A TECHNIQUE FOR DETERMINING THE OPERATING CAPACITY
OF SECONDARY-SCHOOL BUILDINGS

DISSERTATION
Presented in Partial Fulfillment of the Requirements
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By

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M.J.C.
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A TECHNIQUE FOR DETERMINING THE OPERATING CAPACITY
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CHAPTER 1
THE PROBLEM

Need for the Study

The tremendous increase in elementary school enrollments in all
sections of the country during the past few years has brought with it
many serious building and housing problems. Our secondary schools are
beginning to face similar problems and such problems will undoubtedly
increase, both in number and complexity, for the next 10 to 15 years.
With continuing high birth rates, it is difficult to predict when sec-
ondary schools will experience peak enrollments.

To this problem of providing quantitatively adequate facilities
to meet expanding secondary-school enrollments is added the problem of
building to meet the changing needs of the modern secondary-school cur-
riculum. Thus, we find the secondary school faced with both quantita-
tive and qualitative needs. We need not only additional rooms to house
our increasing enrollments but also additional rooms which are adapted
to the needs of the modern secondary-school curriculum.

Most communities, then, will be faced with the necessity of deter-
mining accurately their local school building needs. It is difficult
to imagine local communities undertaking extensive building programs
without making some survey of local needs, but, the extensiveness of
such surveys varies considerably from one community to another. Administrators are becoming increasingly aware of the need for outside assistance in the assessment of the school building needs of their communities, and are calling upon educational consultants to assist with this complex problem.

Until the last quarter century relatively little attention was given to the planning of buildings to meet the specific educational requirements of the school program in a given community. Frequently architects were given no more instructions from the board of education than to plan a new high-school building. In fact architects are still being asked to plan school buildings with little more than their own personal knowledge of what types of activities will be carried on in the buildings. However, administrators and school boards are becoming increasingly aware of the need for educational planning and the development of educational specifications which will help architects to plan more functional school plants, and are increasingly accepting responsibility for such educational planning.

Numerous methods have been employed in doing this educational planning. Some administrators have called upon their local staffs to do the job. Others have made it a cooperative venture of the staff and lay committees of the community. Still others are recognizing the need for outside assistance, and employ educational consultants to assist in this important task. Even though outside assistance is employed, the role of local staff and lay groups cannot be ignored.
If communities with or without outside assistance are to assess accurately their school building needs and then plan buildings to meet those needs, one of the most important problems which has to be faced is that of translating the educational program into quantitative space requirements. The translation of educational program into quantitative room requirements has long been an accomplished fact in the planning of new school buildings. However, the determination of operating capacities of existing buildings has never been so related to educational program, in spite of the fact that the relationship is almost identical.

Utilization studies have been used extensively to determine in a general way whether a given building is overcrowded. However, existing building utilization techniques, when used to arrive at estimates of capacities have certain shortcomings.

First, utilization techniques are based upon abstract standards of space per child and authorities do not agree upon these space allotments. Furthermore, the actual space per child varies according to the type of educational program being carried on. For example, a social studies class of 25 pupils using the lecture-recitation method would need much less space than a similar social studies class of 25 pupils using the activity approach to learning.

Secondly, utilization techniques fail to consider the degree to which the building is adaptable to the educational program. A building utilization study may show a low percentage of utilization indicating much unused space in the building. However, if the educational program
does not require the types of spaces which are in excess, the excess space can hardly be used to increase the operating capacity of the existing building unless such excess spaces are sufficient in quantity and can be adapted to other use. The utilization technique assumes interchangeability of spaces.

Thirdly, utilization techniques assume that it is feasible and educationally sound to adjust class size to size of room. Utilization techniques usually are based solely upon space allotments per pupil to determine the capacity of a room. This approach gives a distorted picture of operating capacity when the educational policies of the school system limit class size to a given number. It is true that scientific studies have failed to justify the educational practice of limiting class size, yet few educators doubt the desirability of limiting class sizes in most subjects, especially where an attempt is being made to shift from the lecture-demonstration method of teaching to more modern techniques.

Most of the shortcomings discussed above can be minimized to a certain extent by variations of the utilization study. However, the final criticism or shortcoming which is to be discussed is basic to the approach of using the utilization study in determining secondary-school building capacities. It is generally agreed that 100 per cent utilization is impractical. Therefore, before the utilization study can be used to determine capacity, some standard of optimal per cent of utilization must be established. No such standard has been generally accepted. Existing standards are based upon status studies of conditions as they now exist. Surely average conditions as they now exist are not a valid approach to
setting the optimal per cent of utilization, since the average implies both higher and lower per cents of utilization. This use of status studies in determining standards of optimal use of buildings is even more questionable in view of the fact that most existing buildings were not scientifically planned for the educational programs being carried on in them.

Morphet suggested a table of tentative maximum per cents of pupil station and room utilization for both regular and special rooms (23:80-92). On the basis of principals' judgments and other data he selected a number of schools which had reached their "optimal" capacity, and then established his standard as the 75th percentile for pupil station utilization and the 90th percentile for room utilization. The question naturally arises, why wasn't the highest reported percentage of utilization chosen for the standard?

If one person can schedule a certain room or type of room every period of the day, why is it impossible in other schools. In most cases, the highest utilization recorded in the various areas was 100 per cent, or very close to 100 per cent. This observation suggests a lack of complete understanding of this factor. Another weakness in this method of arriving at an optimal per cent of utilization is that principals' judgments as to when a building has reached its capacity is a questionable criterion. Buildings have been known to have 50 to 60 per cent overloads (over principals' judgment of capacity) without tangible evidence of the effect of such overloading on the effectiveness of the educational program (16:1116).
It is generally agreed by most authorities in the school plant field that school buildings should be planned in terms of the educational program to be carried on in the building (1:13, 3:343, 25:26-38). If we accept this basic principle, the corollary follows that the capacity of a given building is a direct function of the educational program to be carried on in that building. From this basic principle as a point of reference, the question arises whether an optimal per cent of utilization exists which is applicable to secondary-school buildings in general. It suggests that the maximum per cent of utilization may be no more than the measure of chance relation of existing buildings to their educational programs.

That such an optimal per cent of utilization does exist is a basic assumption underlying the utilization technique for determining capacities of secondary-school buildings. On the surface at least this assumption appears to be contrary to a basic principle almost universally accepted in the school plant field.

From the preceding discussion it would seem that the capacity technique based upon the utilization study, at best, will give only rough approximations of the operating capacities of secondary-school buildings and fails completely to take into consideration differences in the educational programs conducted in different buildings.

It should be pointed out at this time that the criticisms mentioned above are not criticisms of utilization studies in general but of the use of utilization studies to determine capacities. Utilization studies have numerous valid uses. Most utilization techniques have been patterned
after the Morphet technique. In his study Morphet has the following
to say about its use:

It should provide him (the superintendent) with a
convenient method of making, at periodic intervals, a
detailed analysis of the conditions in his school build-
ings. It is only through some such careful analysis that
wasteful and undesirable practices or conditions either
in the educational program or in the buildings will be
prevented from being continued merely on the basis of
tradition.

It will provide him with important measures of the
efficiency of his administration, of the adjustment of
his buildings to his educational program, and the adequacy
of his policies.

It will provide him with a convenient and objective
means of securing and presenting to the board of education
reliable and convincing data to show:

(a) Whether new or different equipment is advis-
able for any type of room.

(b) Whether building alterations are needed.

(c) Whether a new building or an addition to the
present structure is needed.

(d) Whether certain policies should be adopted,
continued, or discontinued.

(e) How certain conditions in the local school
plant compare with conditions in school plants
in other cities. (23:93)

Concerning the utilization study as a proposed measure of capac-
ity, Morphet indicated that capacity is almost entirely relative to the
program of the school and to the building which houses it, and that
normal capacities may be considerably changed by changes in the educa-
tional program (23:90).
Scope of the Study

The problem of this study is to relate capacity to functional use of the building and to develop a formula or technique for determining the operating capacity of a secondary-school building in relation to a given educational program. After developing such a formula or technique, there will be developed as a part of this study a series of forms and work sheets so that the formula may be easily applied. In order to clarify the use of the formula and its varied applications, the formula will be applied in a number of specific school situations. Finally, a preliminary evaluation of the technique will be made in the light of these applications.

Limits of the Study

Certain arbitrary limits have been placed upon the study to make it more definitive and meaningful.

The investigation is confined to studying capacities for regularly scheduled activities and therefore will include only those rooms designed for or potentially available for regularly-scheduled instructional activities. This may or may not include clubs and similar activities depending upon the nature of the individual school program.

The study will not be concerned with the determination of standards of desirability or adaptability of rooms for particular uses. Such questions will have to be answered in the light of additional information which is beyond the scope of this study. For similar reasons the
study is not concerned with setting standards for size of rooms or size of classes.

Although the study will include a limited evaluation of the capacity determining technique, it should be noted here that this evaluation will be a minor part of the study. It will be merely an attempt to point out possible weaknesses which the author sees as a result of the limited applications. The true evaluation of the technique will come in the years ahead by the degree to which the technique becomes used in the school plant field and the changes which are necessitated for such widespread use.

Proposed Plan of Attack

The basic approach to the problem of capacity determination is the reversal of well established school building planning techniques. As early as 1924 Packer developed and published a technique for determining the number of rooms required to house a given high-school enrollment with a given educational program (27). A similar technique with minor variations but with special emphasis upon the junior high school was developed by Anderson in 1926 (9). Both of these techniques determine the number of pupil periods in each subject from the pattern of student elections and transform the pupil-period requirements into number of rooms required. The proposed technique uses this relationship between number of pupil periods and number of rooms in determining building capacity.
The plan of attack in developing this study includes the following steps:

1. Review of significant literature related to secondary-school building capacity.
3. Synthesis of these factors into a formula for determining secondary-school building capacities.
4. Development of forms and work sheets for recording and processing data.
5. Development of detailed instructions to accompany the forms and work sheets so that specialists are not needed to apply the technique.
6. Application of the capacity determining technique in selected school situations.
7. Evaluation of the technique in the light of these applications.

Chapter 2 contains a review of significant literature related to secondary-school building capacity. From the literature and experience of the author in the school plant field, a set of criteria or expectations was developed to guide in the formulation of the technique of capacity determination. These criteria are discussed in Chapter 3, followed by an analysis of the various factors related to secondary-school building capacity. The synthesis of the significant factors into a capacity formula is the concluding part of Chapter 3. Chapter 4
is a discussion of the data necessary in computing secondary-school building capacities and includes the various forms and work sheets developed for this technique of capacity determination. Possible uses of this technique are discussed in Chapter 5 followed by a brief discussion of the selection of schools studied and a detailed analysis of practical applications of the technique in specific school situations. Chapter 6 is a limited evaluation of the capacity determining technique in terms of how well it meets the criteria set up in Chapter 3, how well it overcomes the shortcomings of the existing utilization techniques of capacity determination, and the reactions of administrators involved in the study. The concluding chapter contains a summary of the study and the major conclusions drawn from it.
CHAPTER 2

REVIEW OF LITERATURE RELATED TO SECONDARY-SCHOOL BUILDING CAPACITY

An Overview of the Literature

The number of studies made and articles written in the school plant field is extremely large. The bibliographies accompanying the seven summaries of research in this area published in the Review of Educational Research between 1932 and 1951 contain more than 3,500 references (2, 3, 4, 5, 6, 7, 8). Similar bibliographies on school buildings, grounds and equipment by Smith and others published between 1928 and 1945 contain more than 7,000 references to publications dated prior to January 1, 1937 (29, 30, 31, 32, 33, 34). The authors of the summary of research in the school plant field reported in the 1950 edition of the Encyclopedia of Educational Research (16:1099-1121) have attempted to limit their bibliography to include only the most significant studies and articles in the school plant field. Table 1 shows a distribution of these references by a narrower breakdown of subjects within the school plant field and by type of publication.

Of the 120 references, only eight, those dealing with utilization and housing requirements, were found to be related to the problem of determining building capacities, and none deals with the problem of building capacity as its major concern. Three of these studies deal with the problem of utilization and five with the determination of
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<td>Miscellaneous</td>
<td>-</td>
<td>2</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>38</strong></td>
<td><strong>37</strong></td>
<td><strong>45</strong></td>
<td><strong>120</strong></td>
</tr>
</tbody>
</table>
housing requirements for a given enrollment and educational program. Two of these eight references are unrelated to the secondary-school problem. One is a study of the utilization of college instructional rooms and the other a study of elementary school buildings. Further search into the literature uncovered scores of studies and articles on school building utilization but not a single additional housing requirements formula.

The Cooper Report

One of the studies which has had far reaching influence in many areas of school plant research is that of the Committee on Schoolhouse Planning of the National Education Association made in 1925 (25). The committee was composed of both educators and architects with Frank E. Cooper as chairman. The Committee's complete report is a comprehensive set of procedures to be followed in the planning and construction of a school building. These procedures involve all details from the selection and appointment of an investigating committee to library classification of subject matter in the school plant field.

The Committee made a detailed study of the distribution of floor space of 80 school buildings in 24 different states. The 80 buildings included 35 elementary school buildings, six junior high-school buildings, and 39 high-school buildings, some of which were buildings housing consolidated schools. From this study, the Committee developed the following standards for determining the proper distribution of floor space:
(1) instruction, not less than 50 per cent of total floor area; (2) administration, not over 16 per cent; (3) stairs and corridors, not more than 20 per cent; (4) walls and partitions, not more than 10 per cent; (5) flues and ducts, not more than 3 per cent; and (6) accessories, not more than 1 per cent. These standards have become widely known as the "candle of ratios" in schoolhouse planning. This study centered attention upon efficiency in the construction of school buildings and was the stepping stone to studies of the efficiency of the use of existing buildings.

Utilization Studies

Morphet's Study

The pioneer study in the field of school building utilization is the study made by Morphet in 1927 of 58 junior and senior high-school buildings with enrollments ranging from less than 100 to over 3,000 pupils (23). Morphet considered the utilization of school buildings from two aspects which he called "room utilization" and "pupil-station utilization." The former is a measure of the degree to which rooms are used without regard to the number of pupils using them. For example, a room adequate in size and facilities to accommodate 30 pupils is completely utilized, as far as room utilization is concerned, when occupied by 10 pupils, because it cannot be used for any other purpose during that period. On the basis of pupil-station utilization, this same room with accommodations for 30 pupils has only 33 1/3 per cent utilization.
when occupied by only 10 pupils, since only one-third of its total capacity is being used. These two concepts of utilization have stood the test of time and are still widely used in utilization studies.

Among the major findings of Morphet's study were the following:

1. The average room utilization during class periods for the 58 schools studied was 75.4 per cent and the average pupil-station utilization was 41.1 per cent.

2. From a study of selected schools that gave every evidence of being crowded, it was concluded that the probable maximum pupil-station utilization will be much less than 100 per cent and will seldom exceed 70 per cent for the entire building.

3. Percentages of room utilization for any type of room may be greatly influenced by certain factors chief among which are: degree to which the building is adjusted to the educational program, the physical desirability of rooms, the type of equipment, whether rooms and equipment are used for purposes other than those for which they were originally designed, efficiency of schedule making, type and number of periods in the schedule, and type of schedule (23:99-100).

Although numerous other studies have largely substantiated these findings, Morphet's study served a much greater purpose. Its greatest contribution was that it focused attention upon the problem of efficiency in the use of school buildings and also in the planning of buildings for such use. A second very important contribution was the objective approach to the solution of this problem. The importance of Morphet's contribution in the study of utilization is brought out by the fact that, with one exception, every utilization study found was patterned more or less after the Morphet technique. However, the Morphet technique was so detailed that simplifications have been developed.
Modifications of the Morphet Technique

The literature contains numerous reports of studies made of individual buildings and of large groups of buildings similar to the study conducted by Morphet. For a number of years the Bureau of Educational Research of The Ohio State University has made utilization studies of the buildings involved in their school building surveys. The Bureau uses a technique patterned after that of Morphet but much less cumbersome. In its simplest form this technique uses the regular class period as the unit of time measurement and determines room utilization by comparing the period use of rooms by the possible periods which the rooms might be used. In the case of pupil-station utilization the comparison is made of the pupils occupying the rooms for each period of the entire week with the number which might have occupied the rooms for the same period of time. This comparison is made for both regular and special classrooms. Periodically, an unpublished study is made of the degree of utilization of those buildings which the Bureau has surveyed. The average per cents of room utilization found in such a study of 100 secondary schools were 83.4 in the academic area and 70.6 in special areas. The average per cents of pupil-station utilization for those same 100 schools were 65.8 for the academic area and 54.3 for the special areas. These average per cents of utilization are close to those found by Morphet when he used class periods as the unit of measurement.
The Fordson School District Study

The only study found in the literature which did not follow the pattern developed by Morphet was a study made in 1933 of the Fordson School District by the Bureau of Research and Adjustment, Dearborn, Michigan (11:37-40). The primary concern in this study was the development of a technique of measuring utilization such that its validity would not be destroyed by changes in school policies, organization, activities, or programs. In fact, one purpose of the study was to provide a means for determining and observing, from time to time, the influence of such variables upon utilization. The more common utilization survey was found to be inapplicable to the purposes of this survey since an arbitrary or fixed value for the above-mentioned variables was required. Thus, the problem resolved itself largely into finding a means of measuring, in comparable terms, the actual output or service load of buildings and rooms which were operating under varying conditions with respect to time, numbers of pupils, character of activities, plans of organization, and policies of administration. The result was the development of a relatively simple formula for measuring service load in terms of a pupil-time-area coefficient of utilization, that is, in terms of the pupils served, the length of time they are served, and the areas occupied during the period of service. The coefficient of utilization was defined as the number of pupil hours which a given room or building delivers per week per square foot of instructional area and was expressed by the following formula,

Coefficient of Utilization = $\frac{P^m}{A}$
in which "P" equals the number of pupils under instruction, "T" the length of time in hours per week that they were under instruction, and "A" the area occupied during the period of instruction. The constancy of this utilization measure is brought out by the following illustration:

A secondary school classroom 22' x 30' may be occupied by 30 pupils for 23 hours per week, by 27 pupils 25.5 hours per week, or by 23 pupils for 30 hours per week and have the same coefficient of utilization. Although both the number of pupils and the time use vary in each of these instances, the amount of room service is the same, and is therefore represented by the coefficient 1.04.

It should be noted that this measure of utilization has no relationship to capacity whatsoever and re-emphasizes the fact that most utilization studies are primarily concerned with efficiency of use of space rather than capacity determination.

The Bureau of Research and Adjustment developed the following formula for determining what it called the coefficient of capacity:

$$\text{Coefficient of Capacity} = \frac{T}{A}$$

where "T" is the hours per week on the program and "A" is the area allotted per pupil. It should be noted that this coefficient of capacity formula does not measure the operating capacity of a building but simply measures the relative use of space. One square foot of space used one hour per week equals a coefficient of one. In order for larger spaces to have coefficients of capacity of one, the time use must increase at the same
rate as the area increases. For example, an area of 25 square feet must be used 25 hours per week to have a coefficient of capacity of one.

The following formula relates coefficient of utilization and coefficient of capacity to determine the per cent of utilization:

Per cent of Utilization = \frac{\text{Coefficient of Utilization}}{\text{Coefficient of Capacity}}

An example will help clarify the determination of the coefficients of utilization and capacity, as well as the per cent of utilization. An English classroom 25' x 30', occupied by an average of 28 pupils for five of the six hour-periods in the school day five days a week, would have a coefficient of utilization of:

\frac{\text{PT}}{\text{A}} = \frac{28 \times (5 \times 5)}{25 \times 30} = 0.933

Now if the standard space allotment per pupil were set at 25 square feet, a daily schedule of six hour-periods would have a coefficient of capacity of:

\frac{T}{A} = \frac{6 \times 5}{25} = 1.2

Now dividing the coefficient of utilization (0.933) by the coefficient of capacity (1.2) equals 0.778 or 77.8 per cent utilization. After determining the per cent of utilization for the entire building, the building capacity can be determined in the same manner as other utilization studies have been used to arrive at building capacities.
Although the coefficients of utilization and capacity, developed by the Bureau of Research and Adjustment, are entirely new approaches to the measure of efficiency of use of a building, the technique of capacity determination is the same as the Morphet technique and therefore has the same shortcomings as the Morphet technique which were discussed in Chapter 1.

Studies of Housing Requirements

Packer's Study

As was pointed out earlier, the basic approach to the problem of capacity determination used in this study came from the study and use of formulas for determining the housing requirements of secondary-school programs. Packer developed the first such formula in 1924 (27). The essential elements in determining housing requirements were related by the following formula:

\[
\frac{\text{The registered number of students in subject}}{\text{Average size of class}} \times \frac{\text{Average number of periods daily}}{\text{Number of periods in the school day}} = \text{Number of rooms}
\]

The number of rooms determined by the use of this formula was then corrected to provide an additional allowance for program making. The correction factor was determined by a study of "best" practices in program making and varied according to the size of the school. For non-specialized classrooms the correction factor was 5 per cent for schools enrolling over 1,000 pupils, 8.8 per cent for schools enrolling 500 to 1,000 pupils, and 14.7 per cent for schools enrolling 150 to
500 pupils. The rounding off into whole numbers of the number of rooms determined by the formula was deemed sufficient allowance for program making in the special areas.

Techniques Reported by the Cooper Committee

The Committee on Schoolhouse Planning of the National Education Association, in Chapter 2 of its report published in 1925, reviewed the commonly used methods of determining housing requirements or the schedule of rooms. This report emphasized the soundness of the Packer approach and set the stage for further development and use of the housing requirements formula. The Committee discussed five of the commonly used techniques for determining housing requirements, labeling two of these techniques incorrect and the other three correct (25:26-38).

The first incorrect method discussed by the Cooper Committee was based upon the number of classroom seats and assumed that the capacity of a school was equal to the sum of the number of seats in all the regular classrooms. Capacity was expressed by the formula:

\[ C = C_1 + C_2 + C_3 + \ldots + C_n \]

in which "C" was equal to the capacity of the school and C_1, C_2, etc. were the capacities of the various regular classrooms (25:26). According to this incorrect method, the special rooms were completely disregarded in determining the capacity of the school. When adequate special rooms are provided, this formula, almost without exception, will provide a building which will accommodate more pupils than are given by the use of the formula.
The second incorrect method was based upon homeroom accommodations and assumed that the capacity of the school was equal to the number of seats in rooms that could be used as homerooms. Here the capacity was expressed by the formula:

\[ C = H_1 + H_2 + H_3 + \ldots + H_n \]

in which "C" was equal to the capacity of the building and \( H_1, H_2, \ldots \) were the capacities of the rooms that could be used as homerooms (25:26-27). Most rooms can be used as homerooms but, on account of the varying sizes of classes, this formula overestimates the capacity of the building.

The first correct method discussed by the Cooper Committee was based upon a schedule of classes (25:27-31). This method consisted of making a schedule of classes for the new school which would be suitable when the school reached its maximum capacity. It was clear that no real problem of accommodations will exist when the building is only partially filled. This technique of determining the housing requirements was the first attempt to build a school building in terms of the actual activities which were to be carried on in that building.

The second correct method discussed by the Committee was based upon the number of pupils in each subject (25:31-34). The approach was similar to that used by Packer, although the formula concept was not discussed. In place of the formula, a chart, with necessary explanations, was used.

The final correct method discussed by the Cooper Committee was based upon the average distribution of pupils in classroom instruction, gymnasium,
and study (25:34–38). This method was based upon the assumption that
a known relationship exists between the time spent in classroom instruc-
tion, gymnasium activities, and study, and assumed that gymnasium and
study rooms are the only special rooms needed in a modern secondary-
school program. This differentiation of time use of different facili-
ties was a step in the right direction but failed to consider all the
special areas.

The Anderson Study

In 1926 Anderson developed a procedure quite similar to that devel-
oped by Packer and extended its application to the junior high-school
program (9). From data gathered from the teaching programs of 27 junior
high schools, he developed two formulas: one for determining the number
of rooms required to house a given enrollment with a stated educational
program and one for determining the average capacity of the rooms.

The formula developed by Anderson for determining the number of
rooms required to house a given educational program is as follows:

$$\text{Number of rooms} = \frac{\text{Pupil periods per week in subject}}{\text{Average size of class}} \times \frac{\text{Number of periods per week}}{N} \times (1-S)$$

The allowance for schedule making was included in the formula and
varied with the type of room and size of school. The allowance was ac-
counted for by the quantity $(1-S)$ in which $S$ was equal to:
<table>
<thead>
<tr>
<th>Type of room</th>
<th>Size of school</th>
<th>Less than 800</th>
<th>800-1200</th>
<th>1200-1800</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular classrooms</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Special rooms</td>
<td></td>
<td>.12</td>
<td>.08</td>
<td>.05</td>
</tr>
</tbody>
</table>

An illustration will help clarify the use of the formula and the accompanying table of allowances for schedule making. In a school building being planned for 1,000 pupils, assume that 125 pupils are to take art 10 periods per week. Multiplying 125 by 10 gives a total of 1,250 pupil periods of instruction, which becomes the numerator of the formula. A single art classroom will house 25 pupils per period for 40 periods per week, assuming eight instructional periods per day, or 1,000 pupil periods per week. The allowance for schedule making is found from the above table to be .08. The .08 figure was selected from the table since the building is being planned for 1,000 which falls in the 800-1200 enrollment classification, and the art room is considered to be a special room. Subtracting this allowance of .08 from one, gives a remainder of .92 which, when multiplied by 1,000, causes the 1,000 pupil periods per week to shrink to 920. The number of rooms required for art then is:

\[
\frac{125 \times 10}{25 \times 40 \times (1 - .08)} = \frac{1250}{920} = 1.36 \text{ or } 2
\]

The rounding off of fractional rooms to the next higher whole number actually increased the allowance made for scheduling. It is interesting to note that Anderson concluded that rounding off of fractional rooms was
sufficient allowance for scheduling regular classrooms but that additional allowance needed to be made for scheduling special rooms. Packer concluded the opposite with respect to regular and special rooms.

In calculating the required number of regular classrooms, the number of pupil periods may be added for subjects having the same average class size or the formula may be applied to each subject separately and the results added. However, in the case of special rooms, each subject area must be calculated separately.

The second formula developed by Anderson for determining the average capacity of rooms is as follows:

\[
\text{Average capacity} = \frac{\text{Average size of class}}{(1 - \text{allowance})}
\]

The allowance factor in this formula also varies with the type of room and size of school. The allowance factors developed by Anderson are as follows:

<table>
<thead>
<tr>
<th>Type of room</th>
<th>Less than 800</th>
<th>800-1200</th>
<th>1200-1800</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular classrooms</td>
<td>.20</td>
<td>.07</td>
<td>.04</td>
</tr>
<tr>
<td>Special rooms</td>
<td>.20</td>
<td>.16</td>
<td>.10</td>
</tr>
</tbody>
</table>

Again, an example will help make this formula and the accompanying table of allowances more readily understood. If the art room in the previous illustration is to house an average class size of 25, it must be planned to accommodate a few more than the average since an average class size of 25 implies some classes larger and some smaller than 25.
From the above table, we find the allowance of .16 for special rooms in buildings planned to house 800-1200 pupils. Substituting this allowance in the above formula indicates that the art rooms should have an average capacity of:

\[
\frac{25}{1 - .16} = \frac{25}{.84} = 30
\]

Ohio State University Room Requirements Technique

An adaptation of the Anderson room requirements formula has been used for a number of years by the Bureau of Educational Research of The Ohio State University in its building planning work and has proved equally applicable to both junior and senior high schools. The general approach is the same but the allowance made for scheduling is the average per cent of room utilization which the Bureau has found in the many secondary schools in which surveys have been conducted. This formula, as used by the Bureau, is:

\[
\text{Number of rooms} = \frac{\text{Pupil periods}}{\text{Average number of utilization}} \times \text{periods} \times \text{factor per week}
\]

The Wilson Studies

An entirely different approach to the problem of determining the number of rooms required to house a given enrollment was developed by Wilson in 1933 (38). In his doctoral study, a statistical analysis was made of the educational programs of 345 high schools in the State of New York having enrollments ranging from 50 to 400 pupils. Regression
equations were developed from the correlations of the number of classes with enrollments. From these regression equations the author developed the following simplified formulas:

Total classes = \( \frac{\text{Enrollment}}{5} + 15 \)

Interchangeable classes = \( \frac{\text{Enrollment}}{8} + 12 \)

Interchangeable teacher stations = \( \frac{\text{Enrollment}}{8} + 12 \)

The author uses the term "interchangeable" to refer to classes such as English, mathematics, and social studies which do not require highly specialized equipment and which may be housed in the same room or "interchangeable" teacher station.

From his study the author also was able to set up charts for determining the number of special rooms and study hall capacities required for different enrollments.

The author later extended his study to schools with enrollments ranging from 400 to 3,000 (36). The formulas thus developed are similar in form to the original ones but involve different constants. The formulas for enrollments from 400 to 3,000 are as follows:

Total classes (excluding physical education) = \( \frac{\text{Enrollment}}{7} + 24 \)

Interchangeable classes = \( \frac{\text{Enrollment}}{10} + 20 \)
The formulas developed in this study have been in use for a number of years by the Division of School Buildings and Grounds in the University of the State of New York.

Summary of Findings from the Literature

A review of the literature in the school plant field indicates two basic plans for the study of utilization. The first, and by far the most commonly used, measures the efficiency of use of a given building by comparing the per cent of utilization of a given building with norms based upon status studies of a large number of buildings. In its simplest form the per cent of room or pupil-station utilization is the ratio of room or pupil-station use to the theoretical maximum of using every room and every pupil station every period of the day. It is generally agreed that in actual practice this theoretical maximum cannot be reached.

The second basic plan measures the service load of a building or room in terms of a pupil-time-area coefficient of utilization. The authors of this plan claim certain advantages over the former plan. The major advantage is that the unit of measuring efficiency is not affected by varying conditions with respect to time, number of pupils, character of activities, plans of organization or policies of administration. As yet this plan has not been used extensively and any evaluation of it would be extremely hazardous.
Although the first basic plan of studying utilization has had many minor variations, all variations patterned after the basic plan developed by Morphet have produced similar results. Most of these variations have been simplifications of the original Morphet technique. Certain of these techniques have been so developed and instruction sheets so minutely prepared that a person without previous experience can make the utilization study.

The utilization study has been put to numerous uses. When put to its primary intended use as an indicator of wasteful and undesirable practices, the utilization study has proved very satisfactory. The utilization study is also quite valuable as a rough indicator of crowded conditions but its accuracy is questionable when used to determine operating capacities of secondary-school buildings.

Two basic types of formulas have been developed for determining the housing requirements of secondary-school buildings. The first and most widely used is the type which is based upon the educational program and the pattern of electives in the actual school under consideration. Such formulas are universally applicable and make certain allowances for differences in size of school and the resulting difficulty of scheduling classes.

The second type of formula assumes a more rigid type of educational program and is developed from a statistical analysis of several hundred school programs. The only variable besides enrollment in this formula is the number of daily periods in the class schedule. Such a formula produces a very valuable quick check of room requirements where there
is a high degree of similarity in the educational programs.

The review of the literature in the school plant field indicated a secondary use of the utilization study to determine the operating capacity of buildings but uncovered no technique or formula which had as its primary purpose the determination of operating capacities.
CHAPTER 3
DEVELOPMENT OF THE FORMULA

Historical Development

The problem of determining the capacity of secondary-school buildings has long confronted the worker in the school plant field. The question of how many pupils a given secondary-school building will house is a frequent one to which the survey worker has neither the answer nor an adequate technique of finding one.

The writer has been confronted frequently with this capacity problem in his work in the Survey Division of the Bureau of Educational Research of The Ohio State University. After working on numerous school building planning projects which involved considerable analysis of the educational program to determine the number of rooms required in a proposed new building, the hypothesis was developed that capacity is integrally related to educational program as well as to size of building. Following this hypothesis, it was thought that the capacity of a building might be determined by using in reverse the formula used to ascertain the number of rooms of each type needed for a given number of pupils in a new building. In other words, instead of starting with a given number of pupils and deriving the number of rooms needed in each subject, it would be possible to start with the number of rooms of each kind and work through the process in reverse to determine how large a school enrollment could be accommodated in

- 32 -
each subject, and hence to arrive at an overall capacity of the building.

Criteria for the Development of a Capacity Formula

The suggested criteria which are presented here were based upon two primary sources. The first source was quite naturally the accumulated literature in the school plant field related to the quantitative adequacy of secondary-school buildings. The second source has been the writer's own work experience in the school plant field.

It should be made clear that the writer makes no claim that these criteria will be valid over a long period of time. Although these criteria have not been validated by the frequently used method of submission of a questionnaire to experts in the field, there is little question as to their validity according to present day thinking in the school plant field.

The source of any given criterion cannot always be clearly defined since the two sources have generally complemented each other and the process of development of these criteria was not a formal one. As the writer worked on numerous school building surveys and building planning projects, tested the basic concept of relating capacity to educational program, and read more widely in the school plant field, certain ideas about such a capacity formula crystallized into criteria for the development of a capacity formula. These criteria briefly stated are:
1. The formula should consider the functional use of the building.

2. The formula should attack the capacity problem directly rather than through status studies.

3. The formula should involve all significant factors related to capacity.

4. The factors involved in the formula should be as objective as possible.

5. The formula should be universal in its application.

6. The formula should not involve abstract standards.

7. The formula should be relatively easy to apply.

8. The results obtained from the formula should be easily interpreted.

Criterion 1: The formula should consider the functional use of the building.

That buildings should be planned in terms of the educational program to be carried on in them is a well established principle of school building planning (1:13, 3:343, 25:26-38). This criterion is merely a corollary of this basic principle. In order to arrive at a true operational capacity of a room or building, one must consider the many aspects of the educational program including the established educational policies of the given school system. This criterion is in direct contrast with existing techniques of capacity determination based upon utilization
studies in which the differences in educational programs do not enter into the calculations.

Only in recent years have the broader implications of the basic principle stated above been fully realized. Statistical studies such as Wilson's (37), to determine some type of central tendency of the educational programs of many schools and the resulting planning techniques, were considered consistent with this basic principle. Such techniques are outmoded now because the concept is now interpreted to mean that the planning must be based upon the unique characteristics of the educational program of the individual school under consideration.

Criterion 2: The formula should attack the capacity problem directly rather than through status studies.

This criterion is a corollary to the first but has additional facets which are not included in Criterion 1. If the formula is to produce a capacity consistent with the peculiarities of a given educational program, it cannot be based upon a study of a large number of existing programs (35:64). It must attack the capacity problem directly by considering all the factors of educational program which affect capacity and then relate these factors in such a way as to determine the operating capacity directly. Morphet recognized the shortcomings of the utilization study as a means of determining capacity when he indicated that capacity is almost entirely relative to the program of the school and that "normal capacities" may be considerably changed by changes in educational program (23:90). The determination of capacity
by comparison would be a satisfactory approach if we had the ideal with which to compare. Surely status studies cannot produce this ideal because any measure of central tendency as the ideal implies something better and something worse.

Another implication of this criterion is that a capacity formula should be developed which has capacity determination as its primary aim. The technique must not be a "patent medicine" which solves all the problems in the school plant field. This does not preclude the use of the basic approach in the solution of problems directly related to capacity.

Actually, there has never been a formula or technique developed which had as its primary purpose the determination of building capacity. Existing techniques of capacity determination are based upon the utilization study which was developed primarily for determining efficiency of use of buildings (23:93).

**Criterion 2:** The formula should involve all significant factors related to capacity.

This criterion needs little interpretation. It should be noted, however, that the criterion does not require that the various factors be considered individually in the formula. For example, a product or other combination of significant factors may be more easily obtained than the individual factors. What is really meant is that no significant factors should be ignored in the development of the formula.
Criterion 4: The factors involved in the formula should be as objective as possible.

Objectivity is a desirable criterion in any measuring instrument and the highest possible degree of objectivity which is consistent with the other criteria is desired here. To be sure there will be wide variations in educational programs and policies of differing schools and these will be determined by local administrators largely through subjective means. However, given the educational program and policies of a particular school system, the determination from such data of the building capacity should not be subject to personal valuations, opinions or bias. Thus the principal, his secretary, or an outsider should obtain similar results by applying the formula to a given school situation.

Criterion 5: The formula should be universal in its application.

The formula should be equally applicable to any type of vertical school organization. This means that the formula must involve factors which take into account the differences in educational offerings and patterns of student electives at the different grade levels characteristic of each type of vertical school organization.

Even with similar types of vertical organization one will find extreme variations in the horizontal development of the educational programs. Factors must be involved in the formula which take into account these differences.

Likewise the formula must be so developed as to take into consideration variations in the daily or weekly program or schedule of classes.
The formula must be applicable for short periods or longer periods with supervised study and with all types of lunch period organization.

A formula developed to take into account the many differing factors of educational program will be equally applicable in any state or region of the country or in any country of the world.

Criterion 6: The formula should not involve abstract standards.

Techniques or formulas which include abstract standards require some means for establishing those standards. If standards were such that they could easily be established and generally accepted after being established, the objections would largely be removed. However, this is not the case. It is almost impossible to get agreement of educators concerning standards of class size, space allotments per pupil in the various subject areas, or the length of the school day. Even if it were possible to get substantial majority agreement on such factors, an operating capacity formula based upon such standards would be of no value in determining the operating capacity of a building in which the educational policies of the administration were at variance with the standards. This relates closely to the basic principle of school building planning in terms of the uniqueness of the educational program and to Criterion 1 discussed earlier.

Criterion 7: The formula should be relatively easy to apply.

This criterion needs little clarification except that its relative nature should be emphasized. The resulting formula should not be
condemned in case other criteria make it impossible to develop a formula which is relatively easy to apply. This criterion should serve as a guide in the development rather than as an absolute standard of measuring the end product. That is to say, other criteria should take precedence over this one and any evaluation of the formula in terms of this criterion should be in terms of the extent to which ease of application is permitted by other criteria here discussed.

In spite of what has already been said, it must be remembered that the usefulness of the formula will, to a large extent, be determined by the ease with which it may be applied. This is especially true of its widespread use by others than those especially trained in the school plant field.

Criterion 8: The results obtained from the formula should be easily interpreted.

This criterion is closely related to the previous one. The ease with which the results can be interpreted has even greater significance for widespread use than ease of application. This is true because difficulty of interpretation seriously detracts from the usefulness of such a formula even by the specialist trained in the school plant field.

Analysis of Factors Related to Secondary-School Building Capacity

Before considering the interrelationships of the various factors or attempting to synthesize the more significant factors into a working
formula for determining the operating capacity of a secondary-school building, an analysis will be made of the many factors which are now being used in capacity determination or which are significantly related to operating capacity.

Number and Types of Teaching Stations

Teaching stations in secondary-school buildings are generally classified into two major categories, academic and special. The latter group is again subdivided into the many subject areas requiring different types of specialized equipment. A special room or teaching station is one which requires highly specialized equipment for its intended use. Such specialized equipment generally renders the room undesirable for other use. Shops, science laboratories, and art studios are of this type. The academic rooms or teaching stations are those which require little or no specialized equipment and are, for the most part, equally suitable for a number of different subjects such as language arts, mathematics, and social studies. Such rooms are also commonly called regular or interchangeable classrooms.

Although there is little difference in the major physical requirements of rooms used for mathematics, social studies or language arts, there is a tendency toward specialization even in these rooms. This is brought about primarily by the characteristic types of teaching aids and supplementary materials which are collected into each of these types of rooms. For purposes of capacity determination, academic classrooms may be treated as a single type or may be divided into as many different
types of rooms as desired. However, it should be noted that the building capacity will be somewhat less as the degree of specialization is increased. Interchangeability of rooms increases building capacity. This is due, as will be seen more clearly later, to the fact that the calculated room requirements in each subject area are seldom whole numbers; nevertheless, whole rooms must be provided. Increased specialization of rooms increases the number of these fractional room requirements and results in more rooms being used only partially by the enrollment for which the building is planned.

The number and types of teaching stations are undoubtedly the most significant factors related to capacity of secondary-school buildings. It is commonly thought that the operating capacity of a secondary-school building is directly proportional to the total number of classrooms in the building. This is substantially true of elementary-school buildings, but is only partially true of secondary-school buildings because of the complexity of the secondary-school program. The impossibility of interchangeable use of many of the special rooms makes it necessary that the building be adapted to the educational program. For all practical purposes a secondary-school building has reached its capacity when the classrooms in any one subject area have their capacity even though other classrooms are only partially used. Any further increase in the total enrollment beyond this point means curtailment of activity in that subject area which has reached its capacity, with resulting distortion of the desired educational program. This results in fitting the educational program to the
building rather than the converse, and thus violates a basic principle of school building planning.

A teaching station is defined as the space required by one teacher in the conduct of a group learning process. It should be pointed out that the number of teaching stations in a building does not necessarily correspond to the number of rooms. Frequently special areas such as large shops or gymnasiums may be used by two or more teachers at the same time and if so would be considered as two or more teaching stations. On the other hand, two rooms are sometimes required to produce one teaching station. Certain science laboratories are not adapted to all types of classroom activities but are suitable only for pupil experimentation. In such cases the lecture-demonstration room must be added to the laboratory to produce one teaching station.

From the foregoing discussion, we may conclude that the operating capacity of any subject area will be directly proportional to the number of teaching stations assuming that other factors are constant. It should be noted, however, that this relationship applies only to each particular subject area in question and not to the total number of teaching stations in the building.

Suitability of Rooms

The suitability of rooms is closely related to capacity since the actual number of rooms or teacher stations in a building will be determined in the light of acceptable standards of suitability for any given school system. The relationship of suitability of rooms to capacity is
not a continuous relationship. If a room is judged to be suitable
for use as a teaching station, it adds to the capacity of the building;
if not, it contributes nothing to the capacity. If a room or teacher
station meets the minimum standards its degree of suitability is unre-
lated to capacity. Numerous factors are usually considered in deter-
mining whether a room is suitable for instructional purposes. Among
such factors are: degree to which the room is adaptable to the in-
structional program, location, lighting, heating and ventilation,
equipment, and general physical desirability which includes all physi-
cal characteristics not specifically included under other headings.
Of these factors, the degree to which the room is adaptable to the in-
structional program is by far the most important factor. With the ex-
ception of location all the other factors may be altered.

It is not within the scope of this study to analyze these factors
related to suitability of rooms or to attempt to set up criteria for
judging the suitability of rooms. The literature is voluminous on
this subject.

From the foregoing discussion we find that suitability of rooms
is not continuously related to capacity. It is indirectly related
through the number of teaching stations and need not be considered
directly in the development of the formula since it will have its
effect when determining the total number of teaching stations in a
given building.
Size of Rooms and Number of Pupil Stations

When the utilization study is used to determine capacities, room size is as closely related to capacity as the number of rooms. It has long been recognized, however, that size does not maintain the same relationship to capacity throughout all areas of instruction since some types of activities and equipment require more space per pupil than others. In reality then not size of room but the number of pupil stations (the number of pupils which the room will accommodate) is of primary importance relative to capacity determination, and this, of course, is related to size of room.

The problem of determining the number of pupils which a room of given size will adequately accommodate is a difficult one. What should be the space allotment per pupil in English or in home economics? Can a standard be set for English or any other subject area which is equally applicable to every school situation or must this be determined by a consideration of the unique characteristics of the instructional activities being carried on in the classroom?

It has been shown that in actual practice extremely large or small rooms lend themselves to only limited use (23:52).

Existing techniques for capacity determination based upon utilization studies assume some standard of space allotment per pupil yet there is no agreement among authorities in the school plant field as to what these space allotments should be. Since it is generally agreed that the type of instruction has greater implications for space allotments than subject matter content, it would seem that space allotments per pupil
should not be based upon abstract standards which are supposedly applicable to all school situations but rather upon the unique characteristics of a given educational program. The next section which discusses implications of desirable average class sizes will show that other factors will tend to minimize the importance of space allotments as such.

Desirable Average Class Size

A factor very closely related to size of room and number of pupil stations within the room is the desirable average class size. This factor tends to minimize the importance of size of room or number of pupil stations within the room, although it does not completely overshadow it. In spite of the fact that research studies have failed to justify the educational practice of limiting class sizes (26:212-216), few administrators and even fewer teachers will deny the educational desirability of such limitation. This is especially true where an attempt is being made to shift from the lecture-recitation method of teaching to more modern and varied teaching methods with emphasis upon meeting individual needs. It should be pointed out that research studies dealing with teaching effectiveness with groups of different size were centered largely upon subject matter mastery which is only one objective of the modern school.

If the educational policies of a given school system set a maximum or desirable average class size, the size of rooms and number of pupil stations lose their major significance in relation to capacity. This being the case, a large room with excessive pupil stations beyond
the desirable maximum class size is, in fact, reduced to average size as far as potential operating capacity is concerned. However, smaller rooms with fewer pupil stations than the average class size must still receive consideration in capacity determination. In determining the number of teaching stations in a building, a correction factor must be applied to rooms not large enough to accommodate average class sizes or the desirable average class size must be adjusted downward to correspond to the size of rooms. In either case, not abstract standards but a consideration of the educational policies and standards of the individual school should be considered in making this adjustment.

Since the effect upon capacity of the three factors of space allotments, room size, and maximum pupil stations can be related either to the number of teaching stations or to desirable average class size, these three factors need not be included as separate factors in a capacity formula. This is true, of course, only if due consideration is given to them in establishing the number of acceptable teaching stations or in setting the desirable average class size.

Room Assignment Policies

The educational policies concerning the use of rooms has a significant effect upon the operating capacity of a building. Many schools have the policy of having one room in which each teacher meets all her classes. When the daily schedule includes more periods than the number in the teacher's schedule, the plan would cause a loss in efficiency of the use of the building.
In spite of its effect of reducing the operating capacity of a building, this policy may be justified on educational grounds in cases where the daily schedule includes more periods than the number in the teacher's schedule. This policy allows the teacher one or more non-teaching periods for consultation or planning work. The justification of this loss of capacity is based upon the need of the room by the teacher for preparing the room and teaching aids for future classes.

It would seem that the preparation of the room or of teaching aids might just as well be done before or after regular classes but if the educational policy of a given school system requires a room for each teacher and the educational program justifies it, consideration should be given to this factor in determining the operating capacity of such a school.

This policy causes even greater loss in operating capacity in actual practice because of the complexity of the secondary-school program and the resulting variety of duties in the average teacher's assignment.

The correction for this factor would be a simple mathematical computation. It would be a ratio which should be applied to the gross capacity figure. This ratio would be found by dividing the number of periods per day during which rooms are to be used for class instruction by the total number of periods in the daily schedule devoted to instruction. Although no other policies are common which affect the use of rooms, should such policies develop and be justified, a similar correction should be made in the capacity determination.
Nature of the Educational Program

It is generally agreed that it is impracticable to use every pupil station or every room of a secondary-school building every period of the day. This is caused by the complexity of the educational program of the secondary school and the resulting difficulties of schedule making. That this is true needs little verification for one who has had responsibility for schedule making at the secondary-school level. Morphet recognized this fact and attempted to arrive at a possible maximum per cent of utilization upon which to base capacity estimates (23:80–92). Both Packer (27:40) and Anderson (9:23–34) in their studies of housing requirements made certain allowances for this same factor. It is interesting to note, however, that the conclusions drawn from the latter two studies were contradictory. Packer concluded that no correction for program making was necessary in determining the number of special rooms, other than that secured by considering every fractional part of a room as a whole room. In determining the number of non-specialized classrooms, he made allowances according to the size of the school. Anderson concluded from his study that no correction was necessary in determining the number of academic or non-specialized rooms but made corrections in the number of special rooms similar to that made by Packer for non-specialized rooms. In both academic and special rooms, Anderson made an additional correction for the scheduling of individual pupils which he called allowances for capacity of rooms. He arrived at this correction factor by studying the percentage relationship of average class size to maximum class size as determined
by the average pupil capacity of the various rooms. Although his conclusions were based upon the analysis of an individual school situation for each enrollment classification, there seems little doubt that some such correction needs to be made for individual pupil scheduling.

From the foregoing analysis, there seems little doubt that any capacity determination must take into consideration, either directly or indirectly, a correction factor to offset the impracticability of utilizing every room or every available pupil station every period of the day. It must also be concluded that research is not adequate from which to draw unassailable conclusions as to the amount of such correction. A later section of this study will re-analyze existing research data and offer other data to justify certain assumptions made concerning this factor in developing the working formula.

**Length and Number of Periods**

Conflicting statements have been made concerning the effect of decreasing the length of periods and the resulting increase in number of periods in the school day, assuming no change in the total length of the school day. It is believed by some, that such increases in the number of periods in the school day will increase the capacity of a building. This is only a half truth, for it is true only under certain conditions, and it assumes changes in educational program, which may or may not be educationally justifiable. The inconsistency of this general statement is brought out in certain areas of the curriculum in which
state departments or regional accrediting agencies require a certain number of clock hours to be devoted to instruction. For example, a vocational shop, adequate in size to accommodate 20 students, can accommodate only 40 or twice its unit capacity whether the school operates on a six or eight period day if three clock hours of instruction are required and the total length of the school day is six hours. On a six-period day only three periods will be required; on an eight-period day, four periods will be required; but, in either case the number of pupils served remains the same. In certain laboratory subjects, increasing the number of periods in the school day without increasing the length of the school day, actually decreases the number of pupils who can be served daily by a given room. This is true in subject areas in which the time requirements can be met by a single one-hour period but which require two periods per day when the periods are only 40 or 45 minutes in length. For example, a laboratory under such conditions and a six clock-hour school day, would serve six times its unit capacity on a six-period day but only four times its unit capacity on an eight-period day.

The operating capacity of a building is not necessarily increased by increasing the number of periods in the school day even though the length of periods remains the same, thereby increasing the total length of the school day. Such a change will generally increase the number of pupils which a given room will serve but at the same time it increases the number of periods which pupils must be served by other facilities. Unless other facilities are adequate to serve this extra load and the educational program is changed to make use of them, no increase in the
operating capacity of the building is effected by increasing the number of periods in the school day. For an example of this interrelationship, assume that the number of pupils and the average number of classes remain constant. Increasing the number of periods increases the number of study sittings required and unless additional facilities are available for this purpose, no increase in operating capacity has been effected. Of course, this also assumes that additional study periods are educationally sound. If we assume that space needs to be provided only for classes, and that students are free to do as they please, as is true at the university level, this analysis would not hold true, but such is not characteristically true of secondary schools.

In summary, it can be said that increasing the number of periods in the school day will increase the operating capacity of a building only in those cases where the building is not well adapted to the existing educational program. In essence this means changing the educational program to fit the building which is a direct contradiction to the basic principle of school building planning, namely, that a building should be planned in terms of the educational program.

In spite of all that has been said concerning the misunderstandings of the effect of number of periods upon operating capacity, there is little doubt that a relationship does exist. However, from the foregoing discussion we must conclude that this relationship is not linear but that it must be linked with other factors, one of the most important of which is the number of periods per day or per week devoted to each subject.
That the periods per week devoted to each subject is related to operating capacity has been clearly shown by the illustrations in the preceding paragraphs. The illustrations showed that the relationship is similar in complexity to that of the number of periods in the school day. However, the relationship is an inverse one for it is clearly evident that the total number of pupils which can be served per week by a given classroom decreases as the number of periods per week of the subject increases, assuming that other things remain constant. For example, assuming an eight-period day, a subject area classroom would serve eight times its unit capacity if the subject required only one period per day of each pupil. If the periods per day of the subject were increased to two for each pupil, the room would accommodate only half as many as before, or only four times its unit capacity.

**Staggered Schedules**

The net effect of staggered schedules upon the operating capacity of a secondary-school building is identical to that of increasing the number of periods in the school day without changing the length of such periods. The results are obtained, however, without increasing the length of the pupils' school day since those pupils who come first in the morning go home first in the afternoon. If the operating capacity of a secondary-school building is increased by a staggered schedule, it is due to the fact that there is available what might be termed an "overflow reservoir" of capacity in certain areas and a shortage of capacity in other areas. In effect, the staggered schedule increases the capacity
of certain areas by making such areas available a greater number of periods per day than is otherwise practicable. At the same time the effective number of periods per day is reduced for other areas because classes in these areas must be scheduled primarily in the overlap periods.

**Multiple Sessions**

Another variation of the daily schedule which is sometimes used to increase the operating capacity of a secondary-school building is the device known as the multiple or half-day session. This technique is the equivalent of housing two or more schools in one building. Although this device is an effective means of increasing the operating capacity of a secondary-school building, it is seldom used except under extreme circumstances because of its educational and social implications. If this device is to be resorted to its effect upon capacity is easily determined. The total operating capacity of a building using half-day sessions may be determined by any method developed, by simply applying the method as if the two sessions were two different schools and then adding the capacities so determined.

**Specialization of Rooms**

The nature of the equipment in certain special rooms makes them undesirable for any other than their intended use. However, with the advent of varied teaching techniques, certain special rooms are now being planned so that they are suitable for multiple use. If such is the case, a room so planned may be used to accommodate classes in other
areas when not being used for its primary intended use.

The effect of this factor upon the operating capacity of a secondary-school building does not need to be considered directly. Its effect can be related to the operating capacity by considering rooms so planned for multiple use as fractional teaching stations in two or more different areas.

**Complexity of the Pattern of Subject Elections**

One of the most complex factors which is related to the operating capacity of a secondary-school building is the nature of the educational program offered and the complexity of the pattern of subject elections by students. Due to the complexity of the effect of educational program upon the total operating capacity of a secondary-school building, it is deemed expedient that any consideration of the effect of this factor must be related to what has been termed area capacities. These area capacities then will in turn be related to the total operating capacity of the secondary-school building.

The diversity and complexity of the secondary-school educational program can be mathematically defined in terms of the pupil periods per week devoted to the various activities. Since the number of pupil periods per week devoted to the different activities varies according to total school enrollment, the educational program must be defined not in terms of pupil periods alone but rather by the relative number of pupil periods per week of each activity to the total possible pupil periods per week of all activities.
Even though the number of pupil periods of the various activities provides a convenient mathematical definition of the complexity of the educational program as it affects operating capacity, the complexity of factors which affect the number of pupil periods is unchanged. The number of pupil periods of the various activities will depend upon such factors as: requirements for graduation, college entrance requirements, parental influences, friendship influences, variety of elective subjects, and almost an unlimited number of similar factors. No attempt will be made to isolate these numerous factors or determine their individual influence, but rather to determine their net effect in any given school situation. Assuming other factors constant, an increase in the number of pupil periods per week in any subject area which is required to satisfy the overall educational program will permit fewer students to be served by that area. For example, a teaching station adequate in size and facilities to accommodate 30 students per period can accommodate $30 \times 8 \times 5$ or 1,200 pupil periods of activity per week, assuming an eight-period day and a five-day school week. Now if an enrollment of 600, assuming a given educational program and pattern of student electives, requires a total of 1,200 pupil periods of instruction per week in a given area, one teaching station would just meet the program requirements of the 600 enrollment. However, if the educational program and pattern of student electives of these same 600 pupils were such as to require only 600 pupil periods of instruction in this area, the room would be utilized only half the time, or the room could be used to accommodate twice as many pupils, if fully utilized. Thus we see that the number of pupil periods
per week of instruction in a given area is inversely related to operating capacity of the subject area.

The relationship of area capacities to the total operating capacity of a building is a simple and direct one. The total operating capacity of a building is limited by the smallest capacity limit of any subject area. As has been pointed out earlier, a building has reached its total operating capacity when the classrooms of any one subject area have reached their capacity because any further normal increase in enrollment beyond this point results in curtailment of activity in this particular subject area with resulting distortion of the desired educational program.

Derivation of the Formula

Having analyzed the various factors which are related either directly or indirectly to the operating capacity of a secondary-school building, our next step is to synthesize these various factors into some type of mathematical relationship which will be usable in determining the operating capacity of secondary-school buildings.

As has been pointed out earlier, the development of the capacity formula started with the housing requirements formula as a springboard. The basic housing requirements formula is as follows:

\[
\text{Number of rooms} = \frac{\text{Subject enrollment}}{\text{Average class size}} \times \frac{\text{Periods per week of subject}}{\text{Total number of periods per week}}
\]
Certain minor variations have been made by others in this basic formula to provide for certain correction factors but the basic formula has stood the test of several decades of use in the planning of new buildings. For a development of this basic formula see the original studies made by Anderson (9:21-22) or Packer (27:20-25). An illustration will make clear the use of this formula in determining the number of rooms required to house a given subject area and at the same time will indicate the reasonableness of this basic relationship of educational program and room requirements.

Assume that 400 pupils are to take English five periods per week. Multiplying 400 by 5 gives a total of 2,000 pupil periods of instruction which is the numerator of the formula. Assuming eight instructional periods per day or 40 periods per week, a single classroom adequate in size and facilities to accommodate an average class size of 30 will accommodate 30 x 40 or 1,200 pupil periods of instruction per week, which is the denominator of the formula. The number of rooms required is therefore:

\[
\frac{400 \times 5}{30 \times 40} = \frac{2000}{1200} = 1 \frac{1}{2}/3 \text{ or } 2
\]

Having illustrated the reasonableness of this basic relationship of educational program and required number of rooms, the next step is to show the mathematical derivation of the capacity formula. In order to permit mathematical treatment of this basic relationship, let:
\[ a = \text{number of subject area teaching stations} \]
\[ b = \text{subject area enrollment} \]
\[ c = \text{periods per week of subject} \]
\[ d = \text{average class size} \]
\[ e = \text{total number of periods per week} \]

(1) Then \[ a = \frac{bc}{de} \]

Since "bc" equals the number of pupil periods of a given subject area, the formula can be simplified by the following substitution:

Let \( p = bc \) = number of pupil periods of the subject area

(2) Then \[ a = \frac{p}{de} \]

If we were to use this basic relationship in determining the capacity of an existing building "a" would no longer be the dependent variable but could be determined by counting the number of teaching stations in the existing building suitable to a given subject area. The variables "d" and "e" would remain independent and could be determined as before by a consideration of the educational program and practices of a given school. This would leave "p" the dependent variable such that we could find the possible pupil periods of instruction which the given facilities would accommodate. Solving equation (2) for "p" we would have:

(3) \[ p = ade \]
But this formula gives us possible pupil periods of instruction and we are concerned with finding the maximum total school enrollment which these existing facilities will accommodate.

In an earlier section of this study it was pointed out that total pupil periods of instruction in any given subject area is not universally dependent upon total school enrollments but rather upon a multitude of factors peculiar to each school situation. It was pointed out, however, that the total effect of all these factors is relatively constant in a given school situation, such that an increase in total school enrollment does actually cause a corresponding increase in pupil periods of instruction in the various subject areas. Assuming, therefore, that pupil periods of instruction in a given area increase directly with increases in total school enrollments, we can state mathematically that:

\[(4) \quad p \sim i\]

where "p" is the possible pupil periods of instruction which can be accommodated by the existing facilities and "i" is the total building capacity which could be accommodated by the existing facilities.

\[(5) \quad p = K_1\]

in which "K" is a constant which can be determined by a study of the relationship of pupil periods of instruction in the various subject areas and the total school enrollment. The value of "K_1" for a given subject area and a given school situation would be found by solving equation (5) for "K" and substituting "p_1," the pupil periods per week of the subject
area in the existing school program, for "p," and "i," the total enrollment that produced that number of pupil periods, for "i."

(6) Then $K_1 = \frac{P_1}{i_1}$

Now substituting $\frac{P_1}{i_1}$ for "K" in equation (5) we have:

(7) $p = \frac{P_1}{i_1} \times i$

Then substituting this value of "p" in equation (3) we have:

$$\frac{P_1}{i_1} \times i = ade$$

Then solving this equation for "i" we have:

(8) $i = \frac{adei_1}{P_1}$

which gives us a formula for determining the total building capacity which could be accommodated by the existing facilities of any given subject area.

By applying this formula to each of the various subject areas, a total building capacity which can be accommodated by these various subject area facilities can be determined. The lowest capacity figure thus
obtained is the overall operating capacity of the building since crowding or curtailment of the educational program would take place when the capacity figure for that area is exceeded.
CHAPTER 4

DEVELOPMENT OF THE TECHNIQUE OF APPLICATION
OF THE CAPACITY FORMULA

This chapter will discuss the various elements of the capacity formula derived in the preceding chapter and will set forth data which led the writer to make certain basic assumptions concerning the collection and processing of data. This discussion will furnish the background for a better understanding of the special work sheets and specific detailed instructions for recording and processing data which are developed in the latter part of this chapter.

Necessary Allowances

The discussion of factors related to capacity determination clearly indicated that it is impracticable to utilize every room or every pupil station in a secondary-school building every period of the day. This was generally attributed to scheduling difficulties. It would appear that the capacity formula just developed makes no correction for this factor, but this is not the case. Although the formula does not contain a correction factor as such, the technique of application of the formula in the determination of the operating capacity of a building does compensate for the impracticability of using every room and every pupil station every period of the day.
Desirable Average Class Size

The correction to compensate for the impracticability of using every pupil station every period of the day is included in the elements of the formula entitled "desirable average class size, periods per week of the subject, and number of teaching stations." Rooms must have sufficient pupil stations to permit the indicated desirable average class size in order to be classified as a suitable teaching station. Otherwise, the desirable average class size must be reduced to an attainable goal. This means that a room must be suitable in size and facilities to accommodate more than the desirable average class size in order that the desirable average may become a reality, since average implies some classes above and others below the desirable average.

Anderson, by a study of three school programs of 500, 1,000, and 1,500 pupils, found this correction factor to vary from .04 to .20 (9:31-33). A study of such a limited number of school situations hardly justifies any conclusion concerning the exact amount of this correction factor. The writer was unable to find substantial research upon which to base this correction factor, but was convinced that a greater number of cases would produce a more reliable correction factor than that developed by Anderson on the basis of his three-school study. Additional research needs to be made in order to determine more accurately the necessary pupil stations needed in each room to accommodate a given desirable average class size.

The determination of this correction factor is further complicated by certain school policies which limit class sizes. These maximum class
sizes are usually about five pupils above the desirable average for
class sizes of 25 to 35. The assumption that an additional five pupil
stations must be available to make possible average class sizes from
25 to 35 seems reasonable in view of the limited study made by Anderson.
An allowance of three pupil stations for average class sizes less than
25 and an allowance of eight pupil stations for average class sizes
greater than 35 also seems reasonable until further research is avail-
able to determine more accurately these allowances.

Should additional research show that these assumed correction allow-
ances need to be adjusted, no change would need to be made in the basic
formula but rather in educational policies establishing desirable average
and maximum class sizes and, of course, in the planning of new rooms for
a given average class size.

Periods Per Week of Subject

It is physically impossible to schedule every room every period of
the day in subject areas in which the number of periods of instruction
per week of the given subject is an aliquant part of the total periods
per week of instruction. When this is the case, the actual periods per
week of instruction must be adjusted in the capacity calculation to allow
for this factor. To determine the adjusted periods per week of a subject,
divide the number of periods per week in the operating schedule of classes
by the periods of instruction per week of the subject. If the quotient
is a whole number, no adjustment is necessary. If the quotient is not a
whole number, divide the whole number part into the number of periods per
week in the operating schedule. The quotient thus determined will be the adjusted periods per week which should be applied in the capacity formula. An illustration will clarify when this adjustment is necessary and will demonstrate the procedure for making the necessary adjustment. Assume that a school is operating on a daily schedule which permits eight instructional periods per day or 40 periods per week. If chemistry requires seven periods of instruction per week, divide 40 by 7 which gives a quotient of \( \frac{55}{7} \). This quotient is not a whole number; therefore, it is impossible to schedule classes in the chemistry room every period of the week because 40 will not divide into a whole number of seven period blocks. Now dividing 40 by 5, the whole number part of \( \frac{55}{7} \), gives a quotient of 8, which is the adjusted pupil periods per week for chemistry which should be used in the capacity calculation in place of seven for this particular school situation.

Hidden Allowances

Even though every room of one or more subject areas might be used every period of the week, the complexity of the secondary educational program makes it impractical to utilize every room in every subject area every period of the week. Since the capacity formula developed in this study is to be applied to each subject area separately, no correction needs to be made in the formula for this factor. The allowance for this factor is made in determining the total operating capacity of the building from the capacity limits of each subject area. It was pointed out that the total operating capacity of a given secondary-school
building is the lowest subject area capacity limit determined by the application of the formula. This means that in every subject area except one, there will be unused capacity which in effect allows for the impracticability of scheduling every room every period in the week.

The question might well be raised that this does not allow any correction for the one subject area whose minimum capacity sets the total operating capacity of the building. This is true; but, it is the writer's contention that no correction needs to be made in the formula for this area except that already referred to when the number of periods of instruction per week of a subject is an aliquant part of the total possible periods per week of instruction.

Even though researchers in both the area of school building utilization and the area of housing requirements are generally agreed that it is impractical to use every room in a secondary-school building every period of the week, the cause and the nature of the correction of this factor have not been fully understood.

Additional capacity is not needed because of the impossibility of scheduling but rather because the complexity of the educational program makes it impossible to build a building which exactly fits the capacity requirements of the educational program. To be sure the scheduling problem might be a factor which would need additional capacity allowance if the room requirements of a given educational program were all whole numbers. Rarely do the calculated room requirements of a single subject area reveal a need for a whole number of rooms. The probability is almost infinitesimal that the calculated room requirements of all subject
areas would be whole numbers.

That it is possible to schedule every room in one or more subject areas every period of the week can be seen from the very research data from which it has been concluded that it is impractical to schedule every room of a secondary-school building every period of the week. It should be noted that it is not the writer's intention to invalidate the general conclusion that it is impractical to use every room of a secondary-school building every period of the week but rather to refine this statement so that a better understanding and application of the necessary corrections can be effected. Tables XIV, XV, and XVI of Morphet's study (23:81-84), containing the percentage utilization by areas of the 30 schools having the highest percentage of room utilization of the 78 buildings studied, show that all but two of the subject areas listed were utilized in at least one or more schools 100 per cent of the time. In the three schools which Anderson used as a basis for determining the allowance for schedule making, every subject area except printing, music, and gymnasium were utilized in at least one or more of the three schools 100 per cent of the time (9:24-26). Even in the one school in which Packer shows utilization by subject areas, several subject areas were utilized 100 per cent of the time (27:12). These data clearly indicate that it is possible under certain conditions to schedule certain subject area rooms every period of the day. The usual procedure in schedule making as a building approaches its capacity is to build the schedule around those areas in which there is a need for a high degree of room utilization. The excess capacity in other areas provides the necessary leeway
in the scheduling process.

This lack of complete understanding of why it is impossible to use every room of a secondary-school building every period of the week has led to inaccurate and conflicting procedures for correcting the required number of rooms necessary to house a given enrollment with a given educational program.

The chance fit or lack of fit of the educational programs in the specific buildings studied by Anderson and Packer led them to opposite conclusions concerning the necessary correction for this factor. Both researchers recognized that the educational program for a given enrollment almost never requires a whole number of rooms of a given type and the necessity of providing the next higher whole number of rooms provides excess capacity which provides leeway in scheduling. However, Anderson concluded that this excess capacity was sufficient allowance for scheduling regular classrooms but not for the various special area rooms (9:30-31). Packer concluded just the opposite, that the excess capacity was sufficient allowance for scheduling special area rooms but not regular classrooms (27:40).

For a number of years the Bureau of Educational Research of The Ohio State University used an adaptation of the Anderson formula in determining the housing requirements of new buildings. The Bureau used a correction factor approximately equal to the average room utilization found in existing buildings which they had studied. On the basis of research findings connected with this study, the Bureau of Educational Research of The Ohio State University no longer makes this correction.
Several actual planning situations will show that the need for planning whole rooms when only a fraction of a room is required will provide the necessary excess capacity needed to compensate for scheduling difficulties. These illustrations will further show that the application of the correction factors suggested by Packer or Anderson seldom results in the provision of additional capacity over that provided by the rounding-off of fractional room requirements and when this does occur, the excess capacity is actually greater than the correction factor indicates is needed.

Table 2 shows the desirable average class size and required pupil periods of instruction in the various subject areas of a four-year high school of 600 enrollment and the resulting required number of teaching stations as calculated by the basic housing requirements formula, first without a correction factor and then corrected as indicated by Anderson and Packer. In each case a 40-period week was used in the calculations. The lower part of the table shows the per cents of utilization which the building would have when the school enrollment reaches the planned capacity of 600, if the building were planned according to the various procedures indicated.

Tables 3 and 4 show similar data for junior and senior high schools of 650 and 1,200 enrollments, respectively.
TABLE 2

HOUSING REQUIREMENTS OF A HIGH-SCHOOL PROGRAM FOR 600 STUDENTS, DETERMINED BY THREE DIFFERENT METHODS; AND PER CENTS OF UTILIZATION WHEN THE ENROLLMENT REACHES THE PLANNED CAPACITY

<table>
<thead>
<tr>
<th>Subject area</th>
<th>Desired average class size</th>
<th>Pupil periods of instruction per week</th>
<th>Required number of rooms*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No correction</td>
<td>Packer correction</td>
</tr>
<tr>
<td>Academic</td>
<td>30</td>
<td>7,517</td>
<td>7.16-8</td>
</tr>
<tr>
<td>Business Education</td>
<td>36</td>
<td>3,269</td>
<td>2.59-3</td>
</tr>
<tr>
<td>Driver Education</td>
<td>24</td>
<td>270</td>
<td>a .32-1</td>
</tr>
<tr>
<td>Fine Arts</td>
<td>30</td>
<td>400</td>
<td>.38-1</td>
</tr>
<tr>
<td>Home Economics</td>
<td>24</td>
<td>965</td>
<td>1.15-2</td>
</tr>
<tr>
<td>Industrial Arts</td>
<td>27</td>
<td>1,190</td>
<td>b 1.26-2</td>
</tr>
<tr>
<td>Music</td>
<td>45</td>
<td>1,740</td>
<td>1.10-2</td>
</tr>
<tr>
<td>Physical Education</td>
<td>35</td>
<td>1,500</td>
<td>1.22-2</td>
</tr>
<tr>
<td>Health</td>
<td>35</td>
<td>1,500</td>
<td>a 1.22-2</td>
</tr>
<tr>
<td>Science</td>
<td>24</td>
<td>1,872</td>
<td>a 2.23-3</td>
</tr>
<tr>
<td>Automotive Shop</td>
<td>25</td>
<td>520</td>
<td>b .59-1</td>
</tr>
</tbody>
</table>

Per cents of utilization under varying conditions

<table>
<thead>
<tr>
<th>Rooms included</th>
<th>No correction</th>
<th>Packer correction</th>
<th>Anderson correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>All rooms -- no combination rooms</td>
<td>71.2</td>
<td>71.2</td>
<td>71.2</td>
</tr>
<tr>
<td>All rooms -- indicated combinations</td>
<td>80.1</td>
<td>80.1</td>
<td>73.9</td>
</tr>
<tr>
<td>Academic classrooms -- no combination rooms</td>
<td>89.5</td>
<td>89.5</td>
<td>89.5</td>
</tr>
<tr>
<td>Special classrooms -- indicated combination rooms</td>
<td>75.4</td>
<td>75.4</td>
<td>67.0</td>
</tr>
</tbody>
</table>

* The first number in each column is the calculated number of rooms; the second number is the required rooms rounded-off to the next higher whole number.

Note:
The fractional room requirements of two or more subject areas can often be met by a single room planned to meet the educational requirements of the various subject areas. For example, the fractional room requirements in the No correction column for Driver Education ( .32), Health (.22), and Science (.23) could be met by a single room adapted to meet the needs of all three areas. Other possible combinations are indicated in the above table by the letter designators.
TABLE 3
HOUSING REQUIREMENTS OF A JUNIOR HIGH-SCHOOL PROGRAM FOR 650 STUDENTS, DETERMINED BY THREE DIFFERENT METHODS; AND PER CENTS OF UTILIZATION WHEN THE ENROLLMENT REACHES THE PLANNED CAPACITY

<table>
<thead>
<tr>
<th>Subject area</th>
<th>Desirable average class size</th>
<th>Pupil periods of instruction per week</th>
<th>Required number of rooms*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Packer</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Anderson</td>
</tr>
<tr>
<td>Academic</td>
<td>30</td>
<td>11,590</td>
<td>11.04-12</td>
</tr>
<tr>
<td>Fine Arts</td>
<td>30</td>
<td>1,135</td>
<td>1.08-2</td>
</tr>
<tr>
<td>Home Economics</td>
<td>24</td>
<td>674</td>
<td>.80-1</td>
</tr>
<tr>
<td>Industrial Arts</td>
<td>30</td>
<td>958</td>
<td>.91-1</td>
</tr>
<tr>
<td>Music</td>
<td>35</td>
<td>1,458</td>
<td>1.19-2</td>
</tr>
<tr>
<td>Physical Education</td>
<td>35</td>
<td>1,300</td>
<td>1.06-2</td>
</tr>
<tr>
<td>Science</td>
<td>30</td>
<td>1,025</td>
<td>.98-1</td>
</tr>
<tr>
<td>Total teaching stations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>17.06-21</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>18.13-22</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>17.87-23</td>
</tr>
</tbody>
</table>

Per cents of utilization under varying conditions

<table>
<thead>
<tr>
<th>Rooms included</th>
<th>No correction</th>
<th>Packer correction</th>
<th>Anderson correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>All rooms -- no combination rooms</td>
<td>81.2</td>
<td>77.5</td>
<td>74.2</td>
</tr>
<tr>
<td>All rooms -- indicated combination rooms</td>
<td>81.2</td>
<td>77.5</td>
<td>77.5</td>
</tr>
<tr>
<td>Academic classrooms -- no combinations</td>
<td>92.0</td>
<td>84.9</td>
<td>92.0</td>
</tr>
<tr>
<td>Special classrooms -- indicated combination rooms</td>
<td>66.9</td>
<td>66.9</td>
<td>60.2</td>
</tr>
</tbody>
</table>

* The first number in each column is the calculated number of rooms; the second number is the required rooms rounded-off to the next higher whole number.

Note:
The fractional room requirements of two or more subject areas can often be met by a single room planned to meet the educational requirements of the various subject areas. For example, the fractional room requirements in the Anderson correction column for Fine Arts (.23) and Science (.11) could be met by a single room adapted to meet the needs of both subject areas. This combination is the only one in the above table.
TABLE 4

HOUSING REQUIREMENTS OF A SENIOR HIGH-SCHOOL PROGRAM FOR 1,200 STUDENTS, DETERMINED BY THREE DIFFERENT METHODS; AND PERCENTS OF UTILIZATION WHEN THE ENROLLMENT REACHES THE PLANNED CAPACITY

<table>
<thead>
<tr>
<th>Subject area</th>
<th>Desirable average class size</th>
<th>Pupil periods of instruction per week</th>
<th>Required number of rooms*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>No correction</td>
</tr>
<tr>
<td>Academic</td>
<td>30</td>
<td>15,055</td>
<td>12.55-13</td>
</tr>
<tr>
<td>Business Education</td>
<td>30</td>
<td>3,090</td>
<td>2.58-3</td>
</tr>
<tr>
<td>Driver Education</td>
<td>24</td>
<td>120</td>
<td>a .12-1</td>
</tr>
<tr>
<td>Family Relations</td>
<td>28</td>
<td>768</td>
<td>b .69-1</td>
</tr>
<tr>
<td>Fine Arts</td>
<td>25</td>
<td>450</td>
<td>.45-1</td>
</tr>
<tr>
<td>Health</td>
<td>30</td>
<td>1,268</td>
<td>a 1.06-2</td>
</tr>
<tr>
<td>Home Economics</td>
<td>28</td>
<td>1,420</td>
<td>b 1.27-2</td>
</tr>
<tr>
<td>Industrial Arts</td>
<td>24</td>
<td>1,480</td>
<td>e 1.54-2</td>
</tr>
<tr>
<td>Music</td>
<td>60</td>
<td>1,710</td>
<td>.71-1</td>
</tr>
<tr>
<td>Physical Education</td>
<td>35</td>
<td>1,913</td>
<td>1.37-2</td>
</tr>
<tr>
<td>Science</td>
<td>28</td>
<td>2,109</td>
<td>1.88-2</td>
</tr>
<tr>
<td>Slow Learners</td>
<td>20</td>
<td>800</td>
<td>1.00-1</td>
</tr>
<tr>
<td>Vocational Education</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business</td>
<td>30</td>
<td>730</td>
<td>.61-1</td>
</tr>
<tr>
<td>Shop</td>
<td>25</td>
<td>2,070</td>
<td>c 2.07-3</td>
</tr>
<tr>
<td>Related Instruction</td>
<td>25</td>
<td>1,085</td>
<td>a 1.08-2</td>
</tr>
<tr>
<td>Total Teaching Stations</td>
<td></td>
<td></td>
<td>28.98-37</td>
</tr>
</tbody>
</table>

Per cents of utilization under varying conditions

<table>
<thead>
<tr>
<th>Rooms included</th>
<th>No correction</th>
<th>Packer correction</th>
<th>Anderson correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>All rooms -- no combination rooms</td>
<td>78.3</td>
<td>76.3</td>
<td>76.3</td>
</tr>
<tr>
<td>All rooms -- indicated combinations</td>
<td>87.8</td>
<td>85.2</td>
<td>82.8</td>
</tr>
<tr>
<td>Academic classrooms -- no combinations</td>
<td>96.5</td>
<td>89.6</td>
<td>96.5</td>
</tr>
<tr>
<td>Special rooms -- indicated combinations</td>
<td>82.2</td>
<td>82.2</td>
<td>74.7</td>
</tr>
</tbody>
</table>

Note:
The fractional room requirements of two or more subject areas can often be met by a single room planned to meet the educational requirements of the various subject areas. For example, the fractional room requirements in the No correction column for Driver Education (.12), Health (.06), and Vocational Related Instruction (.08) could be met by a single room adapted to meet the needs of all three subject areas. Other possible combinations rooms are indicated in the above table by the letter designators.
If separate rooms are provided for each subject area indicated,
it will be noted from Table 2 that 27 teaching stations will be required
whether any correction factor is applied or not. It so happens in this
particular case that the corrections are insufficient to raise the cal-
culated requirements beyond the next higher whole number and the round-
ing-off makes them all the same. It must not be concluded, however,
that the application of the correction factor makes no difference. In
actual planning procedures, fractional room requirements can often be
met by the planning of combination rooms to serve two or more areas.
By the planning of a combination shop to serve both areas of automotive
and industrial arts, and a combination room to serve general science,
health, and driver education, the total number of required rooms or
teaching stations could be lowered to 24 if we use the requirements as
calculated without corrections. Since the Packer correction applies only
to academic rooms, the same combinations could be effected in this case
and the total rooms reduced to 24. However, in the Anderson procedure,
where the correction increases the requirements in all the special areas,
these same combinations cannot be made. It will be noted, however, that
a combination science-health room would be possible which would reduce
the total room requirements to 26.

Since the formula, when not corrected, gives the basic room require-
ments for an enrollment of 600, we can roughly calculate the per cent of
room utilization which could be expected when the enrollment reaches 600
by dividing the total calculated room requirements by the total number of
rooms which would be provided under the various planning procedures. It
will be noted from Table 2 that 600 pupils would utilize only 80.1 per cent the very minimum size building necessary to house the educational program. A building planned according to the Anderson procedure, which would include two additional teaching stations to allow for scheduling could be expected to be utilized only 73.9 per cent. This means that on an average one out of every four rooms will be vacant every period of the day rather than one out of five which would be the case without applying a correction factor. It will be noted in this particular planning project that the rounding-off of fractional room requirements alone provides more than 10 per cent excess capacity even in academic rooms. Packer suggests a need for 8.8 per cent excess capacity in the academic area for this size school.

Tables 3 and 4 indicate essentially the same things about the junior and senior high schools which have been said about the four-year high-school requirements found in Table 2. It should be pointed out, however, that the increased academic room requirements in these programs make the Packer correction factor noticeable by the requirement of an additional academic room. It should be noted also from Table 3 that the rounding-off alone provides 8 per cent (100-92) additional capacity in academic rooms while the application of the Packer correction factor provides 15.1 per cent (100-84.9) additional capacity which is almost twice the allowance Packer indicated was necessary to offset scheduling difficulties in this size school. Thus we see that the correction factor when it does make a difference in the number of rooms to be provided, actually over-compensates. This fact will be noted also in the senior high-school requirements summarized in Table 4.
Having discussed the various implications of the impracticability of utilizing every room or every pupil station in a secondary-school building every period of the week, let us turn to the actual data which must be collected and processed in order to arrive at the operating capacity of a secondary-school building. There is no particular order in which the various data must be collected. Since the technique was developed to be used in connection with building surveys made by the Survey Division of the Bureau of Educational Research of The Ohio State University, it was only natural that forms and work sheets were developed to dovetail with existing forms used by the Bureau for the collection of other data. In actual practice, total enrollment and basic room data are still being collected on forms which have been used for some time by the Bureau in other phases of the building survey. Simplified forms for the collection of these data have been developed here to serve only the immediate need of capacity determination. For convenience, this discussion will follow the order in which items appear on the work sheets. These work sheets will be found at the end of this chapter.

**Total Enrollment Data**

The first set of data which is to be collected is probably the simplest and easiest to obtain. Although the formula calls only for the 5-year average total enrollment, it is necessary to collect enrollment data by grades for a 5-year period in order to check the constancy of the
relationship of subject enrollments to total enrollments, and to assist in making adjustments when the relationship of subject enrollments to total enrollments is clearly not a constant. This supplementary use of total enrollment data will be explained in a later section dealing with the adjustment of average subject enrollments.

Subject Enrollment Data

Probably the most time consuming task involved in the capacity determination is the translation of the educational program into pupil periods of the various subject areas of the curriculum. The first task is the listing of all required and elective subjects by subject areas in the curriculum. It is necessary to list separately those subjects in the curriculum which require differentiated equipment and facilities, since each of these areas must be treated separately. Having defined the horizontal organization of the educational program by the listing of all subjects, data must be secured to show the relationship of these component parts. It is easily understood that subject enrollments will be an important factor in defining this relationship. However, subject enrollments will not be sufficient to define the program since the amount of time devoted to instruction varies from one area to another; from one subject to another in the same area; and sometimes the amount of time devoted to instruction in a given subject varies from one grade level to another. Therefore, we need the grade placement and the periods per week devoted to instruction for each subject in order to clearly define the relationship of the various subjects in the curriculum. It
was pointed out in the preceding chapter that subject enrollments vary quite widely from one school to another but under normal circumstances the relationship of subject enrollment to total enrollment is relatively constant in any one given school situation. Since the capacity formula is based upon the constancy of this relationship, a truer measure of capacity can be made if adjustments are made in those instances where this relationship is clearly not a constant. It is clearly evident that the constancy of this relationship will be effected by such factors as: introduction of new subjects, dropping of subjects from the curriculum, changing a subject from elective to required status, or vice versa. When such factors are operative, the subject enrollments should be adjusted in the light of the best information available to produce a relationship which is most likely to represent the relationship for the immediate future.

Having established the average subject enrollments or adjusted averages where necessary, we may proceed to the determination of the total pupil periods of instruction in each area which is a required factor in the capacity formula. The number of pupil periods of instruction in each subject is the product of average subject enrollment by the number of periods of instruction per week of each subject. In the first section of this chapter it was pointed out that an adjustment in capacity is necessary when the number of periods per week of a subject is an aliquant part of the total periods of instruction per week. In order to correct for this factor the number of periods of instruction per week is adjusted as indicated earlier in this chapter. By adding the adjusted
pupil periods of instruction in each subject, the total adjusted pupil periods of instruction in each subject area may be determined and substituted in the capacity formula.

Basic Room Data

Undoubtedly, any secondary-school principal can give the number of teaching stations in his building in each subject area of the curriculum but in order to have detailed information upon which to check the adequacy of such rooms and make certain adjustments in the building better to meet the educational program, certain basic data are needed concerning each room. From these basic room data, the local school authorities with the possible assistance of educational consultants may determine the number of adequate teaching stations which are available in each subject area. The number of such teaching stations is substituted in the capacity formula in order to determine the capacity limit of each area.

Miscellaneous Data

Finally there are factors concerning the educational program and policies of the school which must be determined before the operating capacity of the building can be established. First, what is the desirable average class size? There is much difference of opinion on what constitutes desirable average class size. Although there are no research data which clearly indicate the desirability of small classes, most teachers are convinced that a better job of teaching can be done with smaller classes. Whatever decision is reached concerning desirable average class size, it must be consistent with the physical facilities available and
with the financial ability and willingness of the community to support. Such considerations as these make the resulting operating capacity a very practical figure, and make the technique equally applicable to all types of school situations since the formula contains no fixed abstract standards.

The final consideration necessary in determining the operating capacity of a building is the program organization. Since most secondary-school programs vary from one day of the week to another, it is easiest to define the program in terms of a week. In fact, some school programs vary from one week to the next. In such cases the average must be used. Since the curriculum was defined in terms of pupil periods of instruction per week, the basic additional facts concerning the educational program are the total number of effective periods per week which is available for regularly scheduled class instruction. It is obvious that a building cannot be utilized fully when only a portion of the possible pupil capacity is available for instruction at a given time. This is the case during a staggered lunch period and some correction is necessary in this case. This correction can be made by subtracting five from the total operating periods in the weekly schedule which is equivalent to counting the number of periods which any student would be available for instruction. It is clear that he is not available for instruction during his lunch period.

An activity period may have a similar effect in reducing the total effective periods of instruction per week. If one period each day is set aside for activities during which classes do not meet, such periods
should not be counted as instructional periods for purposes of determining capacity. On the other hand, if activities are scheduled throughout the school day, they should be treated as regular classes and the capacity calculated accordingly.

Building Capacity Forms

In view of the fact that the capacity formula contains many factors which are multiple in nature and not readily available in their present form to the secondary-school principal, it seemed expedient to develop forms for collecting and processing the raw data. Four such forms with detailed instruction sheets to accompany each form have been developed and will be found at the end of this chapter. These building capacity forms and instruction sheets have been given the following names and identification symbols so they may be easily identified:

Form 1 Total Enrollment Data
Form 1-1 Instructions to Accompany Form 1
Form 2 Subject Enrollment Data
Form 2-1 Instructions to Accompany Form 2
Form 3 Basic Room Data
Form 3-1 Instructions to Accompany Form 3
Form 4 Miscellaneous Data
Form 4-1 Instructions to Accompany Form 4
The forms and the accompanying instruction sheets define the step by step process of determining the capacity of a secondary-school building. Forms 1, 2, and 3 are primarily data collection forms although some processing of data is also included on these forms. Form 4 is a summary form which includes the various factors in the capacity formula in such a way that the various steps in the solution of the capacity formula are simple processes of arithmetic.

The instruction sheets accompanying each form are in such detail that there is no need for further explanation here. The applications of the technique in the next chapter will further illumine the use of these forms in determining the capacity of secondary school buildings.
<table>
<thead>
<tr>
<th>Grade</th>
<th>September enrollment for past 5 years</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>(3)</td>
<td>19_  19_  19_  19_  19_</td>
<td>(5)</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
INSTRUCTIONS TO ACCOMPANY FORM 1

TOTAL ENROLLMENT DATA

Item 1. School district -- Record the name of the school district so that forms may be easily identified.

Item 2. Building -- Record the name of the building so that forms may be easily identified.

Column 3. Grade -- Include only those grades which are to be housed in the building.

Column 4. Enrollment for past 5 years -- Record enrollments by grades for each of the past five years. Use comparable data on Forms 1 and 2. If September subject enrollment data are used on Form 2, then September total enrollment data should be used here.

Column 5. Average -- Calculate averages by grades and total.
<table>
<thead>
<tr>
<th>Subjects (e.g., chemistry)</th>
<th>Grade placement</th>
<th>Periods per week of subject</th>
<th>Subject enrollments for past five years</th>
<th>Adjusted average subject enrollments</th>
<th>Adjusted subject periods per week</th>
<th>Adjusted pupil periods per week</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(11) Total adjusted pupil periods per week
GENERAL INSTRUCTIONS -- Use a separate form for each of the special subject areas such as art, science, and home economics but combine on one form, titled "academic," all those subjects which may be taught in a regular classroom such as language arts, social studies, and mathematics.

Item 1. Subject area -- Record the subject area in the upper left hand corner, e.g. science.

Item 2. School district -- Record the name of the school district so that forms may be easily identified.

Item 3. Building -- Record the name of the building so that forms may be easily identified.

Column 4. Subjects -- Record all the different subjects offered during the first semester of any year of the five year period.

Column 5. Grade placement -- If the subject is required, indicate the grade level at which it is required; otherwise, indicate the grade level of the majority of students who elect the subject.

Column 6. Periods per week of subject -- Indicate the number of periods of class instruction per week. If the periods vary from one week to the next, indicate the average number of periods per week.

Column 7. Subject enrollments for past 5 years -- Record enrollments by subjects for each of the past 5 years, and then determine the average subject enrollment for the five-year period.

NOTE -- The average is for a five-year period, therefore, the sum of the enrollments in a given subject must be divided by five even though the subject was offered only two or three times in the five-year period. This will give the proper weight to subjects offered on an alternate year basis.
Column 8. Adjusted average subject enrollments -- When enrollments have maintained a relatively constant relationship to total school enrollments, no adjustment is necessary and this fact should be noted by drawing a line through the appropriate blank space in Column 8. When it is clear that the subject enrollments have not maintained a relatively constant relationship to total school enrollments, the average subject enrollment must be adjusted in the light of the best information which is available. When such is the case, the person responsible for this form should record here the subject enrollment which in his judgment is most likely to result from a total enrollment equal to the average total enrollment of the five-year period. Form 1 contains the average total enrollments by grades and for the entire school.

Several illustrations will help clarify this adjustment process as well as to point out the types of situations where adjustments are necessary. A subject which has become required of all students at a given grade level should be adjusted to the average enrollment of that grade for the five-year period. If the enrollments in a given subject show a trend, either upward or downward, the average subject enrollment should be adjusted to reflect this trend. A subject which has been added to the curriculum recently so that five years of enrollment data are not available will need to be adjusted in the light of the meager data which are available. If the data show a steady increase, the adjustment should reflect this trend. On the other hand, if the enrollment during the first year in which the subject was offered was higher than the following years, it might be attributed to newness of the subject and the adjustment should reflect this. Average enrollments in subjects which have been dropped from the curriculum should be adjusted to zero.

Column 9. Adjusted periods per week of subject -- Certain classes which meet other than five periods per week impose certain scheduling problems. For example, if chemistry meets seven periods per week, it is impossible to schedule classes in a chemistry room for every period of the week when the school operates on a nine-period day or 45 period week because 45 will not divide into a whole number of seven-period blocks. Therefore, some adjustment needs to be made in order to determine the operating capacities of rooms in such subject areas.
To determine the adjusted periods per week of a subject, divide the number of periods per week in the operating schedule of classes by the periods per week of the subject. If the quotient is a whole number, no adjustment is necessary; therefore, record the actual periods per week of the subject from Column 6. If the quotient is not a whole number, divide the whole number part into the number of periods per week in the operating schedule and carry to the nearest tenth to determine the adjusted periods per week. Example: chemistry meets seven periods per week on a nine periods per day or 45 periods per week schedule of classes. Dividing 45 by 7 gives a quotient of 6 3/7 which is not a whole number. Therefore, divide 45 by 6, the whole number part of 6 3/7, which gives a quotient of 7.5 for the adjusted periods per week.

Column 10. Adjusted pupil periods per week -- To determine the adjusted pupil periods per week of each subject, multiply the average or adjusted average subject enrollment, if adjusted (Item 7 or 8) by the adjusted periods per week of each subject (Item 9).

Item 11. Total adjusted pupil periods per week -- Record here the sum of the adjusted pupil periods per week for all subjects in the subject area.
# BASIC ROOM DATA

<table>
<thead>
<tr>
<th>Room number</th>
<th>Location of room</th>
<th>Dimensions of room</th>
<th>Type of room</th>
<th>Present use of room</th>
<th>Existing pupil stations</th>
<th>Desirable maximum pupil stations</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
<td>(7)</td>
<td>(8)</td>
<td>(9)</td>
<td>(10)</td>
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</tbody>
</table>

---

Form 3
INSTRUCTIONS TO ACCOMPANY FORM 3

BASIC ROOM DATA

General Instructions

a. Include every room designed for or which may be used for instructional purposes whether it is USED or UNUSED at the present time during the regular school day.

b. Exclude small storage and work rooms but be sure to include such special rooms as gymnasiums, music rooms, visual education rooms, laboratories, study halls, auditoriums, libraries, and cafeterias.

Item 1. School district — Indicate the name of the school district so that forms may be easily identified.

Item 2. Building — Indicate the name of the building so that forms may be easily identified.

Column 3. Room number — If a room is not numbered, indicate its name, such as foods laboratory, gymnasium, etc.

Column 4. Location of room — Indicate by basement, 1, 2, 3, etc. the floor upon which the room is located.

Column 5. Dimensions of room — Measurements to the nearest foot are satisfactory. In case a room is not rectangular, a small free-hand sketch with various dimensions will be helpful.

Column 6. Type of room — Indicate the type of room by the subject area for which the room was planned or to which it has been adapted by specialized equipment. If a room has no specialized equipment and is not especially adapted to some special use because of its size, it should be classified as "academic." Rooms equally suitable for such classes as mathematics, English, or social studies should be classified as "academic."

Column 7. Present use of room — Indicate the present use of the room by the subject area for which it is being used. If a room is used interchangeably for mathematics, language arts or
social studies, indicate its use by the term "academic."
Additional use made of special rooms should be indicated in Column 10.

<p>| Column 8 | Existing pupil stations -- A &quot;pupil station&quot; may be defined as a desk, chair, or working space for one pupil. In rooms not having desks, chairs, or other definite pupil stations, indicate the maximum size class which could be handled satisfactorily therein. |
| Column 9 | Desirable maximum pupil stations -- In order to maintain any average class size, classrooms must be adequate to accommodate a few more than the desired average since average implies some spread about the average. Indicate here the maximum number of pupil stations which you feel the rooms could satisfactorily accommodate in order to take care of peak loads. |
| Column 10 | Remarks -- Use this space to record the multiple use of rooms indicated under Item 7 and record any other special features about a room which might make it especially suitable or unsuitable for other use. |</p>
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<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
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<th>(11)</th>
<th>(12)</th>
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</tr>
</tbody>
</table>

Form 4

(13) Building capacity

(14) Adjusted building capacity
INSTRUCTIONS TO ACCOMPANY FORM 4

MISCELLANEOUS DATA

Item 1. School district -- Record the name of the school district so that forms may be easily identified.

Item 2. Building -- Record the name of the building so that the form may be easily identified.

Column 3. Subject area -- The more common subject areas are already listed in this column. "Academic" includes all those subjects which do not require specialized equipment. Language arts, mathematics and social studies would all fall into this classification. If the curriculum includes special subjects other than those listed which require specialized equipment, such subject areas should be added at the bottom of the list under special areas.

Column 4. Number of teaching stations -- A teaching station may be defined as any location in the building which is suitable to be used by one teacher in the conduct of a group learning process. In general, the number of teaching stations of a given type will be the total number of such rooms. However, exceptions may be found in certain special areas. For example, one large shop room may represent two teaching stations if it is large enough and so arranged to be used by two class groups at the same time. This is often true also of large gymnasiums. On the other hand, two rooms may constitute only one teaching station when both are required for the normal operation of a single class. This is often true of the science laboratory which is not set up for group discussion and demonstration. In such cases, the laboratory and lecture room should be taken together as one teaching station.

Since study hall facilities vary considerably, both in size and type of facilities, it will be easier to make the capacity calculation if the number of teaching stations available for study purposes is calculated in terms of units of capacity of 100. To determine the equivalent teaching stations for study purposes, find the sum of the maximum pupil stations in all study rooms, multiply by .92 to allow for differences in average and maximum class size and then divide by 100. Record the result to the nearest hundredth.
Excluding any room or teaching station which, for any reason, is not to be used for instructional purposes.

Column 5. Desirable average class size -- Record here the desirable average class size for each subject area. Generally, the desirable average class size varies from one subject area to another depending primarily upon the type of activities carried on in the classroom. For example, class sizes in typing and physical education are usually larger than class sizes in shop or fine arts where more individual attention is necessary. Note that this column calls for desirable average class size and not desirable maximum class size. In order to have an average class size of 25, some classes may be as large as 30 while others are only 10 or 15. This difference is due to the pattern of student electives and to scheduling difficulties at the secondary-school level.

Unless the average maximum pupil stations (Column 9 of Form 3) in the rooms of a given subject area are sufficiently greater than the desirable average class size for that area, the desirable average class size recorded in this column must be adjusted downward. To determine the necessary adjustments, find the average maximum pupil stations in each subject area (Column 9 of Form 3). If the average for any subject area is: 24 or less, subtract three; 25 to 35, subtract five; or 36 or greater, subtract eight. If the remainder, after three, five, or eight have been subtracted, is greater than the desirable average class size for the corresponding subject area, no adjustment is necessary. If the remainder after the above allowances have been subtracted, is less than the desirable average class size, the remainder becomes the adjusted desirable average class size and should be recorded in this column to the right of the original entry.

Column 6. Effective periods per week -- Record here the total number of periods in the weekly schedule which a pupil may use for classroom activities. Exclude homeroom or activity periods during which the regular class schedule is suspended. If pupils eat lunch on a staggered schedule while others are having regular classes, five periods per week should be deducted from the total number of regular class periods per week.

Column 7. Average total enrollment for 5-year period -- Record here the average total enrollment for all grades from Column 5 of Form 1.

Form 4-1
Page 2
Column 8. Teaching station pupil period enrollment -- Record here the product of Columns 4, 5, 6, and 7.

Column 9. Adjusted pupil periods -- Record here the total adjusted pupil periods per week for each subject area from Item 11 of the various Form 2's.

Column 10. Pupil capacity limit -- Record here the quotient of Column 8 divided by Column 9.

Column 11. Teaching station capacity index -- Record here the quotient of Column 10 divided by Column 4.

Column 12. Teaching station adjustments -- At best the adjustment process is one of the trial and error. However, the following procedure will usually save time in arriving at the maximum capacity to which the building can be adjusted. Record in the first sub-column of Column 12, the second lowest capacity limit in Column 10; divide this assumed capacity by the teaching station capacity index, Column 11; round-off the quotient to the next higher whole number; and subtract the result from the number of teaching stations, Column 4. Positive differences show the excess teaching stations in each subject area for the assumed capacity and negative differences indicate the number of additional teaching stations needed for that given capacity figure.

If the additional teaching stations needed for this capacity can be provided by converting the excess spaces to other use, the building capacity can be adjusted upward. If there are insufficient excess teaching stations which can be converted to provide the additional teaching stations needed in other areas, it can be concluded that the adjusted capacity must fall between the lowest and second lowest pupil capacity limits. If the excess spaces are completely utilized in making the necessary conversions, this capacity figure becomes the adjusted capacity of the building. If the necessary conversions do not utilize all the excess spaces, the capacity of the building may be adjusted still further. In this case, repeat the process outlined above with the next higher pupil capacity limit in Column 10, until a capacity figure is reached for which there are insufficient excess teaching stations to provide the additional teaching stations needed in other subject areas. This process will either determine the adjusted capacity of the building or will set the limits within which the adjusted capacity will fall. The fact that the adjusted capacity of the building will always be a multiple of the teaching
station capacity index. Column 11, of one of the subject areas involved in the conversions of spaces will help in determining the maximum capacity to which the building may be adjusted. Select those multiples of the teaching station capacity index of the subject areas involved in the conversions of spaces which fall between the limits already determined and repeat the process outlined above, starting with the lowest figure and continuing until a capacity figure is reached beyond which there are insufficient excess teaching stations to provide the additional teaching stations needed in other subject areas. This capacity figure will be the adjusted capacity of the building.

It should be noted further that the positive and negative adjustment units are teaching stations and will not always have a one to one ratio to each other. For example, it may take two or three academic teaching stations to make one teaching station in certain special areas. Also, it should be remembered that the excess spaces may not be satisfactory for the desired use. For example, the second teaching station of a multiple gymnasium could not be used for any other than its intended use.

Item 13. Building capacity -- The lowest figure recorded in Column 10 represents the maximum number of pupils which the building will house without crowding in any area. This will not be a very realistic figure in most cases unless the building perfectly fits the educational program. Therefore, some adjustment should be made.

Item 14. Adjusted building capacity -- Record the capacity figure obtained by the process outlined in Column 12 above.
CHAPTER 5

APPLICATIONS OF THE CAPACITY DETERMINING TECHNIQUE

Possible Applications of the Technique

This chapter will discuss the possible applications of the capacity determining technique and will illustrate these uses by practical applications of the technique in a number of school situations. Although the technique is primarily one for determining the capacity of a secondary-school building, the capacity relationship does have a number of varied uses.

Determining Quantitative Adequacy of Existing Buildings

Since the capacity determining technique differentiates the many factors of educational program and educational policies of a given school situation, it is equally applicable in determining the capacity of buildings for some projected use as well as for the existing use which is being made of the building. In these days of changing educational programs, the administrator may wish to determine the effect which a given change in educational program will have upon the capacity of the building or whether the building will actually house the projected educational program. School authorities also may be considering the merits of a changed daily program organization. The capacity of the existing building under the present and changed program organization will furnish valuable additional data upon which to base the final decision.
Likewise, the capacity of an existing building can be determined for
different types of vertical organization. A decided difference in the
capacity of an existing building for one program over another may well
dictate whether a new junior or senior high-school building is to be
built. In addition to determining the total operating capacity of an
existing building, the proposed capacity technique determines the sub-
ject areas where overcrowding is taking place and the degree of such
overcrowding. This suggests a whole new area of use for the capacity
determining technique.

Planning of New Facilities

Since the capacity technique establishes a relationship of capacity
to educational program and policies, it is very useful in the planning
of new secondary-school buildings or in the remodeling or enlargement
of existing buildings. Although similar, it is really superior to other
techniques for determining housing requirements for the following reasons:

1. It involves a more realistic correction for the imprac-
ticability of scheduling every room and every pupil
station of a secondary-school building every period of
the week. This is due largely to a more complete under-
standing of this factor — its cause as well as its effect.

2. The technique is very useful in determining the amount
of necessary building expansion of existing buildings
as well as in the planning of new buildings.
3. The technique is very useful in projecting future expansion in the original planning of secondary-school buildings. Due to the difference between fractional and whole room requirement, some areas will not need to be expanded unless extreme increases in enrollment come about while other areas will be used to capacity by the planned enrollment and should be located where they easily can be expanded without destroying the functional relationship of the various areas of the building.

Selection of Schools for Specific Applications

Criteria for Selection of Schools

Since it was clear from the very beginning that some selection of schools would need to be made for the application of the capacity technique, three major criteria were developed for the selection of such schools.

The first criterion was heterogeneity. Since the technique was designed to meet the criterion of universal application, an attempt has been made to select schools of varied types. Schools of various sizes, varied types of vertical school organization, and varied types of educational programs have been selected.

The second criterion for the selection of schools was the ease with which data could be collected. Schools in which the Bureau of Educational
Research had conducted or were currently conducting surveys furnished a very valuable and easy source of data for most of the schools which have been included. Schools which did not fall in this category would have to be located close to Columbus since money was not available to cover the cost of long trips. The final factor which has a bearing on this criterion quite naturally was the willingness of administrative officials to furnish the necessary data for capacity determinations.

The final criterion, and the one which was given the most weight in the final selection of schools for inclusion in this study was variety of applications. Only those school situations which pointed out varied applications of the capacity technique were included in this study.

**Number and Types of Schools Selected**

To illustrate the use of the formula 13 buildings and 23 different types of school programs were selected which represent enrollments from 232 to 1,492 and represent varied educational programs from the very traditional to the more modern types. These illustrations represent only a small number of the actual school situations in which the capacity determining technique has been applied, since it is currently being used by the Survey Division of the Bureau of Educational Research of The Ohio State University. In each case the educational programs and educational policies affecting capacity have been analyzed in detail, showing total enrollment data, student elections in the various subject areas, periods per week of instruction devoted to each subject, basic room data for all instructional rooms of the building, desirable average class sizes, and the number of periods per week available for instruction.
Applications of the Capacity Technique in Specific School Situations

In order to illustrate the use of the various forms developed in the preceding chapter and give a complete picture of the capacity technique, complete detailed data are included in Tables 5 through 16 for the first illustration. These tables have been brought together in the following pages for easy reference. Other applications will include only enough raw data, summarized as much as possible, to illustrate the varied uses of the capacity technique. These data will be found in subsequent tables.

Building A

Building A, the first illustration, is the only secondary-school building of a small city school district in northern Ohio. At the present time six rooms of the building are used also for elementary-school purposes, although there are other elementary schools in the district. It is anticipated that this building will be used exclusively for secondary-school purposes; therefore, the six elementary classrooms have been classified as academic classrooms in this capacity study.

Table 5 shows the total secondary-school enrollment pattern by grades for the five-year period 1947-48 through 1951-52. The total enrollment remained relatively constant during the first four years of the five-year period and then increased approximately 10 per cent the last year. The average total secondary-school enrollment for the five-year period was 602. It is this average total enrollment which
### TABLE 5 TOTAL ENROLLMENT DATA

<table>
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<th>Grade (3)</th>
<th>September enrollment for past 5 years</th>
<th>Average (5)</th>
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<td>TOTAL</td>
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Form 1
### TABLE 6

**SUBJECT ENROLLMENT DATA**

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<th>Subjects (e.g., chemistry)</th>
<th>Grade placement</th>
<th>Periods per week of subject</th>
<th>Subject enrollments for past five years</th>
<th>Adjusted average subject enrollments per week</th>
<th>Adjusted periods per week</th>
<th>Adjusted pupil periods per week</th>
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(11) Total adjusted pupil periods per week: 8,940
### TABLE 7
SUBJECT ENROLLMENT DATA

<table>
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<tr>
<th>Subjects (e.g., chemistry)</th>
<th>Grade placement</th>
<th>Periods per week of subject</th>
<th>Subject enrollments for past five years</th>
<th>Adjusted average periods per week of subject enrollments</th>
<th>Adjusted periods per week of subject enrollments</th>
<th>Adjusted pupil periods per week</th>
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<tbody>
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<td>(9)</td>
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Form 2
### TABLE 8

**SUBJECT ENROLLMENT DATA**

<table>
<thead>
<tr>
<th>Subject area</th>
<th>School district</th>
<th>Building</th>
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<td>(1) Subject area</td>
<td>(2) School district</td>
<td>(3) Building</td>
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<td>Art</td>
<td>A</td>
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<td>Subjects (e.g., chemistry)</td>
<td>Grade placement</td>
<td>Periods per week of subject</td>
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<td>(6)</td>
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<td>Art</td>
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<tr>
<td>Art</td>
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| (11) Total adjusted pupil periods per week | 139 |

Form 2
### Table 9

**Subject Enrollment Data**

<table>
<thead>
<tr>
<th>Subjects (e.g., chemistry)</th>
<th>Grade placement</th>
<th>Periods per week of subject</th>
<th>Subject enrollments for past five years</th>
<th>Adjusted average subject enrollments per week</th>
<th>Adjusted periods per week of subject</th>
<th>Adjusted pupil periods per week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home Economics</td>
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<td>5</td>
<td>45 52 46 32 56 46</td>
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<td>5</td>
<td>230</td>
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<tr>
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<td>10</td>
<td>10 -- 13 14 10</td>
<td>13</td>
<td>10</td>
<td>130</td>
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<td>Clothing</td>
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<td>10</td>
<td>16 23 19 22 23</td>
<td>--</td>
<td>10</td>
<td>230</td>
</tr>
<tr>
<td>Homemaking</td>
<td>11-12</td>
<td>5</td>
<td>24 11 16 -- 14 13</td>
<td>16</td>
<td>5</td>
<td>80</td>
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(11) Total adjusted pupil periods per week: 670
TABLE 10
SUBJECT ENROLLMENT DATA

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<th>Grade placement</th>
<th>Periods per week of subject</th>
<th>Subject enrollments for past five years</th>
<th>Adjusted average periods of subject per week</th>
<th>Adjusted pupil periods per week</th>
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<tbody>
<tr>
<td>Shop</td>
<td></td>
<td></td>
<td>(7) 1947 1948 1949 1950 1951 Average</td>
<td>(8)</td>
<td>(9)</td>
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<td>10</td>
<td>19 23 25 27 26 24</td>
<td>--</td>
<td>10</td>
</tr>
<tr>
<td>Wood I</td>
<td>9</td>
<td>10</td>
<td>24 36 30 36 16 28</td>
<td>--</td>
<td>10</td>
</tr>
<tr>
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<td>10-12</td>
<td>10</td>
<td>13 12 18 18 11 14</td>
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<tr>
<td>Mechanical Drawing</td>
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<td>25 25 25 23 17 23</td>
<td>--</td>
<td>10</td>
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<tr>
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<td>10</td>
<td>22 20 10 11 17 16</td>
<td>--</td>
<td>10</td>
</tr>
<tr>
<td>Mechanical Drawing II</td>
<td>11-12</td>
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<td>22 19 10 10 11 14</td>
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### TABLE II
**SUBJECT ENROLLMENT DATA**

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<th>(1) Subject area</th>
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<table>
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<th>Periods per week of subject</th>
<th>Subject enrollments for past five years</th>
<th>Adjusted average subject enrollments per week</th>
<th>Adjusted pupil periods per week</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
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<td>9-12</td>
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<td>5, 270</td>
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<tr>
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<td>9-12</td>
<td>5</td>
<td>80, 62, 66, 77, 70, 71</td>
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<td>5, 355</td>
</tr>
<tr>
<td>Boys Glee Club</td>
<td>9-12</td>
<td>5</td>
<td>23, 12, 31, 29, 26, 26</td>
<td>--</td>
<td>5, 130</td>
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<tr>
<td>Jr. Hi Glee Club</td>
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<td>2</td>
<td>26, 33, 30, 28, 28</td>
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<td>2, 50</td>
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<td>25, 33, 30, 29, 29</td>
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(11) Total adjusted pupil periods per week 879

| Instrumental             |                 |                             |                                          |                                               |                                |
|--------------------------|-----------------|-----------------------------|------------------------------------------|-----------------------------------------------|                                |
| Varsity Band             | 9-12            | 5                           | 65, 75, 71, 72, 64, 69                  | --                                            | 5, 345                         |
| Reserve Band             | 7-8             | 3                           | 17, 13, 25, 20, 21, 21                  | --                                            | 3.1, 65                        |

(11) Total adjusted pupil periods per week 410

Form 2
TABLE 12
SUBJECT ENROLLMENT DATA

(1) Subject area   Physical Education    (2) School district

<table>
<thead>
<tr>
<th>Subjects (e.g., chemistry)</th>
<th>Grade placement</th>
<th>Periods per week of subject</th>
<th>Subject enrollments for past five years</th>
<th>Adjusted average subject enrollments</th>
<th>Adjusted periods per week of subject</th>
<th>Adjusted pupil periods per week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jr. High Girls</td>
<td>7-8</td>
<td>2</td>
<td>98, 71, 90, 100, 108</td>
<td>93</td>
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<td>186</td>
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<td>Sr. High Girls</td>
<td>9-12</td>
<td>2</td>
<td>98, 119, 90, 100, 105</td>
<td>102</td>
<td>2</td>
<td>204</td>
</tr>
<tr>
<td>Jr. High Boys</td>
<td>7-8</td>
<td>2</td>
<td>97, 102, 90, 107, 106</td>
<td>100</td>
<td>2</td>
<td>200</td>
</tr>
<tr>
<td>Sr. High Boys</td>
<td>9-12</td>
<td>2</td>
<td>97, 102, 90, 107, 99</td>
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<td>198</td>
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(11) Total adjusted pupil periods per week 788
### TABLE 13
SUBJECT ENROLLMENT DATA

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<th>(10)</th>
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</thead>
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<td></td>
<td>Science</td>
<td>School district</td>
<td>Building A</td>
<td>Subjects (e.g., chemistry)</td>
<td>Grade placement</td>
<td>Periods per week of subject</td>
<td>Subject enrollments for past five years</td>
<td>Adjusted average subject enrollments per week</td>
<td>Adjusted periods of subject per week</td>
<td>Adjusted pupil periods per week</td>
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<td>7</td>
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<td>7</td>
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<td>8</td>
<td>128</td>
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<tr>
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(11) Total adjusted pupil periods per week 432

(11) Total adjusted pupil periods per week 2,082
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<th>Adjusted average subject enrollments per week</th>
<th>Adjusted pupil periods per week</th>
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</thead>
<tbody>
<tr>
<td>Machine Shop</td>
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<td>20</td>
<td>19 19 19 16 16</td>
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</tr>
<tr>
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<td>20</td>
<td>16 12 17 10 12</td>
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<td>Related Instruction</td>
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<tr>
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<tr>
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<td>16 12 17 10 12</td>
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(11) Total adjusted pupil periods per week 280

Form 2
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<th>Dimensions of room</th>
<th>Type of room</th>
<th>Present use of room</th>
<th>Existing pupil stations</th>
<th>Desirable maximum pupil stations</th>
<th>Remarks</th>
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<td>Machine shop</td>
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<td>Related Machine</td>
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<td>109</td>
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<td>Printing</td>
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<td>Elementary</td>
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<td>36</td>
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<td>Academic</td>
<td>Elementary</td>
<td>40</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>212</td>
<td>2</td>
<td>21x34</td>
<td>Academic</td>
<td>Elementary</td>
<td>22</td>
<td>30</td>
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</tr>
</tbody>
</table>
TABLE 15
(cont'd)
BASIC ROOM DATA

(1) School district ____________________________ (2) Building A

<table>
<thead>
<tr>
<th>Room number</th>
<th>Location of room</th>
<th>Dimensions of room</th>
<th>Type of room</th>
<th>Present use of room</th>
<th>Existing pupil stations</th>
<th>Desirable maximum pupil stations</th>
<th>Remarks</th>
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<tr>
<td>301</td>
<td>3</td>
<td>34x60</td>
<td>Study</td>
<td>Study</td>
<td>122</td>
<td>126</td>
<td></td>
</tr>
<tr>
<td>302</td>
<td>3</td>
<td>33x30</td>
<td>Academic</td>
<td>Academic</td>
<td>45</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>303</td>
<td>3</td>
<td>27x22</td>
<td>Academic</td>
<td>Academic</td>
<td>32</td>
<td>32</td>
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<td>304</td>
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<td>24x28</td>
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<td>36</td>
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<td>305</td>
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<td>24x26</td>
<td>Science</td>
<td>Science</td>
<td>31</td>
<td>30</td>
<td>Laboratory tables only</td>
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<tr>
<td>306</td>
<td>3</td>
<td>24x20</td>
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<td>Lecture only</td>
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<tr>
<td>307</td>
<td>3</td>
<td>36x23</td>
<td>Science</td>
<td>Science</td>
<td>30</td>
<td>30</td>
<td>Demonstration desk only</td>
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<tr>
<td>308</td>
<td>3</td>
<td>33x30</td>
<td>Music</td>
<td>Music</td>
<td>42</td>
<td>50</td>
<td>Vocal. Lavatory in room</td>
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<tr>
<td>310</td>
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</tr>
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<td>314</td>
<td>3</td>
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<td>Art</td>
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<td>24</td>
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</tr>
<tr>
<td>Auditor.</td>
<td>1</td>
<td>70x90</td>
<td>Assembly</td>
<td>Assembly</td>
<td>1,200</td>
<td>1,200</td>
<td>Includes balcony</td>
</tr>
<tr>
<td>Gym.</td>
<td>1</td>
<td>72x34</td>
<td>Phys. Ed.</td>
<td>Phys. Ed.</td>
<td>50</td>
<td>50</td>
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</tr>
<tr>
<td>Subject area</td>
<td>Number of teaching stations</td>
<td>Desirable class size</td>
<td>Effective periods per week</td>
<td>Average total enrollment for 5-year period</td>
<td>Teaching station enrollment</td>
<td>Adjusted pupil periods</td>
<td>Pupil capacity limit</td>
</tr>
<tr>
<td>------------------------</td>
<td>----------------------------</td>
<td>----------------------</td>
<td>-----------------------------</td>
<td>------------------------------------------</td>
<td>----------------------------</td>
<td>------------------------</td>
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<tr>
<td>Academic</td>
<td>17</td>
<td>30</td>
<td>40</td>
<td>602</td>
<td>12,280,800</td>
<td>8,040</td>
<td>1,527</td>
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<td>Business Education</td>
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<td></td>
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<td></td>
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<td>Typing</td>
<td>1</td>
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<td></td>
<td></td>
<td>963,200</td>
<td>620</td>
<td>1,554</td>
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<td>Other</td>
<td>1</td>
<td>30-25</td>
<td></td>
<td></td>
<td>602,000</td>
<td>545</td>
<td>1,106</td>
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<tr>
<td>Fine Arts</td>
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<td>15</td>
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<td></td>
<td>361,200</td>
<td>139</td>
<td>2,599</td>
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<tr>
<td>Home Economics</td>
<td>1.5*</td>
<td>24-21</td>
<td></td>
<td></td>
<td>758,520</td>
<td>670</td>
<td>755</td>
</tr>
<tr>
<td>Industrial Arts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shop</td>
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<td></td>
<td></td>
<td>553,840</td>
<td>660</td>
<td>339</td>
</tr>
<tr>
<td>Mechanical Drawing</td>
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<td>25-19</td>
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<td>457,520</td>
<td>530</td>
<td>863</td>
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<td>Music</td>
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<tr>
<td>Instrumental</td>
<td>1</td>
<td>75-65</td>
<td></td>
<td></td>
<td>1,565,200</td>
<td>410</td>
<td>3,818</td>
</tr>
<tr>
<td>Vocal</td>
<td>1</td>
<td>50</td>
<td></td>
<td></td>
<td>1,204,000</td>
<td>879</td>
<td>1,370</td>
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<td></td>
<td></td>
<td>842,800</td>
<td>788</td>
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<tr>
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<td>24</td>
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<td></td>
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<td></td>
<td></td>
<td>577,920</td>
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<tr>
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<td>24</td>
<td></td>
<td></td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Speech and Dramatics</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voc. Machine Shop</td>
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<td></td>
<td></td>
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<td>320</td>
<td>1,204</td>
</tr>
<tr>
<td>Print Shop</td>
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<td>12</td>
<td></td>
<td></td>
<td>288,960</td>
<td>240</td>
<td>1,204</td>
</tr>
<tr>
<td>Related Vocational</td>
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<td>30</td>
<td></td>
<td></td>
<td>722,400</td>
<td>280</td>
<td>2,580</td>
</tr>
</tbody>
</table>

* One room is used half time for cafeteria kitchen.

(13) Building capacity 355
(14) Adjusted building capacity 839
produced the average subject enrollments recorded in Tables 6 through 14. This 602 figure is also recorded in Column 7 in Table 16 since it is one of the factors in the capacity formula.

Tables 6 through 14 show detailed subject enrollments by individual subjects for the five-year period 1947-48 through 1951-52. The subjects have been arranged according to subject areas, with a separate copy of the form for each subject area. Where subjects within a subject area require entirely different facilities and rooms provided for such subjects cannot be used interchangeably, the data are treated separately even though the data are included on the same copy of the form. The business education area (Table 7) is an example of this. Typing has been treated separately from other business education subjects. If the typing room were equipped with drop head desks or combination tables, this separation would not be necessary. In the case of science (Table 13), chemistry and physics enrollment data have been treated separately but then added to the other subject enrollment data for this area. This is necessary since the science facilities are interchangeable in only one direction. Facilities adapted to individual experimentation as well as lecture demonstrations may be used for any science subject but general science facilities which are not adapted to wide experiences in pupil experimentation are not adequate for chemistry or physics. By this treatment, the capacity limit of the more specialized facilities can be determined separately and then the capacity limit of the combined science facilities may be determined. The smaller of these two capacity limits will be the capacity limit of the
science area. These capacity limits are shown in Table 16, Column 10. It will be noted in this table that the laboratory facilities are ample, but that the total science facilities actually limit the total operating capacity of the building.

Tables 6 through 14 show, in addition to the subject enrollment data, the periods per week of instruction devoted to each subject and the conversion of these data into adjusted pupil periods of instruction per week. Column 8 in each of these tables shows the adjusted average subject enrollment in those cases where the ratio of subject enrollment to total enrollment is clearly not a constant. The following adjusted average subject enrollment will be noted in Table 6. The average enrollment in driver education has been adjusted upward to the current enrollment since local school authorities have concluded that this represents about the number out of 600 who would be taking driver education at any one time. Speech in grades 7 and 8 is no longer offered; therefore, this average has been adjusted to zero. Speech for grades 9 through 12 has been adjusted upward to 22, the average of the past four years, since it was clear that the 1947-1948 enrollment was inconsistent with the general pattern of the next four years.

Column 9 in Tables 6 through 14 shows the actual or the adjusted pupil periods of instruction per week for each subject in which the number of periods of instruction per week is an aliquant part of the total possible periods of instruction per week. No adjustment is necessary in any of the academic subjects since all these subjects require five periods of instruction per week and five is an aliquot part of 40, the
total possible periods of instruction per week. The science area contains the only major adjustment of periods of instruction per week. Chemistry and physics require seven periods of instruction per week (see Table 13, Column 6). Since seven will not divide into 40 a whole number of times, not every possible pupil period in the week can be scheduled for instruction and a correction for this factor is necessary. Since only five sections of chemistry or physics may be scheduled in a 40-period week, the seven periods have been adjusted to eight (see Table 13, Column 9) in accordance with the instructions to accompany the subject enrollment data, Form 2-1 (see Chapter 4). As will be seen, considering the five sections as using eight periods per week is equivalent to five sections using seven periods per week but with five extra periods which cannot be used to schedule another section. Using eight in place of seven corrects for this lost use of five periods due to scheduling.

Column 10 in Tables 6 through 14 shows the adjusted pupil periods of instruction in each subject. This was determined by multiplying the average or adjusted average subject enrollment (Column 7 or 8) by the adjusted periods of instruction per week (Column 9). The total number of adjusted pupil periods of instruction in each subject area (Item 11) was then found by adding the adjusted pupil periods (Column 10). The total adjusted pupil periods for each subject area was then recorded in Table 16, Column 9.
Table 15 shows detailed information concerning each instructional room in the building. From this table the total number of teaching stations in each subject area are counted and recorded in Table 16, Column 4. The desirable maximum pupil stations in each classroom (Table 15, Column 9) has been determined by local school authorities in terms of the type of activities carried on in each particular room. A check of these desirable maximum pupil stations is necessary in order to determine whether the existing facilities are adequate to accommodate the desirable average class sizes indicated in Table 16, Column 5. Unless the average maximum pupil stations in the rooms of a given subject area are sufficiently greater than the desirable average class size for that area, the desirable average class size (Table 16, Column 5) must be adjusted downward. This required difference is three for average class sizes under 25, five for average class sizes of 25 to 35, and eight for average class sizes greater than 35. This check reveals average maximum pupil stations for the various areas as follows: academic, 36; typing, 45; other business education, 30; fine arts, 20; home economics, 26; wood shop, 28; machine shop, 24; printing, 16; related shop subjects, 30; mechanical drawing, 22; instrumental music, 75; vocal music, 60; physical education, 50; laboratory science, 30; and other science, 30. These average maximum pupil stations indicate that certain facilities are not adequate to accommodate the desirable average class sizes in each of the corresponding subject areas. Therefore, the desirable average class sizes in business education, home economics, wood shop, mechanical drawing, and instrumental music were
reduced as indicated in Column 5 of Table 16 for purposes of capacity
determination. The second figure indicated in Column 5 of Table 16
is the adjusted figure used in the subsequent computations. It should
be noted here that if remodeling of this building were to be undertaken
which involved these subject areas, the remodeled rooms should be
planned to accommodate the desirable average class sizes indicated
first in Column 5 of Table 16 and the teaching station capacity index
should be recalculated on the basis of true desirable average class
sizes rather than the adjusted figures.

It has been pointed out in the preceding pages that Table 16 is
a summary of much of the data found in the preceding tables. Table 16
contains all the essential summarized data which are required in the
capacity calculation for Building A. Columns 4, 5, 6, and 7 contain
the factors of the numerator of the formula and Column 8 is the product
of these factors. Column 9 contains the summary of adjusted pupil per-
iods by subject areas and constitutes the denominator of the formula.
Column 10 contains the pupil capacity limit of each subject area and
is the quotient of Column 8 divided by Column 9. The smallest figure
in Column 10, which is 355 in this case, is the maximum enrollment
which can be accommodated in the building without overcrowding or cur-
tailment of the desired educational program unless some shifting or
remodeling of existing facilities can be effected. Unless the building
perfectly fits the educational program, the figures in Column 10 will
vary widely as they do in this illustration, showing considerable ex-
cess capacities in certain areas.
It will be noted in Column 10 of Table 16 that special study facilities are adequate to serve a total enrollment of only 355 pupils and science facilities only 555 pupils. On the other hand, there are enough academic classrooms to serve a total enrollment of 1,527. Therefore, 355 is not a very realistic capacity figure and needs to be adjusted by shifting certain spaces to other use. In order to make such shifts it is necessary to know the capacity index of a single teaching station in each of the various subject areas. The teaching station capacity index (Table 16, Column 11) represents the total school enrollment which can be accommodated by one teaching station in each of the subject areas. This index is found by dividing the pupil capacity limit (Column 10) by the corresponding number of teaching stations in each subject area of the building (Column 4). The importance of this index is emphasized by the wide variation in the indexes of the different subject areas. The academic area requires a teaching station for every 90 pupils in total enrollment while typing requires one teaching station for 1,554 pupils in total enrollment. This difference is due to the fact that relatively few pupils elect typing, while every pupil averages two to three academic classes each day.

In order to determine the adjusted building capacity (Table 16, Item 14) it is necessary to consider possible conversions of rooms to other use. Column 12 contains a number of sub-columns for recording by means of positive or negative numbers the excess or shortage of teaching stations for a given adjusted capacity figure. The trial adjusted capacity figures of 555, 839, and 863 (Table 16, Column 12) were
selected according to the instructions outlined on Form 4-1 (see Chapter 4).

The number of teaching stations in each area required for a given adjusted capacity can be determined by dividing the adjusted capacity figure by the teaching station capacity index of each subject area and rounding-off the quotient to the next higher whole number. The difference between the required and actual number of teaching stations indicates the number of additional teaching stations needed or the number of excess teaching stations which may be converted to other use. Positive numbers indicate the excess teaching stations and negative numbers indicate the additional teaching stations needed. An example will help clarify the process of determining these adjustments. The $10$ in the first sub-column of Column 12 in Table 16 was determined as follows:

1. The first trial adjusted capacity figure of 555 (Column 12) was divided by 89.8 (Column 11).
2. The quotient of 6.13 was rounded off to seven, the next higher whole number.
3. Subtracting this 7 from the 17 teaching stations in this subject area gives a remainder of $10$.

The first sub-column of Column 12 in Table 16 shows an excess of 10 academic teaching stations for an adjusted capacity of 555 and shows a need for one additional teaching station for study purposes. It is clear that one academic classroom would not offset the need for an additional teaching station for study since the teaching station for study
purposes must be adequate to house an average of approximately 100 pupils. Any two large regular classrooms might well be used to house an average of 100 pupils per period for study. Two such rooms might be used independently or joined by removing a partition between them, thus making supervision by a single teacher possible. This would still leave an excess of eight academic teaching stations for the adjusted capacity of 555. This excess indicates that the capacity can be adjusted beyond the 555 figure.

The second sub-column of Column 12 in Table 16 indicates the necessary adjustments for a capacity of 839. For a capacity of 839, there is an excess of seven academic teaching stations and a need for two additional teaching stations each for science and study purposes. By the provision of demonstration tables, two of the large academic classrooms on the second floor (see Table 15) might be converted to science rooms suitable for science classes which do not involve extensive pupil experimentation. Four additional academic classrooms could be used for study as noted above. This would still leave an excess of one academic teaching station.

Sub-column 3 of Column 12 in Table 16 shows the necessary adjustments for a capacity of 863. It will be noted that these adjustments are the same as those required for a capacity of 839 except that an additional teaching station is required for shop activities. Since the science and study hall requirements utilize six of the seven excess spaces, only one academic classroom is left to be converted to shop facilities. It is clear that such a conversion would be impossible
since shop activities require more space. Therefore, the capacity of
the building cannot be adjusted beyond the 839 figure. The 839 figure,
therefore, is the adjusted capacity of the building. This is entered
as Item 14.

In summary, then, Building A has a capacity of only 355 as it
stands. However, by converting two academic classrooms to study pur­
poses, the capacity rises to 555; by converting two academic classrooms
to science rooms and four academic classrooms to study purposes, the
capacity goes to 839.

It should be noted here that the conversion of existing rooms to
other use usually requires considerable remodeling and is often diffi­
cult and expensive. When academic classrooms are small, as is usually
the case, two or more academic classrooms are often required to obtain
the necessary area needed for a single teaching station in certain spe­
cial areas. The existence of large rooms, which had been used for ele­
mentary school purposes (see Table 15), made possible the necessary
conversions in Building A on a one-to-one ratio. In the following
illustrations this one-to-one ratio does not always hold true.

Building B

Building B (see Table 17) is a new senior high school in a small
suburban city school district in northern Ohio. Since a very large
percentage of students attend college, the subject enrollment data show
a high percentage of student subject elections in the academic area.
This is reflected in a low teaching station capacity index of 64.6
<table>
<thead>
<tr>
<th>Subject area</th>
<th>Number of teaching stations</th>
<th>Pupil average class size</th>
<th>Effective periods per week</th>
<th>Average total enrollment for 5-year period</th>
<th>Teaching station-pupil period</th>
<th>Adjusted pupil periods</th>
<th>Pupil capacity limit</th>
<th>Teaching station capacity index</th>
<th>Teaching station adjustments</th>
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<td>35</td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
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<td>&quot;</td>
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<td>&quot;</td>
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<td>25</td>
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<td>&quot;</td>
<td>264,250</td>
<td>180</td>
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<td>1,468</td>
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<tr>
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<td>1,585,500</td>
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<td>456</td>
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<tr>
<td>Other Special Areas</td>
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<td></td>
</tr>
</tbody>
</table>

Form 4

(13) Building capacity 452

(14) Adjusted building capacity 517
for the academic area as compared with a corresponding index of 89.8 in the previous illustration. This comparison of indexes indicates that for a given enrollment, the second school program will require one and one-half times as many academic classrooms as the other. This clearly indicates the need for basing capacity calculations upon the unique characteristics of the educational program of a particular school rather than upon abstract standards. It will be noted also that most of the special subject areas have only one teaching station, yet these single teaching stations furnish capacities two and three times the maximum operating capacity of the building which is limited by academic classrooms to 452.

This building capacity calculation illustrates the adjustment procedure necessary when the total adjusted capacity of the building is less than the second lowest pupil capacity limit. The first sub-column of Column 12 in Table 17 shows the necessary adjustments for a capacity of 684. There are no excess spaces for this capacity figure but a need for four additional teaching stations in the academic area. Since there are no excess spaces, it is clear that the capacity cannot be adjusted to the 684 figure, and the adjusted capacity, without adding to the building, must fall between the lowest pupil capacity limit of 452 and the 684 figure just tested. The second sub-column of Column 12 shows the excess teaching station for a capacity of 452. Since the excess teaching station in physical education cannot be converted to other use, the excess teaching station in science is the only one which might be converted to other use to permit an upward adjustment.
of the capacity. Since the adjusted capacity must be a multiple of 267 or 64.6, it is easy to see that 517 (452 plus 64.6 or 8 times 64.6) is the maximum capacity to which the building can be adjusted because only one teaching station is available for conversion.

Building C

Building C is the old high-school building in the same school district as the new senior high-school building in the previous illustration. Summary data for this building will be found in Table 18. This old high-school building is now being used exclusively for junior high school purposes. This particular illustration presents one solution to a problem which has been quite perplexing in the development of the capacity technique. Local school authorities concluded that the elective program in music would be limited to a beginners' band, an all-school band, a beginners' choir, an all-school choir, and an orchestra, and that enrollments if necessary would be limited by higher standards of admission to these groups. In addition to this elective program, two periods per week of vocal music are required of all seventh and eighth grade pupils. The music facilities consist of one large studio which is used for both vocal and instrumental music and a second smaller room used exclusively for the required vocal classes. It was clear that the main studio would be used five periods per day for the elective program and that this requirement would not increase with the increasing enrollment, thereby leaving the main studio available for use two periods out of the seven-period day for the required music classes. This is equivalent to .28 of a teaching station. This .28
### TABLE 16
**MISCELLANEOUS DATA**

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<tr>
<th>Subject area</th>
<th>Number teaching stations</th>
<th>Desirable average class size</th>
<th>Effective periods per week</th>
<th>Average total enrollment for 5-year period</th>
<th>Teaching station pupil period enrollment</th>
<th>Adjusted pupil periods</th>
<th>Pupil capacity limit</th>
<th>Teaching station capacity index</th>
<th>Teaching station adjustments</th>
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</thead>
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<td>441</td>
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<td>707</td>
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<td>Other</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speech and Dramatics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
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</tr>
</tbody>
</table>

*Adjusted for five classes which have controlled maximum size groups.

#Adjusted capacity, except for physical education facilities which limit capacity to 490.

(13) Building capacity __________________________ 381

(14) Adjusted building capacity __________________________ 490 - 635
was added to the other available teaching station and the resulting 1.28 teaching station was substituted in the capacity formula to determine the pupil capacity limit of the music area. It will be noted in Table 18 that the music facilities are adequate to accommodate a total school enrollment of 1,046.

Although the lowest pupil capacity limit (Table 18, Column 10) is in the study area, there are sufficient excess teaching stations in the academic area which may be converted to study purposes. The adjusted capacity of the building is limited to 490 by the shortage of physical education facilities. Even though there are excess teaching stations in the academic area for the capacity figure of 490, they would not be suitable to provide an additional teaching station for physical education. The third sub-column of Column 12 shows that, except for physical education, the capacity of the building could be adjusted to 635 since two of the three excess teaching stations in the academic area could be used for study purposes and the other which is quite large for art activities. In actual practice the desired educational program would probably be altered by increasing the average class size in physical education so that 635 pupils might be accommodated in this building.

Building D

Building D is a large senior high school in one of Ohio's larger cities. This building has just undergone extensive remodeling and expansion to meet the tide of increasing enrollments in that particular part of the city. Table 19, the summary data for this building, shows
### Table 19: Miscellaneous Data

#### (1) School district

<table>
<thead>
<tr>
<th>Subject area</th>
<th>Number of teaching stations</th>
<th>Desirable class size</th>
<th>Effective periods per week</th>
<th>Average total enrollment for 5-year period</th>
<th>Teaching station capacity</th>
<th>Pupil capacity limit</th>
<th>Teaching station capacity index</th>
</tr>
</thead>
<tbody>
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<td></td>
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<td></td>
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<tr>
<td>Business Education</td>
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<td>30</td>
<td>40</td>
<td>1,270</td>
<td>38,100,000</td>
<td>18,045</td>
<td>2,111</td>
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<tr>
<td>Typing</td>
<td>2</td>
<td>50</td>
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<td>5,080,000</td>
<td>2,735</td>
<td>1,858</td>
<td>929</td>
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<td>Other</td>
<td>3</td>
<td>30</td>
<td></td>
<td>4,572,000</td>
<td>4,310</td>
<td>1,062</td>
<td>354</td>
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<tr>
<td>Fine Arts</td>
<td>2</td>
<td>24</td>
<td></td>
<td>2,438,400</td>
<td>610</td>
<td>3,998</td>
<td>1,999</td>
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<tr>
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<td>24</td>
<td></td>
<td>4,876,800</td>
<td>1,085</td>
<td>4,496</td>
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<td>4,876,800</td>
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</tr>
<tr>
<td>Vocal</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Physical Education</td>
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<td>45</td>
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<td>4,572,000</td>
<td>2,102</td>
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<td>2,438,400</td>
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<tr>
<td>Speech and Dramatics</td>
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</tr>
</tbody>
</table>

#### (2) Building

| Teaching station adjustments | 1062 | 1858 | 2098 | 1944 | 1982 |

(13) Building capacity

(14) Adjusted building capacity
an extreme variation in the pupil capacity limits of the various subject areas. This variation indicates the lack of careful planning of the expansion of this building. The fifth sub-column of Column 12, which indicates the adjustments necessary to reach an operating capacity of 1,982, shows that the science and business education areas have not been expanded enough while all other areas have been over expanded. It is fortunate, however, that the shortages in both of these areas are easily corrected. The science rooms for extensive pupil experimentation are adequate to serve the adjusted maximum capacity of the building while the other necessary science and business education rooms are easily attainable by converting other existing rooms.

Building E

The illustration involving Building E is particularly interesting because it shows the versatility of the capacity determining technique to meet extreme variations in building, program, and educational policies. The building houses kindergarten and grades 1 through 12; therefore, the capacity calculation had to be applied only to that part of the building which was available for secondary-school purposes. Frequently rooms were used for both elementary and secondary-school purposes which meant that certain rooms had to be considered as fractional teaching stations in determining the capacity for secondary-school use. Being a private school, the educational program has many variations not very common among public secondary schools. The program is built around the core curriculum with the core periods varying in
length from one and one-half to three and one-quarter hours according
to grade level. The periods during which electives were offered also
varied in length from 45 minutes to one hour. In order to have a com-
mon unit of measure, the school day of six hours and 15 minutes was
divided into 25 periods of 15 minutes each, which is equivalent to 125
periods per week. Thus, a 45-minute class was considered to be of
three periods duration and therefore to require 15 periods of instruc-
tion per week. Since the actual classes were of 3, 4, 6, or 10 per-
iods duration, the resulting periods of instruction per week in each
subject were not aliquot parts of the total possible periods per week
and therefore had to be adjusted to compensate for scheduling difficul-
ties. Table 20 shows the summary data and the calculation of capacity
for this building. Although there is one excess teaching station in
the home economics area, it is impossible to adjust the capacity beyond
the calculated capacity of 270, since this excess teaching station is
neither suitable nor adequate in size to be converted to the related
arts area where additional capacity is needed.

Building F

In order to illustrate further the need of careful planning of a
building in terms of the educational program which is to function in
the building and to show that capacity must likewise be related to edu-
cational program, the capacity of Building F has been calculated on the
basis of two entirely different educational programs. The capacity of
this building, located in a large city, has been calculated on the basis
of the educational program now in operation in the building and also on
### Table 20
**Miscellaneous Data**

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<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
<th>(10)</th>
<th>(11)</th>
<th>(12)</th>
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</tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>Study*</td>
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<td></td>
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<tr>
<td>Other Special Areas</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

*No study halls required.*

(13) Building capacity 270

(14) Adjusted building capacity 270
the basis of the educational program of a suburban high school in a
different part of the state. Tables 21 and 22 show the capacity cal-
culations for this one building on the basis of these two different
educational programs. Table 21 is the capacity calculation on the
basis of existing program and Table 22 is the capacity calculation on
the basis of an entirely different educational program and set of edu-
cational policies. Although the building is not very well adapted to
the existing educational program, with minor adjustments, the building
could house a total enrollment of 1,502. Table 22 shows that the
building would accommodate far fewer pupils with the second educational
program. In this case, the capacity is limited to 980 by physical
education facilities. Even if class sizes in physical education were
increased so that physical education facilities would not be a limit-
ing factor, the capacity would still be limited to approximately 1,250,
or about 250 less than with the current program. This difference in
capacity is attributable to a number of different factors. Probably
the most significant single factor is the fact that the second program
requires fewer study hall facilities, yet these facilities cannot very
well be converted to other use since five-sixths of the study hall ca-
pacity is in a combination cafeteria-study hall. Other factors which
cause this difference in capacity include: variations in desirable aver-
age class size, variations in the daily program affecting the total per-
iods of instruction per week, and variations in the pattern of subject
elections by students. The differences in the pattern of subject elec-
tions by students can be noted by comparing the teaching station capacity
**TABLE 21**

**MISCELLANEOUS DATA**

<table>
<thead>
<tr>
<th>Subject area</th>
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<th>Average total enrollment for 5-year period</th>
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(13) Building capacity       1,148
(14) Adjusted building capacity 1,502
**TABLE 22**  
**MISCELLANEOUS DATA**

(1) School district preparation

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</tbody>
</table>

---

* Only one teaching station can be converted.

The rest of the study hall capacity is in a combination cafeteria-study hall.

# One was used here to obtain the teaching station capacity index.

** Adjusted capacity, except for physical education facilities which limit capacity to 980.

---

(13) Building capacity

801

(14) Adjusted building capacity

980-1,258**
indexes for the two different programs. The greatest variations are
in the academic, physical education, science, and study areas.

Building G

Building G is a large modern junior high-school building in one
of the larger cities of Ohio. The educational program has taken on
some of the marks of a true junior high-school program. Multiple per-
iods provide opportunities for integration of common learning experi-
ences and opportunities to learn to know pupils better, thus providing
better opportunities to meet individual needs and provide a better type
of guidance program. The program is varied to provide ample opportuni-
ties for extensive exploratory activities. Table 23 shows that the
building is reasonably well adapted to the program even though there
are excess rooms in four subject areas. Since the educational program
does not require a large number of separate study periods, these excess
rooms might well be used for study as is the practice at the present
time. The extensiveness of work in the various special areas is indi-
cated by the relatively small teaching station capacity indexes for
most of these areas. This results in a need for more than one teaching
station in all special subject areas except one. The maximum operating
capacity of the building is limited to 1,198 by the physical education
facilities. Although there are excess spaces in four areas for the
capacity figure of 1,198, these excess spaces will need to be utilized
for study purposes.
### TABLE 23
MISCELLANEOUS DATA

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<th>Subject area</th>
<th>Number of teaching stations</th>
<th>Desirable class size</th>
<th>Effective periods per week</th>
<th>Average total enrollment</th>
<th>Teaching station capacity per periods</th>
<th>Adjusted pupil period</th>
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# One was used here to obtain the teaching station index.

* Adjusted capacity, except for physical education facilities which limit capacity to 1,198.

(13) Building capacity 1,198

(14) Adjusted building capacity 1,198-1,251*
Buildings H and I

Buildings H and I are the only two secondary-school buildings in a rapidly growing suburban area in southern Michigan. The capacities of both of these buildings have been calculated on the basis of two different types of vertical organization and also on the basis of two different types of daily schedules. Building H is a new high-school building and I is the existing junior high-school building. The junior high-school building is extremely overcrowded at the present time and the educational program is suffering as a result of it. Upon completion of the new high-school building the ninth grade is to be housed temporarily in the new building thus furnishing some relief for the junior high school. It is a common belief that increasing the number of periods in the daily schedule increases the capacity of a building. Before local school authorities were willing to make the shift from six one-hour periods to eight 45-minute periods per day, they were interested in knowing just what effect such a change would have upon capacity, if any. These capacity calculations furnished that additional information upon which to base their final decision. Table 24 shows the capacity calculation of the new high-school building on the basis of a six-period day or thirty-period week and housing grades 9 through 12. The adjusted capacity of the building under these conditions is 1,440. Table 25 shows the capacity of the same building under the same vertical organization but with daily periods shortened to 45 minutes so as to provide 40 periods of instruction per week. The adjusted capacity of the building under these conditions is 1,567.
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<th>Effective periods per week</th>
<th>Average total enrollment for 5-year period</th>
<th>Teaching station-period enrollment</th>
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Form 4

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Form 4

(13) Building capacity 1,198
(14) Adjusted building capacity 1,567
Thus a shift from the 30 to 40 periods per week increases the capacity by 127. A study of these two capacity calculations shows that the shift from 30 to 40 periods of instruction per week changes the capacity limits of the various areas to a considerable extent even though the adjusted operating capacity is changed by only 127. For example, the pupil capacity limit for the academic area is raised from 1,352 to 1,803 by shifting to the 40-period week. This is easily understood, since it is possible to teach one-third more sections of such classes. However, the opposite effect is noted in certain special areas where the shifting to the 40-period week requires two periods of instruction for each class section instead of one. This is the case in such laboratory classes as home economics, fine arts, industrial arts, and the laboratory sciences. In these areas the pupil capacity limits were lowered approximately one-third since only four double period sections can be taught in an eight-period day. An even greater change took place in the pupil capacity limit for the study area. In the study area, the capacity decreased from 3,079 to 1,666.

Tables 26 and 27 show similar capacity comparisons for the same building but with enrollments limited to grades 10 through 12. The comments which have been made concerning the capacity comparisons for the two different types of daily schedules for grades 9 through 12 are equally applicable to these illustrations. The difference between the adjusted capacities of the building for grades 10 through 12 for the two types of daily schedules is approximately twice as much as it was for grades 9 through 12. The greater capacity for grades 10 through
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Form 4

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(14) Adjusted building capacity 1,440
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Form 4

(13) Building capacity

(14) Adjusted building capacity 1,672
12 can be attributed to the better fit of the building to the educational program in the case of the 40-period week.

A comparison of the capacity of the building for the two different types of vertical organization, with the daily schedule kept constant, shows equal operating capacities (1,440) for the building when operating on the 30-period week. However, when operating on the 40-period week, the building has a capacity 95 greater when used to house grades 10 through 12 as compared with grades 9 through 12.

A word of caution should be made at this point. No generalizations should be drawn from this illustration concerning the effect upon capacity of vertical organization or number of periods of instruction per week. Each case must be studied individually since there are many variables, both in program and building, which cannot be categorized. In fact, to be able to take into account all these unique factors for each school situation is one of the major strong points in favor of the technique developed in this study.

Tables 28, 29, 30, and 31 show similar capacity comparisons for the junior high-school building in the same school district as the high-school building of the previous illustration. A glance at these capacity calculations shows the differences in capacity to be practically negligible for both variations of daily schedule and vertical organization. The similarity of capacity under these varying conditions is largely attributable to the fact that the seventh and eighth grade programs are totally required and there are few electives even in the ninth grade. The lack of any large spaces which can be utilized for study
### TABLE 28
MISCELLANEOUS DATA

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<th>Number of teaching stations</th>
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* No study halls are provided in the existing building and none are required for this program.

(13) Building capacity: 360
(14) Adjusted building capacity: 720
### Table 29

**MISCELLANEOUS DATA**

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</table>

* Since the existing building contains no study halls, "1" has been used here in order to determine the teaching station capacity index for this area.

(13) Building capacity 320

(14) Adjusted building capacity 755
### Table 30

#### Miscellaneous Data

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<th>Number of teaching stations</th>
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<th>Effective periods per week</th>
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* Since the existing building contains no study halls, "1" has been used here in order to determine the teaching station capacity index. Regular classrooms are currently being used for study purposes.
### Table 31
MISCELLANEOUS DATA

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* Since the existing building contains no study halls, "I" has been used here in order to determine the teaching station capacity index. Regular classrooms are currently being used for study purposes.

Form 4

<table>
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<tbody>
<tr>
<td>(14) Adjusted building capacity</td>
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makes it necessary to use, for study purposes, the excess spaces saved by the shift to the 40-period week. These illustrations further emphasize the need for individual study of building capacities based upon the unique characteristics of the educational program and policies of the school.

Building J

The question of vertical school organization quite naturally arises as a school district grows to the point where a second secondary-school building is required. If there has been a six-year high school and a decision is reached to shift to the 6-3-3 plan of vertical organization, another decision must be made concerning the type of building to be built, a new junior high-school building, or a new senior high-school building. Of course the first consideration should be the qualitative adequacy of the existing building for each type of secondary-school program. In addition to the qualitative adequacy, the quantitative adequacy of the building for both types of programs should be considered and compared with probable future enrollments. The technique developed in this study makes possible the evaluation of the quantitative adequacy of a building for two entirely different types of educational programs. The writer is firmly convinced that qualitative adequacy should be the most important single factor in determining the use of an existing building; however, as much additional information as possible should be brought to bear on the solution of the problem.
Table 32 shows the capacity calculation of this building for senior high-school purposes and Table 33 shows the capacity calculation for the same building for junior high-school purposes. Although no consideration was given in this study to the qualitative adequacy of the various rooms for either junior or senior high-school purposes, these calculations show that quantitatively the building is much better suited to the senior high-school program than to the junior high-school program. The adjusted operating capacity of the building is 1,386 for senior high-school use and only 1,200 for junior high-school use. Moreover, only five conversions are necessary to reach the maximum capacity for senior high-school purposes while 15 conversions are required to reach the maximum adjusted capacity for junior high-school purposes.

Building K

To further illustrate the fact that each building and each educational program presents a unique problem and must be studied independently, a similar capacity study is included for another building. Table 34 shows the capacity calculation of a building for senior high-school purposes and Tables 35 and 36 show, respectively, the capacity calculations of the same building for junior high-school purposes and for six-year high-school purposes. These capacity studies show that the building is not well adapted to any one of the three programs, but is just about equally adaptable to any one of them. The operating capacity of the building varies less than 2 per cent for any one of the
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Form 4

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* This program requires no special study hall facilities. Since the study hall capacity is in a combination cafeteria study hall, it cannot be converted to other use.

Form 4

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(14) Adjusted building capacity ___________ 1,200
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| Form 4       |                                  |                                  |                               |                                               |                                      |                          |                          |                                  |                             |
| (13) Building capacity | 1,282                          |                                  |                               |                                               |                                      |                          |                          |                                  |                             |
| (14) Adjusted building capacity | 1,759                          |                                  |                               |                                               |                                      |                          |                          |                                  |                             |
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MISCELLANEOUS DATA

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Form 4

(13) Building capacity _______ 1,578 _______

(14) Adjusted building capacity _______ 1,744 _______
three types of programs. It is interesting to note that the use which has the highest operating capacity requires almost twice as many conversions of spaces as either of the other two programs in order to reach its maximum adjusted capacity.

**Building I**

An even greater variation in the use of a building is the use of an elementary-school building for secondary-school purposes. In a recent survey of the school building needs of a rapidly growing suburban area, an extremely large and poorly located elementary school building was being considered for junior high-school use. Quite naturally, some capacity rating for the building had to be established. Previously, this would have been done by estimation. Although previous capacity techniques are incapable of such capacity determination, the new technique developed in this study was easily adapted to this task. The building was found to have 30 separate rooms, plus a gymnasium and cafeteria. The first step in determining the capacity of such a building was to consider the type of educational program to be housed in it, and from such a program to determine the teaching station capacity indexes for the various subject areas of the program. Since the capacity of the existing junior high-school building in this city had already been determined, the teaching station capacity indexes were already known for this particular school system's junior high-school program. No special form has been developed for this type of problem since Form 4 is easily adapted to it. Table 37 contains the summary data for this
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**MISCELLANEOUS DATA**

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**Form 4**  

(13) Building capacity: __________

(14) Adjusted building capacity: 790
capacity calculation. Column 11 of this table contains the teaching station capacity indexes which were taken from the previous calculation of the existing junior high-school building. Column 12 has been used to indicate the number of teaching stations required in each area for capacities of 600, 700, 800, and 900 pupils. To determine the number of teaching stations required for a given capacity, it is necessary merely to divide that capacity figure by each of the teaching station capacity indexes and round off the quotient to the next higher whole number. For example, 600 divided by 72, the teaching station capacity index for the academic area, equals 8.33 which has been rounded off to 9. Therefore, nine academic classrooms are required for a capacity of 600 pupils with this particular educational program.

After determining the number of teaching stations required for various capacities, it was necessary to check the building carefully in order to determine how many of the various types of special rooms could be developed from the 30 existing rooms in the building. This procedure was pretty much a matter of trial and error. However, the trials were somewhat controlled by the previous calculations of room needs for various capacity figures. The first attempt was made to convert the necessary rooms for a capacity of 600. The following conversions were deemed necessary regardless of final operating capacity: two adjoining rooms for library, two rooms for a music studio, two rooms for teachers' restrooms, one small room for student activities and one room for administrative offices. After considering the
conversions necessary to satisfy the other special room requirements for a capacity of 600, there were found to be 15 rooms left which were suitable for academic classrooms. Since only nine such rooms were needed for a capacity of 600, it was clear that the building could be adjusted to a higher capacity figure. This same process was repeated for a capacity of 700. The result was still an excess of rooms so the process was again repeated for a capacity of 800. In this case there was a shortage of one room. This indicated that the adjusted capacity of the building must fall between 700 and 800. Since the adjusted capacity of a building is always a multiple of one of the teaching station capacity indexes, there were only three possibilities which fell between 700 and 800 and the adjusted capacity was found to be 790. The final adjustment of spaces to provide the proper number of teaching stations for this capacity of 790 is recorded in Column 4, Table 37. By multiplying the teaching station capacity indexes by the number of teaching stations, the pupil capacity limit (Column 10) of each subject area was determined. It will be noted that all areas except one have pupil capacity limits greater than 790.

A similar procedure was followed to determine the capacity of this building for junior high-school purposes if six elementary classrooms and a kindergarten were retained for elementary-school purposes. The capacity was reduced to 600 under these conditions.

Building M

It was indicated earlier that the capacity formula developed in this study was easily adapted to a technique for determining the housing
requirements of new buildings and that the new technique had certain advantages over existing techniques for determining housing requirements. The preliminary steps which must be taken in determining the housing requirements for a new building are, with one exception, identical to those for determining the capacity of an existing building. The only exception is that no consideration needs to be given to the existing facilities which currently house the desired educational program. The number "1" is substituted for the number of teaching stations in each subject area on Form 4. Forms 1 and 2 are completed according to instructions outlined on the instruction sheets (see Chapter 4). The data thus determined on these forms are then summarized as indicated on Form 4 along with the other raw data called for on this latter form.

Table 38 contains the summarized data necessary to illustrate the use of the technique in this building-planning procedure. It will be noted that "1's" are recorded in Column 4 for the number of teaching stations. This is done to obtain directly the teaching station capacity index which indicates the total enrollment which one teaching station will accommodate. Items 5, 6, 7, 8, and 9 are determined in exactly the same manner as if we were determining the capacity of an existing building. From here on the procedure is changed in order to adapt it to the building-planning process. Dividing Column 8 by Column 9 produces the pupil capacity limits for the various subject areas of a hypothetical building which contains only one teaching station in each subject area. This is true since "1" was substituted in Column 4 for the number of teaching stations in each subject area. However, the quotient obtained
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<td>&quot;</td>
<td>488,250</td>
<td>496</td>
<td>--</td>
<td>984</td>
<td>1</td>
<td>984</td>
</tr>
<tr>
<td>Music</td>
<td>1</td>
<td>45</td>
<td>&quot;</td>
<td>732,375</td>
<td>1,348</td>
<td>--</td>
<td>540</td>
<td>2</td>
<td>1,080</td>
</tr>
<tr>
<td>Instrumental</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vocal</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Education</td>
<td>1</td>
<td>35</td>
<td>&quot;</td>
<td>569,625</td>
<td>1,162</td>
<td>--</td>
<td>490</td>
<td>2</td>
<td>980</td>
</tr>
<tr>
<td>Science</td>
<td>1</td>
<td>24</td>
<td>&quot;</td>
<td>390,600</td>
<td>1,451</td>
<td>--</td>
<td>269</td>
<td>3</td>
<td>807</td>
</tr>
<tr>
<td>Laboratory</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speech and Dramatics</td>
<td>1</td>
<td>100</td>
<td>&quot;</td>
<td>1,627,500</td>
<td>563</td>
<td>--</td>
<td>2,888</td>
<td>1.5*</td>
<td>4,332</td>
</tr>
<tr>
<td>Other Special Areas</td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>Driver Education</td>
<td>1</td>
<td>24</td>
<td>&quot;</td>
<td>390,600</td>
<td>209</td>
<td>--</td>
<td>1,867</td>
<td>1</td>
<td>1,867</td>
</tr>
<tr>
<td>Voc. Auto Shop</td>
<td>1</td>
<td>25</td>
<td>&quot;</td>
<td>406,875</td>
<td>403</td>
<td>--</td>
<td>1,010</td>
<td>1</td>
<td>1,010</td>
</tr>
</tbody>
</table>

* The cafeteria is sufficient in size to provide study facilities for an average of 150 pupils per period.

(13) Building capacity

(14) Adjusted building capacity
by dividing the figures in Column 8 by the corresponding ones in Column 9 have been recorded in Column 11, the teaching station capacity index. This is done because, by definition, this index is synonymous with the pupil capacity limit of one teaching station.

Having determined the teaching station capacity indexes, the room requirements can easily be determined for any desired capacity. The teaching station adjustment column, Column 12 in Table 38, has been adapted for this use. The desired capacity of the new building is 600. This figure is recorded in the first sub-column of Column 12. To determine the required number of teaching stations in each area, this 600 figure is divided by the teaching station capacity index and the quotient rounded off to the next higher whole number.

A fundamental principle of school building planning is that provision should be made for future expansion. Too frequently, provision for expansion has meant no more than a shift to an open type of construction plan. This technique of determining housing requirements provides a means for more definite planning for future expansion. The second sub-column of Column 12 in Table 38 shows the actual pupil capacity limits of the various areas when planned for a capacity of 600. These figures show that the art facilities are adequate to house a total school enrollment of 1,575, and that little or no attention needs to be given to providing additional art capacity in any early building expansion. A similar situation exists in numerous other subject areas. The third, fourth, and fifth sub-columns of Column 12 indicate the necessary additional teaching stations for capacities of 700, 800, and 900 respectively. It
will be noted from these figures that the business education and academic areas are the only areas affected by increased enrollments up to 700 or 800 while an additional science room is needed in order to raise the building capacity to 900. With this information, the probable first addition to the building can be forecast and consideration can be given in the original planning of the building so that the functional relationship of rooms will not be destroyed. In this particular example, the architect should be instructed to locate the business education and science suites so they can easily be expanded at a future date. This could be accomplished by so locating these suites that they could be expanded by new construction. A second possibility would be to locate academic classrooms adjacent to these suites and roughing in the necessary service facilities so they could be converted easily to the desired use and then be replaced by new construction for academic classroom use.

Summary

The first illustration in this chapter contained complete detailed information and explained in detail the collection and processing of all data in order to clarify each step of the process of capacity determination. The other illustrations contained only summary data and were included to show the many applications of the capacity determining technique. These illustrations included capacity studies for both present and projected use of certain buildings. The projected use included the use of buildings for different types of vertical and horizontal organization and daily schedule of classes. In order to illustrate the close
relationship of capacity to educational program, the capacity of a high-school building in a large city was determined on the basis of its own educational program and also on the basis of the educational program of a suburban high school in a different part of the state. The final illustration indicated the use of the technique (with slight modifications) as a method for determining the housing requirements in the planning of new buildings.

Table 39 has been prepared to give the reader a summary of the different types of school situations which were used to illustrate the technique of capacity determination. The subscripts used with the letter designators of certain buildings show that the capacities of such buildings were determined under varying conditions of educational program or policies.
### TABLE 39

**SUMMARY OF SCHOOL SITUATIONS USED IN ILLUSTRATING THE TECHNIQUE OF CAPACITY DETERMINATION**

<table>
<thead>
<tr>
<th>Building</th>
<th>Total teaching stations</th>
<th>Present ENROLLMENT</th>
<th>Grades included</th>
<th>Effective periods of class instruction</th>
<th>Desirable average capacity size#</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>31.5</td>
<td>602</td>
<td>7-12</td>
<td>40</td>
<td>29</td>
</tr>
<tr>
<td>B</td>
<td>20</td>
<td>302</td>
<td>10-12</td>
<td>35</td>
<td>28</td>
</tr>
<tr>
<td>C</td>
<td>24</td>
<td>341</td>
<td>7-9</td>
<td>35</td>
<td>26</td>
</tr>
<tr>
<td>D</td>
<td>48</td>
<td>1,270</td>
<td>10-12</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>E</td>
<td>15.8</td>
<td>232</td>
<td>7-12</td>
<td>125#</td>
<td>25</td>
</tr>
<tr>
<td>F₁</td>
<td>37</td>
<td>666</td>
<td>10-12</td>
<td>40</td>
<td>31</td>
</tr>
<tr>
<td>H₂</td>
<td>37</td>
<td>666</td>
<td>10-12</td>
<td>35</td>
<td>26</td>
</tr>
<tr>
<td>G</td>
<td>40</td>
<td>938</td>
<td>7-9</td>
<td>40</td>
<td>32</td>
</tr>
<tr>
<td>H₁</td>
<td>47</td>
<td>**</td>
<td>9-12</td>
<td>30</td>
<td>28</td>
</tr>
<tr>
<td>K₂</td>
<td>47</td>
<td>**</td>
<td>9-12</td>
<td>40</td>
<td>28</td>
</tr>
<tr>
<td>H₃</td>
<td>47</td>
<td>**</td>
<td>10-12</td>
<td>30</td>
<td>28</td>
</tr>
<tr>
<td>L₁</td>
<td>28</td>
<td>861</td>
<td>7-8</td>
<td>30</td>
<td>29</td>
</tr>
<tr>
<td>L₂</td>
<td>28</td>
<td>861</td>
<td>7-8</td>
<td>40</td>
<td>29</td>
</tr>
<tr>
<td>L₃</td>
<td>28</td>
<td>861</td>
<td>7-9</td>
<td>30</td>
<td>29</td>
</tr>
<tr>
<td>J₁</td>
<td>44</td>
<td>1,492</td>
<td>10-12</td>
<td>30</td>
<td>31</td>
</tr>
<tr>
<td>J₂</td>
<td>44</td>
<td>1,492</td>
<td>7-9</td>
<td>30</td>
<td>31</td>
</tr>
<tr>
<td>K₁</td>
<td>50</td>
<td>1,405</td>
<td>10-12</td>
<td>40</td>
<td>31</td>
</tr>
<tr>
<td>K₂</td>
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<td>1,405</td>
<td>7-9</td>
<td>40</td>
<td>31</td>
</tr>
<tr>
<td>K₃</td>
<td>50</td>
<td>1,405</td>
<td>7-12</td>
<td>40</td>
<td>31</td>
</tr>
<tr>
<td>L</td>
<td>50</td>
<td>878##</td>
<td>7-9</td>
<td>40</td>
<td>29</td>
</tr>
</tbody>
</table>

* These figures are exclusive of study halls.

# Since the length of periods varied from 30 minutes to two and one-half hours, 15 minute equivalents were used. There were actually only 30 different instructional periods per week.

** New building, not yet occupied.

## This figure represents elementary-school enrollment since this building is currently being used for elementary-school purposes.
CHAPTER 6
EVALUATION OF THE CAPACITY DETERMINING TECHNIQUE

The logic of the capacity formula developed in this study has been demonstrated in the process of its development. A complete evaluation of the technique as a method for determining the operating capacity of secondary-school buildings is beyond the scope of this study, but will come automatically in the years ahead. The true test of the worth of the technique might well be measured by the degree to which it is used by others in the assessment of the quantitative adequacy of existing school plants and its supplementary use in building planning procedures.

Although the more complete evaluation of the technique of capacity determination must await time, a limited evaluation can be made at this point. First, the technique as such will be evaluated in terms of how well it avoids the shortcomings of existing capacity determining techniques and how well it measures up to the criteria set up in Chapter 3 for the development of such a capacity formula or technique. Secondly, the technique will be evaluated on the basis of how accurately it measures the operating capacity of secondary-school buildings. This latter evaluation will be limited by the fact that the true operating capacities of secondary-school buildings are not known. Therefore, the evaluation can be no more than a summary of the statements of those best qualified to judge probable operating capacities.
Evaluation on the Basis of Criteria

Criterion 1, as stated in Chapter 3, was that "the formula should consider the functional use of the building." One of the major shortcomings of existing capacity determining techniques based upon utilization studies is the failure of such techniques to consider the functional use of buildings. The new technique overcomes this failure and satisfies the above criterion since its basic approach is that of considering the functional use of the building. The technique not only measures the capacity of each subject area separately, but it takes into consideration the unique characteristics of each subject area and the pattern of student electives in that area. This fact was illustrated repeatedly in those applications in which the capacity of a single building was found to vary considerably when used to house different types of educational programs. Building F (see Tables 21 and 22) was a classic example of this.

The second criterion, which stated that "the formula should attack the capacity problem directly rather than through status studies," is likewise basic to the approach underlying the new technique and there can be little doubt that the capacity problem is attacked directly. The new technique does not attack the capacity problem by comparison with other buildings or other educational programs but is built squarely upon the unique characteristics of the educational program and policies of the school system under consideration. This was clearly illustrated by the numerous applications in the preceding chapter.
The third criterion indicated that "the formula should involve all significant factors related to capacity." There may be some question as to the extent of involvement of all significant factors in the capacity technique since only five variables are found in the formula and more than twice this many factors were discussed in Chapter 3 as being related to the capacity of secondary-school buildings. However, as one considers the total capacity determining technique as developed on the forms and accompanying instruction sheets, he will note that these five factors of the formula are multiple ones which embrace a number of additional factors. Every factor discovered, which was significantly related to capacity, has been considered in the development of the over-all capacity technique.

Criterion 4 as stated in Chapter 3, was that "the factors involved in the formula should be as objective as possible. It is difficult to determine to what extent this criterion of objectivity has been met. To be sure, local school policies affecting capacity are determined by administrators largely through subjective means. However, once these policies are determined, the quantities required in the formula become quite objective. The only exceptions to this are the adjustments of subject enrollments and building capacities on Forms 2 and 4, respectively. These adjustments are made largely by a subjective analysis of the available data. The adjustment of subject enrollments is made when the ratio of subject enrollment to the total school enrollment is not relatively constant over the five-year period considered. This adjustment is necessary in only a small proportion of the total subject enrollments and the effect
of this adjustment is seldom very great. The adjustment of building capacities occurs in almost every building capacity calculation. However, the actual number of such conversions is calculated objectively and the subjective analysis is limited to the decision of whether certain conversions are feasible. It should be pointed out further that much has been written concerning the requirements of good classrooms in all subject areas of the curriculum and a consideration of such literature tends to limit the subjectivity of the decisions concerning these conversions.

It is almost impossible to determine to what extent Criterion 5, which stated that "the formula should be universal in its application," has been met. The formula has been applied to six different types of vertical school organization; to large schools and small schools; to schools with traditional and modern educational programs, including the core curriculum; and to school systems with many different educational policies. Although not positive proof of universality, the variety of applications to which the new formula has been successfully applied does indicate wide applicability. The fact that the technique involves so many factors which take into account differences in both vertical and horizontal school organization further indicates the degree to which this criterion of universal application has been met.

There is little doubt that Criterion 6 which stated that "the formula should not involve abstract standards," has been met by the new technique of capacity determination. The basic approach in the new capacity technique has been to include all factors of educational program and
policies which were in any way related to the operating capacity of a particular building. This approach permits capacity determination on the bases of the working standards of educational program and policies of each school rather than by comparison with abstract standards based upon status studies of average conditions as they now exist or upon some author's concept of the ideal.

By meeting Criterion 6, the new technique has overcome two major shortcomings of existing capacity techniques based upon utilization studies. It overcomes the criticism of abstract standards of space per child, standards upon which authorities have never been able to agree. The new capacity technique permits varying amounts of space per child depending upon the type of activity carried on in the classroom and at the same time permits the adjustment of space allotment per child to each particular school system's educational policies concerning desirable average class size. This overcomes the failure of the other capacity techniques to adjust downward the operating capacities of large rooms which, according to abstract standards of space per child, may have capacities two or three times the desirable maximum class size indicated by local school policies. Thus the distorted picture of capacity, determined by other techniques, of those buildings in school systems which operate on a policy of limited class size is replaced by a truer picture of the practical operating capacity.

By the direct approach, the new capacity technique has also overcome the need for establishing an optimal per cent of utilization, a theoretical standard which has never been generally accepted. All
approaches to this standard have been through status studies which are dubious means of establishing the ideal. The new technique establishes practical operating capacities directly by considering all factors of educational program and policies which affect the operating capacity of a secondary-school building and by making certain corrections for those factors which prevent the use of every room and every pupil station every period of the week. These corrections are adjusted to the unique characteristics of the educational program and policies of the school under consideration. Furthermore, the corrections have been delineated to such a degree that as new educational policies develop in the future which affect operating capacities, their effect may be determined and applied without destroying the basic approach to capacity developed in this study.

Criterion 7, as stated in Chapter 3 was that "the formula should be relatively easy to apply." It is difficult to evaluate the degree to which this criterion of ease of application has been met. To be sure, the number and complexity of factors have made the capacity technique more burdensome. This detail was necessary, however, in order to satisfy the other criteria to a higher degree. The factor of educational program is probably the most burdensome single factor in the new technique, whereas, this factor is not analyzed in other capacity determining techniques based upon utilization studies.

It must be remembered, however, that quantitative burdensomeness is only one aspect of ease of application. If ease is measured by the degree of difficulty of the process, the new technique meets this criterion to a
very high degree. The difficulty of application has been minimized by reducing the technique to a number of simple tasks with work sheets to record each step and detailed instructions to accompany each work sheet.

The eighth criterion stated that "the results obtained from the formula should be easily interpreted." Although the capacity formula determines the various capacity limits of the subject areas, the simple relationship of these limits to total operating capacity of the building leaves little doubt that this criterion on ease of interpretation has been met.

Evaluation on the Basis of Reactions to the Technique by Men in the Field

As was pointed out in the beginning of this chapter, the type of evaluation employed here has definite limitations, and conclusions drawn from such an evaluation must be tempered by such limitations. Regardless of these limitations it was deemed advisable to give attention to the reactions to the new capacity technique by administrators and building consultants in the field. The following reactions to the new capacity determining technique have been gathered from principals, superintendents, building coordinators, and special building consultants in the school plant field who have seen the technique in operation. These reactions have been very helpful in overcoming certain shortcomings of the technique which were revealed by the early applications.
Reactions of Administrators in the Field

In the early development of the study, consideration was limited to purely instructional activities and study hall requirements were ignored. An early dual calculation of the capacity of a certain building for either junior or senior high school purposes revealed extreme variations in the capacity of the building for the two different programs. The questioning by a superintendent of these extreme differences in capacities for the two programs revealed that study hall requirements were considerably different and led to a revision of the technique which now includes study hall requirements as an integral part of the capacity determination. With this exception, superintendents' reactions have been favorable toward the new technique. They have generally accepted the building capacities determined by the new formula as the basis for determining the numerical adequacy of existing school plants and for determining needed additional school plant facilities. Superintendents' reactions have been most favorable toward that aspect of the new capacity technique which permits determination of building capacities under varying conditions of vertical school organization and projected educational programs.

Building principals have generally agreed that the capacities determined by the application of the new capacity technique reflect very accurately their personal estimates of capacities of their own buildings. Although experience and "off the cuff" opinion were most commonly used as the basis for the principal's estimate, some principals' estimates were based upon a more careful analysis. In several cases where estimates by
principals were at variance with the capacities determined by the formula, the principals agreed, after more careful analysis, that the capacities determined by the formula were more reasonable than their own original estimates.

In those cases where the capacity determining technique indicated existing areas of overcrowding, there was no disagreement on the part of principals that such overcrowding existed.

Reactions of School Building Consultants

The favorable reaction to the new capacity technique by school building consultants is demonstrated by its use in the Survey Division of the Bureau of Educational Research of The Ohio State University in determining the numerical adequacy of all secondary-school buildings studied in its survey work. For years the Bureau has made utilization studies of all secondary-school buildings in order to make some estimate of the numerical adequacy of each building. However, from such utilization studies, the Bureau has never been willing to set an operating capacity for an existing secondary-school building but has had to resort to generalities concerning overcrowding or poor utilization. The new technique of capacity determination has filled this gap.
CHAPTER 7
SUMMARY AND CONCLUSIONS

The Problem

The capacity technique developed and illustrated in this study constitutes only one of a series of steps to be taken into consideration in measuring the adequacy of secondary-school buildings. Any comprehensive survey of school plant facilities must include the qualitative aspects of school plant facilities as well as the quantitative ones considered in this study. This problem of determining the practical operating capacity of secondary-school buildings has long confronted the worker in the school plant field. The utilization study, although not developed primarily as a capacity determining technique, has long been used to assess the quantitative adequacy of secondary-school buildings. However, the utilization study, when used as a capacity determining technique has certain major shortcomings. The utilization study is based upon abstract standards of space per child and authorities do not agree upon these space allotments. In fact, the actual space per child varies according to the type of educational program. The technique of capacity determination based upon the utilization study not only fails to consider the type of educational program but also fails to consider the degree to which the building is adaptable to the educational program and, therefore, gives a distorted picture of the true operating capacity. Moreover, it is generally agreed that 100
per cent utilization is impractical, which makes it necessary to set
some arbitrary optimal per cent of utilization as the basis for capacity
determination. Such an optimal per cent of utilization has never been
generally accepted. Moreover, it is questionable whether such an opti-
mal per cent of utilization exists which is equally applicable to all
school situations. So we find that the question of practical operating
capacity of secondary-school buildings is still not only a frequent one
but one to which the survey worker has neither the answer nor an adequate
technique of finding the answer.

The problem, then, has been to relate capacity to functional use of
the building and to develop a technique for determining the practical
operating capacity of secondary-school buildings which overcomes the
weaknesses of the existing techniques which are based upon utilization
studies. After developing such a technique, it was deemed necessary to
translate the technique into a series of forms, work sheets, and detailed
instructions to facilitate its application.

Certain arbitrary limits were placed upon the study to make it more
definitive and meaningful. The investigation was limited to studying
capacities for regularly-scheduled activities and, therefore, included
only those rooms designed for or potentially available for regularly-
scheduled activities. The study was limited to quantitative aspects of
building adequacy; therefore, setting standards of desirability or adapta-
bility of rooms for particular uses was considered to be beyond the scope
of the study. Likewise, the study was neither concerned with setting
standards for size of rooms nor size of classes.
Summary of Findings from the Literature

A review of the literature in the school plant field uncovered no formula or technique which had as its primary purpose the determination of operating capacities. Studies of school building utilization and housing requirements were found to be related to building capacity. Two basic plans for the study of utilization and two basic housing requirements formulas were found. The Morphet technique, by far the most commonly used utilization technique measures the efficiency of use of a given building by comparing the percent of utilization of that building with norms based upon status studies of a large number of buildings (23). In its simplest form, the percent of room or pupil station utilization is the ratio of room or pupil station use to the theoretical maximum of using every room and pupil station every period of the day. Since it is generally agreed that this theoretical maximum is impracticable, an optimal percent of utilization must be established upon which to base the quantitative adequacy of existing buildings. Numerous standards of optimal percent of utilization have been established but no such standard has been generally accepted.

The second basic plan of utilization study uncovered, measures service load of a building or room in terms of a pupil-time-area coefficient of utilization (11). The authors of this plan claim certain advantages over the former plan. The major advantage is that the unit of measuring efficiency is not affected by varying conditions with respect to time, number of pupils, character of activities, plans of organization or
policies of administration. Adaptations of this plan of utilization study were also made for determining the capacity of secondary-school buildings. However, the adaptations reduced the plan to a procedure similar to that developed by Morphet.

Two basic types of formulas were found for determining the housing requirements for a given school enrollment. The most widely used type of formula is based upon the educational program and pattern of student electives in the school under consideration (9, 27). This basic relationship of educational program and room requirements was used by the writer as a springboard in the development of the new capacity formula.

The other type of formula found for determining room requirements for a given school enrollment assumes a more rigid type of educational program and was developed from a statistical analysis of several hundred school programs (36, 38).

Criteria for the Development of the Capacity Formula

As guides in the derivation of the new capacity formula the following criteria were developed:

1. The formula should consider the functional use of the building.
2. The formula should attack the capacity problem directly rather than through status studies.
3. The formula should involve all significant factors related to capacity.
4. The factors involved in the formula should be as objective as possible.

5. The formula should be universal in its application.

6. The formula should not involve abstract standards.

7. The formula should be relatively easy to apply.

8. The results obtained from the formula should be easily interpreted.

Derivation of the Capacity Formula

With these criteria as guides, a new approach to capacity determination was developed. The basic assumption underlying this approach was that capacity is integrally related to the educational program and policies of the given school system rather than dependent upon abstract standards applicable to all school situations. This assumption is really a corollary to a long-standing basic principle of school building-planning, namely, that a school building should be planned in terms of the educational program to be carried on in them.

In order to develop a capacity formula or technique consistent with this basic assumption and the criteria mentioned above, it was necessary to analyze the many factors of educational program and policies related to the capacity of secondary-school buildings. The following factors were found to be related, either directly or indirectly, to the capacity of secondary-school buildings: number and types of teaching stations, desirable average class size, room assignment policies, nature of
the educational program, length and number of periods, staggered schedules, multiple sessions, specialization of rooms, and complexity of the pattern of subject elections. After analyzing these various factors to determine their interrelationships, and their net effect upon capacity, they were synthesized into the following capacity formula:

\[ i = \frac{a de}{p1} \]

in which "i" is the total building capacity which could be accommodated by existing facilities in each subject area; "a" is the number of teaching stations in a given subject area; "d" is the desirable average class size for the particular subject area; "e" is the total number of periods of instruction per week; "i1" is the average total school enrollment for a given period; and "p1" is the average total number of pupil periods of instruction in the given subject area for the same period of time.

It is generally agreed that it is impracticable to use every room and every pupil station of a secondary-school building every period of the day and some allowance needs to be made for this factor in determining the capacity of a secondary-school building. Although the capacity formula developed in this study contains no correction factor as such, certain allowances are made in processing the data and in the technique of application of the formula in the determination of the operating capacity of a building. These allowances are not made universally but vary according to the peculiarities of the educational program and policies of each individual school.
In order to determine the operating capacity of a building, it is necessary to apply the formula to each subject area separately. This process determines the total school enrollment which could be accommodated in the various subject areas of the building. The lowest pupil capacity limit thus obtained for any subject area is the maximum school enrollment which can be housed in the building without modification either of the building or the educational program. When a building is ill-fitted to the educational program, these capacity limits of the different subject areas will vary considerably. In such cases it is often possible to adapt the excess spaces in those subject areas with high pupil capacity limits to the subject areas with low pupil capacity limits and thus increase the total operating capacity of the building.

Development of Work Sheets

In order to facilitate the use of the capacity determining technique, four data collection and work sheet forms were developed. Detailed instruction sheets, keyed to each of these forms, simplify the capacity technique and make it relatively easy to apply to any secondary-school building.

Practical Applications of the Capacity Determining Technique

To illustrate the use of the capacity technique developed in this study, the technique was applied in 13 buildings and 23 different types
types of school situations ranging in educational programs from traditional to very modern and in enrollments from 232 to 1,492.

The first illustration contained complete detailed information and explained in considerable detail the collection and processing of all data in order to clarify each step in the process of capacity determination. The other 22 illustrations contained only summary data and were used primarily to show the many different applications of the capacity determining technique. In addition to illustrating the capacity of numerous types of buildings with their present educational program and policies, the illustrations included capacity studies of buildings on the basis of projected educational programs. Such projected use included the use of buildings for different types of vertical and horizontal organization and daily schedule of classes. In order to illustrate the close relationship of capacity to educational program, the capacity of a high-school building in a large city was determined on the basis of its own educational program and also on the basis of the educational program of a suburban high school in a different part of the state. The adjusted capacity of the building was about 250 (20 per cent) greater when used to house the existing program. A second building showed a similar marked difference in capacity when used for junior or senior high school purposes. The capacity of this building was approximately 200 (15 per cent) greater when used for senior high school purposes. However, a third building showed no appreciable difference in capacity (less than 2 per cent) when used for junior high, senior high, or six-year secondary-school purposes. Such illustrations emphasize the
necessity for a new approach to capacity determination based upon the peculiarities of each individual school program.

The final illustration indicated the use of the capacity technique (with slight modifications) as a method for determining housing requirements in the planning of new buildings. The major advantage over existing techniques for determining housing requirements is the ease with which future expansion can be projected and planned in the original planning of the building so that the functional relationships of spaces are not destroyed by expansion.

Evaluation of the Capacity Determining Technique

It was not within the scope of this study to attempt a comprehensive evaluation of the accuracy of the capacity technique as a determiner of secondary-school building capacities. However, the logic of the technique was demonstrated in the process of its development and a limited evaluation of the capacity technique was made. The technique as such was evaluated on the bases of how well it avoided the shortcomings of existing techniques based upon utilization studies and how well it measured up to the criteria set up for the development of such a formula. A limited evaluation was also made on the basis of administrators' comments. This evaluation has shown that the new technique of capacity determination does avoid the shortcomings of the existing techniques based upon utilization studies and measures up well to the criteria for developing a capacity formula. Furthermore, principals, superintendents, building coordinators, consultants in the school plant field who have seen the
capacity determining technique in operation are in general agreement that the technique does provide an accurate measure of capacity.

Areas of Needed Research

The major area of needed research which has been revealed by this study is that of the relationship of average to maximum class size. The only study of this relationship which the writer was able to uncover was a study of three school programs made by Anderson a quarter century ago (9:31-33). This study simply compared the average class size with the average maximum capacity of rooms. This was merely a status study of existing conditions in the three schools. No consideration was given to whether educational policies existed which limited class sizes or whether room capacity was the only limiting factor. Since educational policies are increasingly being adopted which set maximum limits on the size of classes and at the same time set desirable average class sizes, this relationship of average to maximum class size will become increasingly important in assessing the numerical adequacy of secondary-school buildings and also in the planning of new buildings.

The age old problem still remains whether there is any significant difference in the quality of teaching or the products of instruction with different size classes. Although scores of studies have been made on class size and have dealt with a variety of factors, no one of the factors has been measured adequately under sufficiently controlled and sufficiently extensive studies to provide a sound base for decisions on
class size (26:214). Research has barely touched the instructional aspect of class size. As long as rather conventional, routinized group procedures are used in teaching, there is little likelihood that any research, regardless of how carefully it is done, will show that measurable differences exist between large and small groups. However, modern teaching techniques require a variety of activities and extensive research may well show major differences in both quality of teaching and quality of products for large and small groups. Further research on class size is urgently needed since class size is so intimately related to the numerical adequacy of existing school plants and also to the planning of new facilities.

Some schools have room assignment policies which require a room for each teacher and which permit the teacher to use his room for preparation and conferences during those periods in which he is not required to teach regular classes. Although most administrators can see certain educational advantages of such room assignment policies, few administrators are willing to pay the price in loss of operating capacity for these advantages. The necessary allowances in capacity for such policies were treated in Chapter 3 of this study, although no schools with such policies were illustrated in Chapter 5. Research is needed to measure the effect of room assignment policies upon educational outcomes before such policies become widespread.
Major Conclusions

Two major conclusions seem justifiable from this study. First, there seems little doubt that the true operating capacity of a secondary-school building is more than an abstract function of size and number of classrooms and must be related to the characteristics of the educational program and policies of each individual school system. Second, it has long been recognized that it is impractical to utilize every room and pupil station every period of the week and that some allowance must be made for this factor in determining the operating capacity of a secondary-school building. This study has shown that this factor has several facets each of which must be analyzed separately and the necessary allowance made on the basis of its relation to a specific educational program.
BIBLIOGRAPHY


