7,800
18. " " " 3	0	0	7,800	7,800
19. " " " 4	0	0	0	7,800
20. Secondary Schools	11,070	22,140	22,140	22,140
	0	0	11,070	19,720
TOTAL	70,350	127,050	179,810	226,330
Sum of #1-#15	51,480	89,310	123,200	153,270

OPERATING COSTS

51. Roads	$ 6,100	11,100	14,100	17,100
52. Sanitation	8,600	17,200	25,800	34,400
53. El. Sch. Stage 1	40,200	72,000	72,000	72,000
54. " " " 2	0			
55. " " " 3	0	0	40,200	72,000
56. " " " 4	0	0	0	
57. Secondary School	64,400	104,000	139,000	175,000
58. Fire Protection	7,500	15,000	22,600	30,000
59-65 Standard Cost Items	109,220	218,400	327,650	436,800
TOTAL	236,020	437,700	641,350	857,300
TOTAL YEARLY COST	306,370	564,750	821,160	1,064,630

TABLE 57

DETAILED TOTAL YEARLY COSTS FOR MEDIUM DENSITY CONTINUOUS DEVELOPMENT MODEL (Model 2c) AT HIGH STANDARD OF SERVICE

CAPITAL COSTS	Year 5	10	15	20
1-15 Standard Cost Items	$ 45,910	81,920	125,110	160,890
16. Elementary School Stage 1	11,830	11,830	11,830	11,830
17. " " " 2	0	11,830	11,830	11,830
18. " " " 3	0	0	11,830	11,830
19. " " " 4	0	0	0	11,830
20. Secondary School A	15,160	30,320	30,320	30,320
21. " " B	0	0	15,160	27,180
TOTAL	72,900	135,900	206,080	264,710
OPERATING COSTS				
51. Roads	4,550	8,480	13,100	17,100
52. Sanitation	8,600	17,200	25,800	34,400
53. Elementary Sch. Stage 1	62,200	113,000	113,000	113,000
54. " " " 2	0			
55. " " " 3	0	0	62,200	113,000
56. " " " 4	0	0	0	
57. Secondary Schools	98,300	160,000	213,000	270,000
58. Fire Protection	18,000	35,900	53,700	71,700
59-65 Standard Cost Items	109,220	218,400	327,650	436,800
TOTAL	300,870	552,980	808,450	1,056,000
TOTAL YEARLY COSTS	373,770	688,880	1,014,530	1,320,710

TABLE 58

DETAILED TOTAL YEARLY COSTS FOR MEDIUM DENSITY JUMP DEVELOPMENT MODEL (Model 2d)

AT HIGH STANDARD OF SERVICE

CAPITAL COSTS	Year 5	10	15	20
1-15 Standard Cost Items	$ 51,480	89,310	123,200	153,270
16. Elementary Schools Stage 1	11,830	11,830	11,830	11,830
17. " " " 2	0	11,830	11,830	11,830
18. " " " 3	0	0	11,830	11,830
19. " " " 4	0	0	0	11,830
20. Secondary School A	15,160	30,320	30,320	30,320
21. " " B	0	0	15,160	27,180
TOTAL	78,470	143,290	204,170	259,090
OPERATING COSTS				
51. Roads	6,100	11,100	14,100	17,100
52. Sanitation	8,600	17,200	25,800	34,400
53. Elementary Schools Stage 1	62,200	113,000	113,000	113,000
54. " " " 2				
55. " " " 3	0	0	62,200	113,000
56. " " " 4	0	0		
57. Secondary Schools	98,300	160,000	213,000	270,000
58. Fire Protection	18,000	35,900	53,700	71,700
59-65 Standard Cost Items	109,220	218,400	327,650	436,800
TOTAL	302,420	555,600	809,450	1,056,000
TOTAL YEARLY COSTS	380,890	698,890	1,013,620	1,314,950

DETAILED TOTAL YEARLY COSTS FOR HIGH DENSITY CONTINUOUS DEVELOPMENT MODEL (Model 3a) AT LOW STANDARD OF SERVICE

CAPITAL COST	Year 5	10	15	20
1. Interest on Land and Right of way for Main Road	$ 30	30	30	30
2. Main Road	1,880	1,880	3,760	3,760
3. Subsidiary Roads Stage 1	7,490	7,490	7,490	7,490
4. " " " 2	0	7,490	7,490	7,490
5. " " " 3	0	0	7,080	7,080
6. " " " 4	0	0	0	7,080
7. Sidewalks Stage 1	5,400	5,400	5,400	5,400
8. " " 2	0	4,520	4,520	4,520
9. " " 3	0	0	5,170	5,170
10. " " 4	0	0	0	4,280
11. Sewage Treatment Plant	3,180	6,070	8,920	11,150
12. Sewers Stage 1	2,460	2,460	2,460	2,460
13. " " 2	0	1,730	1,730	1,730
14. " " 3	0	0	1,100	1,100
15. " " 4	0	0	0	1,100
16. Elementary Schools Stage 1	7,800	7,800	7,800	7,800
17. " " " 2	0	7,800	7,800	7,800
18. " " " 3	0	0	7,800	7,800
19. " " " 4	0	0	0	7,800
20. Secondary School A	11,070	22,140	22,140	22,140
21. Secondary School B	0	0	11,070	19,720
TOTAL	39,310	74,810	111,760	142,900
Sum of Items #1-#15	20,440	37,070	55,150	69,840

OPERATING COSTS

51. Roads	$ 1,880	3,290	4,970	6,370
52. Sanitation	8,600	17,200	25,800	34,400
53. Elementary School Stage 1	40,200	72,000	102,000	132,000
54. " " " 2	0			
55. " " " 3	0	0		
56. " " " 4	0	0	0	
57. Secondary Schools	64,400	104,000	139,000	175,000
58. Fire Protection	7,500	15,000	22,600	30,000
59-63 Standard Cost Items	109,220	218,400	327,650	436,800
TOTAL	231,800	429,890	622,020	814,570
TOTAL YEARLY COSTS	271,110	504,700	733,780	957,470

TABLE 60

DETAILED TOTAL YEARLY COSTS FOR HIGH DENSITY CONTINUOUS DEVELOPMENT MODEL (Model 3b AT HIGH STANDARD OF SERVICE

CAPITAL COSTS	Year 5	10	15	20
1-15 Standard Cost Items	$ 20,440	37,070	55,150	69,840
16. Elementary School Stage 1	11,830	11,830	11,830	11,830
17. " " " 2	0	11,830	11,830	11,830
18. " " " 3	0	0	11,830	11,830
19. " " " 4	0	0	0	11,830
20. Secondary School A	15,160	30,320	30,320	30,320
21. Secondary School B	0	0	15,160	27,180
TOTAL	47,430	91,050	136,120	174,660
OPERATING COSTS				
51. Roads	1,880	3,290	4,970	6,370
52. Sanitation	8,600	17,200	25,800	34,400
53. Elementary School Stage 1	62,200	113,000	161,000	206,000
54. " " " 2	0			
55. " " " 3	0	0		
56. " " " 4	0	0	0	
57. Secondary Schools	98,300	160,000	213,000	270,000
58. Fire Protection	18,000	35,900	53,700	71,700
59-63 Standard Cost Items	109,220	218,400	327,650	436,800
TOTAL	298,200	547,790	786,120	1,025,270
TOTAL YEARLY COSTS	345,630	638,840	922,240	1,199,930

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