R E P O R T R E S U M E S

ED 020 624 EF 000 672

DESIGN AND CONSTRUCTION OF SCHOOL BUILDINGS. PROCEEDINGS, ASSOCIATION OF SCHOOL BUSINESS OFFICIALS OF THE UNITED STATES AND CANADA, ANNUAL MEETING AND EDUCATIONAL EXHIBIT, (50TH SAN FRANCISCO, CALIFORNIA, OCTOBER 21-22, 1964).

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PUB DATE 65

EDRS PRICE MF-$0.25 HC-$0.72 16P.

DESCRIPTORS- *BUILDING DESIGN, *COMPUTERS, *CRITICAL PATH METHOD, *PROGRAMING, *SCHOOL CONSTRUCTION, INFORMATION PROCESSING, MODELS, NETWORKS, SCHEDULING, SYSTEMS ANALYSIS,

PROBLEMS IN THE SCHEDULING AND COMPLETION OF SCHOOL BUILDING DESIGN AND CONSTRUCTION PROJECTS ARE DISCUSSED WITH REFERENCE TO THE CRITICAL PATH METHOD OF PROGRAMING. THE DISCUSSION GIVES A BROAD OVERVIEW OF THE METHOD WITH DETAILED SUGGESTIONS FOR SCHOOL ADMINISTRATORS. SPECIFIC SUBJECT AREAS INCLUDE--(1) CPM, A NEW MANAGEMENT TOOL, (2) CPM DEFINED, (3) THE BAR DIAGRAM--ITS DISADVANTAGES, (4) METHODS OF USING CPM IN CONSTRUCTION, (5) CPM SPECIFICATION REQUIREMENTS, AND (6) BENEFITS AND ADVANTAGES OF CPM TO SCHOOL BUSINESS OFFICIALS. THE PROBLEMS AND PRACTICES OF USING COMPUTER PROGRAMING WITH CPM ARE DISCUSSED, INCLUDING THE DETAILS OF PROGRESS COMPUTER RUNS. EXAMPLES ARE DRAWN FROM THE APPLICATION OF CPM BY THE BOARD OF EDUCATION, CITY OF NEW YORK, AND A SPECIFIC JUNIOR HIGH SCHOOL IN THE BRONX. SOME REFERENCES ARE INCLUDED FOR FURTHER BACKGROUND READING IN CPM. THE ENTIRE PROCEEDINGS OF THIS MEETING ARE AVAILABLE FROM CHARLES W. FOSTER, OFFICE OF THE EXECUTIVE SECRETARY, 2424 WEST LAWRENCE AVENUE, CHICAGO, ILLINOIS 60624 FOR $5.00. (MM)

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Schoolhouse Planning and Construction

MONDAY AFTERNOON, OCTOBER 19, 1964

Brooks Hall, Meeting Room 4 — 3:00-4:30 P.M.

ED020624

CHAIRMAN: SIMEON J. DOMAS
Administrator
Massachusetts School Building Assistance Commission
Boston, Massachusetts

RECORDER: WILLIAM L. CLEMENTS
Superintendent of Operations
Phoenix Elementary Schools
Phoenix, Arizona

Topic: CRITICAL PATH METHOD

DESIGN & CONSTRUCTION OF SCHOOL BUILDINGS

by MORRIS LIEBESKIND
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A. INTRODUCTION

School Business Officials charged with the responsibility for the design and construction of school buildings, are constantly faced with this problem: how to assure the completion of the design and construction on a certain date previously estimated and established by the Board of Education. There is general agreement that a large majority of school projects are not completed on time. Delays will not only result in denying a number of children full time and adequate education, but may end up in additional costs to the board. Liquidated damage clauses are rarely invoked and change orders, claims, and law suits are difficult to resolve.

All this is due to the fact that the usual method of checking progress, or assessing field conditions are either too difficult to determine or the information is entirely inadequate. Under such conditions there is a tendency to increase the time set for the completion of a school, and when a minor delay does occur, to again extend the time scheduled for completion. As a result, this may also tend to limit competition to certain types of contractors, who prefer long periods with opportunities for submitting claims for unreasonable amounts. If the delay is the contractor's fault, he will generally offer many excuses by either blaming the board or one of the other prime contractors. All this ends up with a school, which is not completed on time and with excessive claims which may end up in a lawsuit. We may now have the answer to this perplexing problem and how to combat it.

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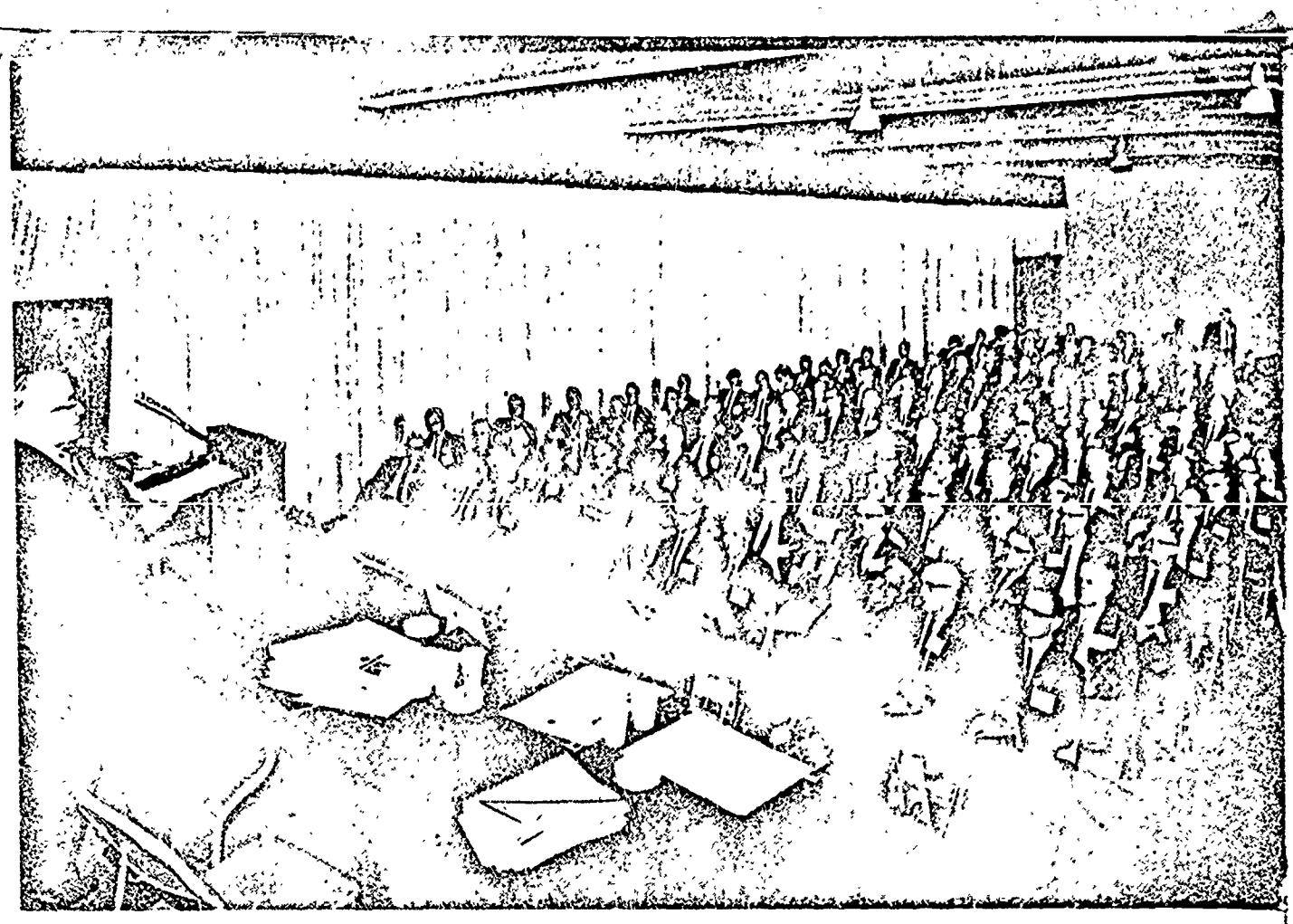

Morris Liesbeskind, Deputy Superintendent of Maintenance for the New York City Board of Education, presents his topic — Design and Construction of School Buildings — to the Schoolhouse Planning and Construction Section Meeting assembled.

B. CRITICAL PATH METHOD — A NEW MANAGEMENT TOOL

During the last three years, considerable progress has been made in the use of a totally new concept in planning and scheduling. This new concept known as the "Critical Path Method" (CPM) is rapidly gaining acceptance in the design and construction fields. It has many advantages, both to the Board of Education and to the contractors, when applied to the design and construction of school buildings.

My paper will be confined to the use of CPM by the School Business Official and his staff. No attempt will be made here to explain this new concept in detail, but a general understanding of its basic principles and advantages will prove to be useful and will provide sufficient information for decision making on the part of the school official, especially after the reports are digested by his staff or by the architect or engineer employed by the board to design and supervise the inspection of the project.

For those interested in a detailed study of the techniques of CPM, courses of one to five days duration are being offered by management consultants, who have specialized in that field and who also prepare CPM diagrams and act as consultants during the construction period. Lectures and courses are also offered by the computer manufacturers, who also provide manuals and literature on this subject. Certain universities and engineering societies also offer such courses.

Here is a management tool that can be effectively used by the school

official to pinpoint responsibilities, to determine periodically whether the school will be opened in time, or if delays occur, ascertain who is at fault. He is then in a position to make a decision accordingly, whether to direct the contractor to increase his labor force for certain activities if the contractor is at fault, or to order overtime for certain critical activities, if the board is at fault. This can be done at an early stage, when the additional costs to the board or to the contractor can be held to a predetermined minimum.

C. CPM DEFINED

The Critical Path Method may be defined as a program which will assist the School Business Official to visualize the entire design or construction progress clearly, so that immediate decisions can be made which will be in the best interest of his board. This program breaks down all the steps in the design and construction of a school building and arranges them into a specific logical order which takes into consideration the interrelationship and coordination of all interested parties. The monitoring and analysis of the progress reports which lists all the activities, provide a basis for determining delays, so that decisions may be made accordingly.

In the planning stages of a new school building, an addition, or a modernization project, every step can be scheduled from the inception of the project, the approval of the bond issue, the selection of the architect, the purchase of the property, the steps in the completion of the plans, advertising for bids and the awards of contracts. After awards are made, every step in its construction can then be scheduled. All such scheduling and then the analysis by progress computer run reports can be carried out by the use of CPM techniques.

D. BOARD OF EDUCATION — CITY OF NEW YORK — DESIGN PROJECT

The best way to explain the use and advantages of CPM is by a simple illustration of a design project.

Mr. Eugene E. Hult, Superintendent of the Office of School Buildings, Board of Education, City of New York, is faced with the problem of reducing the time taken in the planning of about 35 new school or addition projects and 50 modernization projects at an annual cost of about $182,000,000. A study was made of the various steps in the planning operation. CPM was found to be idealistically suited. Separate typical CPM diagrams were prepared for schools designed by the board's staff and by private architects and for modernization projects designed by private engineers.

The following basic CPM principles may be stated by examining the sample CPM diagram for an elementary or junior high school to be designed by a private architect. Figure 1. (Visual aid presentation.)

1. The first step is to subdivide the project into activities, which directly or indirectly effect its completion and which require time to perform. Their relationship is then determined. For each activity a determination is made as to what activities must be accomplished before it can be started, what other activities can be carried out concurrently or independently and what other

activities require its completion before they can start.

2. The three planning stages are separated, i.e. sketch, preliminary and working drawings.

3. Each activity is shown by a line, is numbered with the arrow point showing the direction and is identified, for example: Activity 5-13 is "Preliminary Plans Prepared" as the name or designation above the line.

4. Each activity has the number of working days or duration given below the line. Activity 5-13 will take 15 working days to complete. The length of the line has no significance and need not be drawn to scale.

5. When a number of activities terminate at a junction, called an "event," this indicates that the activity starting from that even may not start before all activities terminating thereto have been completed. The event number is given in a circle which indicates the sequence.

6. If one event takes precedence over another event that is not connected by a specific activity, a dummy activity, shown by a dotted line, is used to join the two events. Such dummy activities have no duration. Dummy activities can also be used to indicate constraint that the occurance of one event has on a subsequent event.

7. The Critical Path is shown by a heavy line and represents the sequence of activities requiring the longest time duration for completion. Any delay in one of the activities on the Critical Path will delay completion. But such delays can be spotted at early stages and a decision can be made by the school official to order overtime on the part of the architect, if the delay is attributed to him. If, on the other hand, the board at a certain stage makes changes which require time-consuming revisions, then as a matter of fairness, the architect is entitled to additional compensation for such changes and for the overtime involved.

8. Activities not on the Critical Path are non-critical and may, therefore, experience limited amounts of delays or acceleration in starting and completion time without affecting the completion of the project. The amount of time that limits the latitude that is permissible is called "float." If such float time limits are exceeded, certain non-critical activities can become critical. For example, Activity 28-30 allows 20 days, therefore, there are 10 days of float for completion of this activity to meet at event 31.

The use of CPM for design projects has the following advantages:

1. It indicates that certain activities not an integral part of the design project could be carried on simultaneously before a critical stage is reached. For example, Activities A B and B C, calling for the topographical survey have to be completed and submitted to the architect before the preliminary plans are started. In other words, the diagram can be used to give a clear picture of certain activities which go on during the design stage, but the resulting information does not effect the work of the architect until a certain stage is reached. The activities are known as restraints and are tied into the project by a dotted line or dummy.

2. Progress can be checked monthly by means of one report. All activities are first typed with the corresponding designation and the scheduled

starting and completion calendar time is determined from the number of working days. A blank column is provided for each of the months during the design period. At the end of each month the architect supplies the information for each activity whether completed, percentage completed, etc. By using tracing paper only one report is needed. Copies can then be made available by the architect to board members and school officials. At the end of the project a complete history is available for use on other projects. Comments may be added by the architect with special indication of delays, changes, etc.

3. As indicated, activities on the Critical Path can be expedited to keep the project on time.

4. The board's contract with the architect can include provisions that the architect prepare the CPM diagram and progress report and submit copies for approval. This method also lends itself for expansion into more activities by the architect, for his use in cost accounting and scheduling a number of projects in his office for manpower distribution. The CPM technique has already been adopted by certain architectural firms and can be advantageously used by boards of education, who have their own architectural and engineering staff.

5. As the result of this study, the office of school buildings has effected a reduction of two months in the time specified for completion of design projects by private architects.

6. The same techniques, as will be demonstrated, may well be applied to the construction work. However, this involves a different approach and the use of a computer since as many as 1000 to 1500 activities may be involved instead of 60 to 100. Generally for construction projects about 10% of the events are on the Critical Path.

E. THE BAR DIAGRAM — ITS DISADVANTAGES

The Bar Diagram or Gantt Chart is a familiar document to everyone in the construction industry for showing progress, but as we all know, it has been a failure in its use as an accurate and workable construction schedule. I am indeed happy to report that it is — however, gradually — on its way out. When compared to CPM, it is like running a Model T car against a Continental.

The Bar Diagram is nothing more than a number of lines with a list of dates, showing when each major operation will start and the date when it will be completed. This is virtually of no use to the school official, and I might add, to the contractor, as a tool that will indicate actual progress. Everything from it is a matter of implication and speculation. Interrelationship and coordination cannot be indicated.

The Bar Diagram may have about 100 operations listed to correspond generally to the contractor's payment items, but it does not facilitate the determination of the amounts of such payments. It is woefully inadequate as an instrument for use on change orders, assessment of liquidated damages, claims, lawsuits and modifications of the schedule. CPM, on the other hand, should not be considered as a cure-all for all the building ills. Therefore, a

few words of caution are necessary. A poorly prepared CPM diagram may even turn out to be worse than the bar chart. But, it can become a most useful management tool and a prod that will assist the school official and the contractor, since all information can be arranged in a more orderly pattern, which can then be monitored periodically, through the use of a computer to show progress and delays.

F. METHODS OF USING CPM IN CONSTRUCTION

There are two methods of incorporating the use of CPM in a school construction project as follows:

METHOD I – The Board can employ a consultant who is a specialist in this field, at an agreed fee to perform certain functions. This is now being used by the Board of Higher Education of the City of New York in connection with the construction of the Staten Island Community College to be erected at an estimated cost of about $9,000,000. Among the functions to be performed by the consultant are:

(a) To work with the architect and prepare a preliminary CPM diagram for the project which consists of about 700 activities. The diagram will be made available to all bidders as a guide.

(b) To prepare a specification covering the CPM project planning, the scheduling and control for building purposes.

(c) To conduct a one-day introductory training of all prime contractors on CPM techniques. In New York State, separate contracts must be awarded for general construction, plumbing, heating and ventilation and electrical work.

(d) To develop, after the award of the prime contracts, a final CPM diagram by working with the prime contractors, who under the terms of these specifications will be required to furnish the necessary information. The number of activities may run as high as 2000 in this case. To provide the initial computer run.

(e) To prepare status reports by means of computer runs, based on information furnished by the contractors at the end of each two week period. It is planned that all contractors, the board's representatives, together with the consultant's staff meet at that time to review the problems and decide on the changes that may be necessary to the schedule. The consultant will also analyze the computer runs and send a report to the board.

METHOD II – This second method in my opinion is more desirable and has the following features. It is planned to be started by Mr. Eugene E. Hult for the Board of Education.

(a) The specification now provides that the general contractor for construction work assume the responsibility for the coordination of the work of the other prime contractors. This program, started about one year ago, has proven to be most successful although CPM has not as yet been used as a requirement. When CPM is started additional advantages, which will be covered later, are anticipated.

(b) The general contractor for construction work, soon after the award of

contracts will be responsible for the preparation of the CPM diagram and the furnishing of the progress computer runs. He may prepare this diagram himself, if he submits evidence of such competency, after consultation with the other prime contractors and sub-contractors, or he may engage a consultant who also must be approved by the board. The cost of the consultant's fee and other costs for the computer runs, etc. will be included in this contractor's bid. In other words, the responsibility is placed in the hands of this contractor and not partly in the hands of the board by engaging the consultant as under Method I.

It is important that the architect's specification spell out in detail, what the CPM diagram will show and what the computer runs will indicate, otherwise each contractor may have his own ideas and the cost for the CPM may even be the determining factor when close bidding occurs.

Once CPM becomes the general practice in private and public construction work and the techniques are fully utilized by the contractor, beyond those required by the board, to achieve the full benefits, such as cost accounting, manpower use, etc., this additional CPM cost will be more than compensated by the potential saving to the board and larger profit margin to the contractor.

(c) The consultant arranges for the computer runs if he is engaged by the contractor as under Method I. If the contractor prepares the diagram, he will arrange for the use of the computer on a time basis with one of the computer manufacturers who have service centers and computer programs in the larger cities.

(d) As under Method I, a one-day training course for prime contractors and their subs by the consultant or by a representative of the computer company is necessary. The following interesting articles are available on the use of CPM in the design and construction of school buildings.

1. *Nation's Schools*, January 1964: "How Critical Path Method is Worked for Schools."
2. *School Management*, July 1963:
   (A) "How to Meet Your Construction Deadlines" by Roger T. Dombrow.
   (B) "How CPM Works for a School District" by Dr. Harold F. Martin.
3. *Architectural and Engineering News*, March, 1963: "CPM scheduling for Architects" by Gustave R. Keane.

G. CPM SPECIFICATION REQUIREMENTS

The following items are recommended to be included in the specifications under Method II, particularly items which often cause delays. These are to be represented as activities or the building to be subdivided into sections, floors, etc., and be shown on the CPM diagram in their proper relationship. This will be made evident later by the sample.

(a) The submission of shop drawings, samples, sample installations, special inspections for the architect's approval.

(b) Subletting of all contracts.

(c) Subdivision of foundations by sections of the building, such as the audi-

torium, gymnasium, cafeteria and classroom wings.

(d) Subdivision of sections of building by wings and by floors as required by the design.

(e) Landscaping and other exterior work.

(f) Inspection and tests by the various city and state agencies if required. This timing is necessary so that other work may proceed.

(g) Temporary work such as erection of shanties, fences, permits, temporary lights, workmen's toilets, sewer work, street openings, stairs, etc.

(h) Ordering of important items of materials, and equipment.

(i) Delivery and erection of important items such as boilers, pumps, etc.

(j) Subdivision of activities by trades in all its sub-divisions. One minor trade may hold up completion of important work.

(k) Delivery of furniture, custodial supplies, school supplies, shop equipment and other items which the board may contract for separately but which are necessary for the opening of the school and which require coordination, interrelationship and use of stairways, equipment, elevators, completed spaces for storage purposes, etc.

(l) Items involving different trades which have to be placed before pouring of concrete or erection of walls, such as conduits, piping, hangers, boxes, etc.

(m) And most important the CPM diagram should show all salient construction operations or activities in a logical order. With the exception of material deliveries, the time duration for an activity should not exceed 15 working days. A change in responsibility, different trade, locations, phases generally indicates a new activity.

(n) In identifying activities attention should be given to the partial dependency which exists between construction operations. For example, the placing of concrete footings is not dependent on completion of all foundation, but can be started when a part of the excavation is completed.

In addition, the following requirements are recommended for inclusion in the specifications, so as to pinpoint responsibilities:

1. The general contractor for construction work is to arrange for a one-day training course for all the prime contractors and their main sub-contractors, the architect and his staff, the contractor's staff, the school official's staff, etc.

2. The general contractor is to make an analysis of all the essential components and assume the responsibility of assembling similar information from the other prime contractors. He will be held responsible for the coordination as previously indicated.

3. The mechanical contractor is to make available within a stipulated time, to the General Contractor, the required information and be held responsible for delays.

4. Each activity must be determined for time duration in working days. The time of year should be taken into consideration, such as lost time during winter months.

5. The general contractor is to determine the order of the activities and

their relationship.

6. The general contractor is to be responsible for the preparation of the CPM diagram and computer runs and submit same to the board, school official and architect for approval as required.

The time from start to finish must, however, conform to that stipulated in the contract. Generally, more than one computer run is made at the start from the diagram to fit the contract time. The diagram is changed accordingly. The computer also converts the time duration for each activity into calendar days taking into consideration holidays and week ends.

7. On he fifth day of each month each prime contractor is to report the progress of each activity under way on forms supplied by the computer company and any other pertinent information, changes, etc. which will effect the program. This report is sent to the architect or school official on the afternoon of the report date or it may be sent directly for a computer run. Copies of the initial and progress computer runs are to be sent by the general contractor to the prime contractors, to the school official and to the architect.

8. Separate computer runs are to be provided as follows:

(a) For activities for which each of the prime contractors is responsible, i.e. general construction, heating and ventilating, plumbing, and electrical. If the single contract is used, it is still advisable to have separate computer runs.

(b) For activities for which the architect is responsible, i.e. approval of shop drawings, samples, special inspections, etc.

(c) Activities on the Critical Path.

H. SAMPLE PROJECT — BOARD OF EDUCATION, N. Y. C. — J. H. S. 145, BRONX

To illustrate some of the main features of the CPM techniques for a school construction project, I have brought along a diagram of Junior High School 145 in the Borough of The Bronx of the City of New York. The general contractor for construction work was not required under the terms of his contract to prepare this diagram, but he had the responsibility for the coordination of all mechanical trades, although awarded separately. This diagram has only 163 activities and is not a sample of a complete diagram which may have 1000 or more activities and which may be four or five times as long. It will, however, illustrate its advantages above that of the bar diagram, which was all that was required. Surprisingly enough, a bar diagram was also furnished, but it was produced by the Computer, G-E-225 – something new. Although there are only 163 activities, a computer run was ordered by the contractor to be issued monthly. It is evident that this contractor felt that the preparation of this CPM diagram by his staff and the computer runs (all at his own expense) were warranted and will pay off. Contractors are using this new management tool, and in my opinion, those contractors who fail to understand it, and do not use it and derive all the benefits, will find that they cannot compete.

In this case (please note) the general construction activities are in detail to a certain degree, but the mechanical activities are not in detail.

I. PROGRESS COMPUTER RUNS

Cards are punched at the start of each activity, showing the basic information taken from the CPM diagram. The initial computer run is made. This may be done two or three times before the completion calendar time agrees with the contract time. Forms for showing progress are supplied by the computer company. Each prime contractor is required to report the actual progress as compared to the start and completion dates as set forth in the schedule. The general contractor responsible for coordination collects the forms, reviews same and sends them either directly to the computer company or the architect as previously noted. For example, each prime contractor submits the following for activities scheduled to start or for activities underway: activity number, activity start, and actual finish.

Figure 2, is a composite and shows the different computer runs, i.e.:

1. The initial computer run. Note items in the Critical Path are marked "Critical" under the heading "Status."
2. Progress Computer Run.
3. Critical Path Activities.
4. Second Level Float Activities.

The sample computer run .. mber 2, showing monthly progress, is a most useful document for the school official, the architect who may supervise the construction, and the contractor. The school official who must make decisions should understand and know how to read and interpret these computer runs. A complete set of such reports will furnish a complete history of the project for use in the approval of payments, assessment of liquidated damages, change orders, claims and lawsuits. The first approved computer run from the approved CPM diagram is an ideal set-up for all activities, but as progress is made, it becomes evident that many adjustments have to be made, which the progress computer runs will indicate.

Let us now examine this progress computer run. If ordered by the contractor for his own use such items as cost and manpower distribution can be added. The progress report retains the schedule originally set up in the initial computer run and includes the results of the actual progress. The computer programming is based on the use of General Electric Company GE-225. Other computer companies have similar programming. The numbers in circles are explained as follows. The same explanation applies to the initial computer run for the corresponding terms.

1. Gives the name of the project, the contractor, Monitor Run No.
2. Gives the scheduled and expected date for completion of the entire project. The expected finish may be later than the scheduled finish from the initial computer run at a certain progress stage, and is a warning that a delay has already occurred and adjustments must be made or immediate action must be taken.
3. Gives the date when the status of the activities are compiled.
4. Gives the actual number of days the entire project is ahead or behind the schedule.
5. This identifies the activity. "I" represents the tail of the line on the

CPM diagram and "J" represents the head or arrow.

6. Gives the status of the activity, whether it is "overdue" in starting as scheduled or in finishing. The notation "overdue" may indicate that: (a) All predecessors are furnished and the activity has not started, although it is not yet scheduled to start. (b) The activity is not reported finished by the earliest finish date.

7. Gives the scheduled duration of the activity in weeks and days and its description. The letters G, E, H. & V., P & D., correspond to the four prime contracts, i.e. general construction, electrical, heating and ventilating and plumbing. In this case the diagram gives the total number of days which includes weekends and holidays. In other cases, the diagram is prepared on the basis of working days and the computer automatically takes core of this by conversion into calendar days. The time actual "used" in weeks and days is also given.

8. Gives the *Starting Dates* under three headings.

(a) *Scheduled* – is based on the concept that non-critical activities may have limited amounts of delay or acceleration in start and completion time. The first computer run has for each activity, the total and scheduled float available. Items on the Critical Path at the start of a project have no float time.
Float Time is defined as the maximum time that is made available for an activity minus the time to do the job. It is the time latitude available to the non-critical activities.
Scheduled Float is the float allocated to an activity, based on priority weights established by the contractor. Certain items assume greater importance, or which are more difficult to assess as to time, are given higher weights. Activities that are near completion time of a project also have high priority.
Therefore, if more than one activity is to be completed at a certain point or event as shown on the diagram, the scheduled starting dates for such activities can be set depending on these priority weights. This is for the contractor's benefit so that he may be guided accordingly. The weights are generally one to nine. This scheduled starting date may change at each progress report and will depend on the float available at that time.

(b) *Earliest* – is the earliest date on which the activity can start. It may not be the one which the contractor will use, if it is not on the Critical Path. The date is replaced by the word "started" if actual start is reported.

(c) *Latest* – is the latest date for starting the activity and still completing it on time, unless there is a minus float under Column 10. This date remains the same as on the first computer run, unless a new schedule is established for the project.

9. *Finish Dates* give corresponding dates to the start dates. The "earliest" finish is replaced by the word "finished," if actual finish is reported and the "latest" is replaced by the actual finish date.

10. The *Float* is given in weeks and days and may be plus or minus. It indicates the amount of leeway currently available for each activity or the amount of apparent slippage or minus float. A minus float may cause the entire project to finish late.

On the initial computer run, activities on the Critical Path indicate no float and the scheduled, earliest and latest starts are the same. This is axiomatic. But as a project advances, the total float of each activity may change and items on the Critical Path may show up with a minus or plus float. This will change the scheduled, earliest, and latest start and finish dates. Where there is a minus float you will note that the earliest start and finish is the corresponding number of float days before the latest start and finish dates. A minus float is a warning that the entire project may finish late.

11. *Early Late* – gives the amount of time an activity was started or finished plus ahead of time or minus behind time. A minus occurs if a predecessor had lagged and the activity had not an opportunity to start.

12. *Gain Loss* – gives the amount of time gained (+) or lost (–) with respect to the time duration used and the actual start. The activity may have started at the time its predecessors were finished or the activity lost time by not starting when it was in a position to start. This can become serious unless steps are promptly taken.

13. *Slip* gives the accumulated number of times an extension has been made to the duration of the activity or the scheduled finish date.

14. *Miscellaneous* –

(a) An asterick before the finish date of an activity points out the fact that the scheduled finish date was changed to a later date than the allowable finish date, otherwise the present schedule if followed for the activity will cause the project to fall behind.

(b) All "dummy" items are run off on the computer separately for each progress run. The starting and finishing dates are the same, since there is not time duration.

(c) The attached composite computer run also shows a separate progress run which is made for the items on the Critical Path. This lists the item number and the total float (+) or (–) available as of the date of status and the previous float as of the previous run. This is an important check if delays are beginning to accumulate, or if the project is ahead of the schedule.
Separate computer runs are also made for four or five more levels of float, listing the present and previous float for plus 1, 2, 3, 4, and 5 levels. The float level may change in each progress run and certain items may become critical and show up as zero or minus float.

(d) If a change in the duration of certain activities must be made, it means a new analysis by the computer, since such changes can result in a drastic change of the completion date for the project. If a major change is necessary a revised schedule must be developed by replanning the CPM Program.

J. GENERAL OBSERVATIONS

It is important that the following general observations be reviewed for a better understanding of the uses and the possible abuses that may occur in adopting CPM.

1. Diagrams must be carefully prepared by architects, engineers, contractors or consultants. The computer will only show the information available on the CPM diagram.

2. Periodic up-dating by progress computer runs on construction work with its proper implementation in the field by the field superintendent and the architect or board's representative will provide excellent results.

3. Prompt decisions by the school official, the architect or board, as required, is a prime requirement.

4. Training and orientation of all parties concerned in the technique of CPM is essential. The school official need not be concerned with all details which affect the contractor. Details primarily for the school official's benefits are estimating, contractor's cost, equipment and man power scheduling, but the school official and his staff should know the fundamentals.

5. Cooperation of all contractors and sub-contractors is essential. CPM can show, however, which subcontractor is holding up the schedule, and it is an easy matter to point out to that contractor where he is causing the delay. Many of us are concerned with the subcontractors who handled certain important portions of the work and who delayed the submission of shop drawings and samples because they have not completed contract arrangements with their own subs and suppliers.

6. Since this technique is relatively new, there is a reluctance for its adoption, as was the case 10 or 12 years ago when data processing and computers were introduced. General acceptance of a new system lags behind development. To assure success board members, school officials and those at the lower echelon must be oriented and convinced of CPM merits, its uses and its abuses.

7. CPM creates an equitable situation to the board and to the contractor. An extension of time to a contractor is no compensation to him when the delays, which may be the board's fault, result in overhead expenses being extended, or the contractor's equipment being idle or wages being increased or different weather conditions result. However, the reverse is also true. The board is entitled to a complete building on time, so that the children have an uninterrupted education. This does not mean the opening of the school with still incompleted work necessary to be done while classes are in session.

8. CPM is not a cure-all for all building ills. It will aid the contractor to arrange the information in an orderly pattern which will result in an understanding of the project by the school official. The monthly computer run automatically acts as a prod to keep up with the schedule.

9. Contractors who abuse the CPM techniques should not be permitted to bid. Sufficient information will be available to assess liquidated damages and as proof for their disqualification.

10. The CPM techniques can be considered as a check list device, there-

fore facilitating expediting where needed by the board and the school official.

11. CPM is as good as the assumptions made and information assembled. Contractors who specialize in school construction will gain experience with each project. In large cities or school districts this is invaluable and will tend to reduce costs and time for completion. If it is desirable or necessary to revise the CPM plan, it should be done without hesitation.

12. Time spent by contractors and subcontractors on the CPM diagram will be less than the overall time previously spent in managing the project. This will also ferret out the fact that subcontractors also subcontract their work. Showing the diagram to all subcontractors and others involved will stimulate interest and point out their importance of adhering to the time schedule. The subcontractor can see how his work relates to the entire project.

13. In certain cases, updating or the issuance of computer runs should be on a two-week basis instead of monthly. This will depend on the complexity of the project.

14. Regularly planned meetings should be held to discuss poor performance and how improvements could be made, if delays become apparent from the reports.

15. Combining too much work into one arrow activity will produce an unworkable schedule. This is one of the main objections to the bar chart.

16. It is advisable that the contractors and their superintendents who will direct the project work together in the preparation of the CPM diagram. CPM can only succeed and is only as good as the logic that is used in developing the diagram. Only experienced persons should be used.

17. CPM Consultants, who offer their services, may have men in their staffs who lack building experience, although they may have excellent training in computer technology. Accurate information must be supplied by the contractors and the CPM diagram must be carefully reviewed when prepared by such consultants.

K. BENEFITS AND ADVANTAGES OF CPM TO SCHOOL BUSINESS OFFICIAL

What are the benefits, results and advantages to the board and to the school business officials in adopting CPM as a management tool?

1. A standard system of planning for design and construction work is established which means literally building the job graphically on paper. A clear picture of the scope of each project is then available. The possibility of overlooking a critical fact is substantially reduced.

2. A tool for periodic rescheduling and evaluating is provided.

3. CPM will give the general contractor better control over his job, and those who use it effectively will submit lower bids. Trouble spots are detected easily and a majority of lost motions is eliminated so that the project can be finished on time.

4. It offers the most reliable basis for extension of time and negotiations or assessment of liquidated damages.

5. If a change in personnel is necessary, it can be accomplished without

difficulty since the records are available at any point. This is especially important in case of claims and lawsuits when the personnel of the board may retire, change positions or die.

6. At present when a project is delayed by labor troubles, weather or reasons which may be attributed to the board, overtime may be ordered for the entire project or for a large portion. The additional expense may be charged to the board. Under CPM such overtime, if ordered, would only apply to the critical jobs.

7. Present practice indicates that there is a reluctance on the part of a contractor to expedite certain parts of the project at an early stage since immediate danger signs are not evident. CPM will correct this situation.

8. CPM is a good aid in training inexperienced engineers and inspectors, who may represent the board.

9. The board or school official or top management need only be advised when something goes wrong and when a decision is needed involving costs.

10. Quick rescheduling of a project to meet unpredictable conditions or emergencies is provided.

11. For the first time the school official will know what is going on. Realistic schedules make it possible to order furniture, school and custodial supplies in advance for delivery at proper time.

12. A better analysis of change orders can be made. When ordered the exact status and its effect on costs can be determined. Furthermore an immediate appraisal can be made, if the entire project will be delayed.

13. CPM can be effectively used to provide the board with correct information, which fixes responsibilities of the school business officials, the architect, the contractor and others.

14. The board is in a position to arrange the financing more efficiently. This applies where the school district issues bonds. Since the project can be scheduled accurately the board could determine payments to contractors.

15. A number of design projects performed by the board's staff can be scheduled and such parallel schedules can be interconnected. This increases the efficiency in the development of the staff. The illustration given herein can be enlarged with more activities depending on the organization. Effective design cost and time control will result.

16. When changes are necessary, the diagram and progress computer runs show at what point they are made, and therefore, will indicate the impact of such changes on the project, as far as time completion and cost. Adjustments can be readily made accordingly.

17. The most important advantage after experience is gained is the reduction in the number of days to complete a project. This will not only result in educational benefits, but in the reduction of the cost of school construction.

18. For those school districts or board which have prequalification, CPM will provide a better yardstick to disqualify certain contractors.

19. More time will be available for inspection by the architect, clerk of works and inspectors, since too much time is now spent, especially where

separate contracts are involved, with coordinating, interferences of trades, etc.

20. The cost of temporary heat and lighting can be reduced.

21. Delivery of furniture and supplies can be scheduled properly. Additional cost, for rehandling, storage, etc. can be avoided.

22. The opening of a school can be scheduled with better assurance that the date will be met. This is particularly advantageous in connection with good public relations.

23. Scheduling of modernization projects with a minimum interference of school sessions can be effectively scheduled by cooperative planning by the school official, architect, principal, custodian and contractors with some assurance of time completion.

24. The use of materials and equipment which may result in delays and are costly can be eliminated in future design. Future designs will benefit accordingly.

L. CONCLUSIONS

In conclusion, I wish to summarize my paper as follows:

1. CPM is here to stay and the bar chart will gradually disappear. This management tool has recently had wide acceptance by government agencies and in private industry, in the construction field. It is not a cure-all but it is the latest innovation to planning and scheduling which can be effectively used by the busy school business official as a guide for making decisions for his Board of Education.

2. CPM is an educational device which will give the board members, school officials and his staff a better understanding of all the activities involved in the design and construction of a school building and their interrelationship. At least a one -or two-day orientation course to get acquainted with its techniques is recommended.

3. CPM will highlight critical activities which can be expedited and helps to define responsibilities of the school official, the architect and the contractor. tor.

4. The use of CPM gives certain assurances that a school will be completed on time, and if delays do occur, immediate action can be taken at a minimum expense to the board. In the long run as experience is gained, CPM will reduce the time set for erecting a school.

5. Contractors when they begin to understand CPM and realize its full potential will submit lower bids. Costs resulting from the hiring of a consultant and the computer time will be small and will be absorbed in the contractor's bid.

6. Resolution of such problems as assessment of liquidated damages, change orders, claims, and lawsuits will be grealty facilitated to the benefit of the board.

7. And last and most important of all, CPM may be the answer to what all boards of education had hoped for — a tool whereby a school could be completed on time as planned, so that the children could enjoy full time education without disturbance.