Reprinted from THE INDIAN CONCRETE JOURNAL, March 1977

Planning techniques for building and civil engineering works

Surinder Singh and G. C. Sofat

The paper shows the necessity for using planning techniques for building and civil engineering works and describes the merits and demerits of the various techniques available. While showing that bar and milestone charts have basic limitations of not being able to clearly indicate interdependency of different activities/events, it suggests the use of network techniques, of which, the precedence diagram type of network can represent operations more logically. For repetitive type of construction like houses, the line of balance technique is most appropriate and its widespread use is, therefore, proposed. Other factors like personnel participation, knowledge of techniques, practicability of programme, and use of past experiences are important for the successful application of these techniques.

Construction management is a cumbersome job. The project manager is responsible for completing the job on schedule and within the budgeted cost. He is required to accomplish his goal through co-ordinating the efforts of many separate individuals and organisations, most of whom are not under his direct control. In a construction project, these include architects, engineers, main contractors, sub-contractors and suppliers, in addition to people directly under him.

The project manager's main task is to direct and co-ordinate the work of the various agencies involved in constructing the objective. Yet the complexity of todays operations force him to divorce himself from matters of detail and to deal only with the broader aspects of the problem. He is inclined to think and act only in generalities. Lacking suitable planning techniques or management aids, he is unable to comprehend in detail the full aspect of an operation. He is not always aware which operations are critical, and thus, require special attention, or precisely how a delay or failure in one activity will affect other activities following it, or affect the success of the operation as a whole. It is clear that what is needed is a master plan, which will provide the project manager with an upto date picture of the operation at all times. The plan should follow a uniform system which can be clearly understood by all. For building and civil engineering works this need is fulfilled by a suitable planning technique.

This paper describes various planning techniques used for building and civil engineering works, and compares their merits, limitations and essential prerequisites for success.

Need for planning techniques

The main reasons for using planning techniques in building and civil engineering works can be given as :

(*i*) better co-ordination of various agencies involved in construction

(*ii*) better control during construction

(*iii*) better assessment of effects of change in planning

(*iv*) to meet completion date

(*v*) to reduce construction time

(*vi*) to reduce indirect cost and in certain cases direct cost as well

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Hence, it can be said that there is need for planning techniques to increase efficiency in construction.

Types of planning techniques

The various planning techniques which can be used by a project manager are :

(*i*) Gantt or bar chart

(*ii*) milestone chart

(*iii*) network methods, such as
critical path method (CPM), or
project evaluation and review technique (PERT), or
flow chart or precedence diagram

(*iv*) line of balance.

Gantt chart or bar chart : This method was developed by Henry Gantt around 1900 and consists of two co-ordinate axes, one representing the time elapsed and the other the jobs or activities performed. The activities are represented in the form of bars, *Fig* 1. The length of a bar indicates the duration the activity takes for completion. Generally, in any building or civil engineering work some activities can be taken up concurrently and some will have to be completed before others can begin. Thus, in a Gantt chart, some of the bars time-wise run parallel or overlap each other, while others run serially with one bar beginning after the preceding bar ends.

The limitations of the bar chart are that it does not clearly show the interdependences among the various activities in a programme. A simple fact that two or more activities scheduled for simultaneous or overlapping completion does not necessarily make them related or interdependent, or completely independent. For example, in a project involving foundation excavation, for erecting shuttering and laying of concrete the time to be consumed would be as follows : foundation excavation ten weeks, erecting shuttering seven weeks, laying concrete eight weeks.

If the activities are allowed to run in strict sequence, the total time taken for the completion of the project would be 25 weeks. As can be seen, the erection of shuttering can only start after the completion of, say, one half of foundation excavation. Similarly, laying of concrete can only start say, 2½ weeks after the erection of shuttering starts. The bar chart for this is shown in *Fig* 2. According to this plan, the shuttering erectors still have two weeks of work after the excavation work

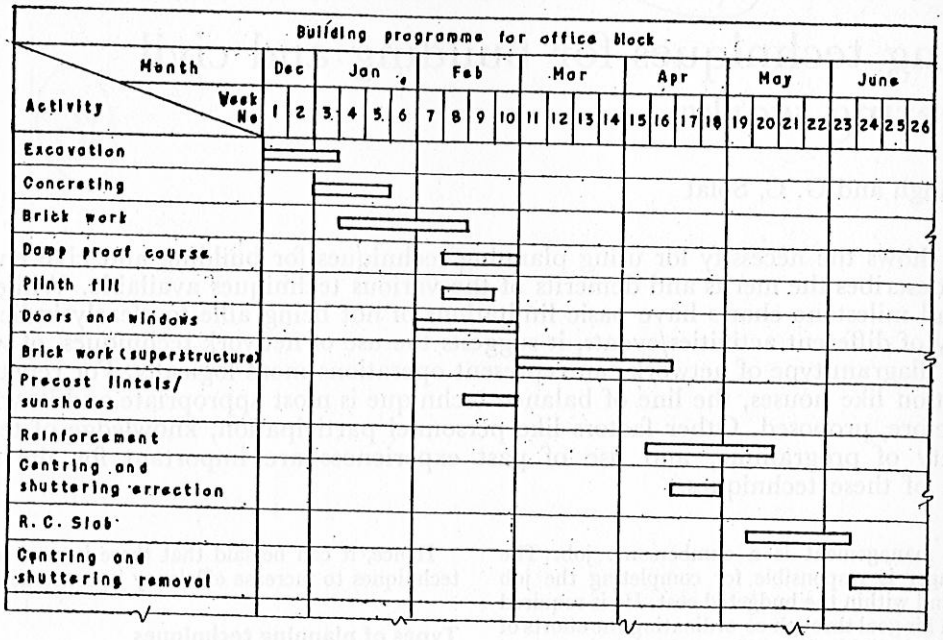


Fig 1 Bar chart partly showing a building programme

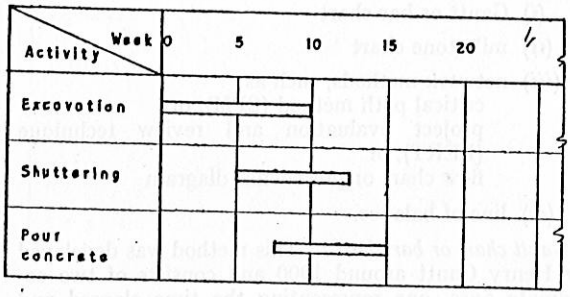
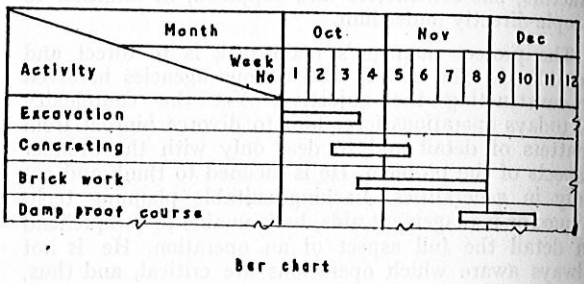


Fig 2 Limitation of bar chart — interdependencies of activities not clear



is over. If now, say, due to certain unexpected difficulties the excavation work is delayed by one or two weeks how will this reflect on the shuttering erection or the concrete laying jobs? This is not revealed by a bar chart.

A bar chart cannot be used as a control device since it does not show the progress of work. In a dynamic programme, the knowledge of the amount of work in progress or that completed is absolutely necessary. Changes in a plan are a necessary part of a large project and a bar chart does not offer much assistance under such circumstances. Further, a bar chart is unable to reflect the uncertainties or tolerances in the duration times estimated for various activities.

Milestone charts : Due to the limitations of the bar chart to meet the requirements of modern day management, efforts were made to modify it by adding new elements. One such modification was the evolution of the milestone chart. Milestones are events which as the project progresses can be identified when completed. In the bar chart a bar which represents a long-term job is broken down to several pieces each of which stands for an identifiable event. Each event is numbered and an explanatory table given identifying the number with the event. This work breakdown increases the awareness of the interdependencies between tasks. *Fig* 3 shows a bar chart and a corresponding milestone chart.

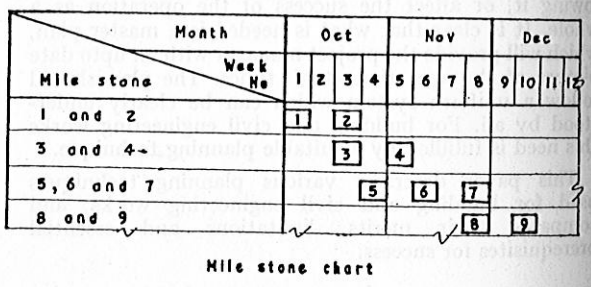


Fig 3 Milestone chart corresponding to a bar chart

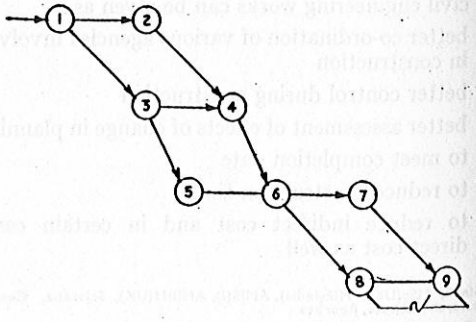


Fig 4 Network of milestone chart shown in *Fig* 3

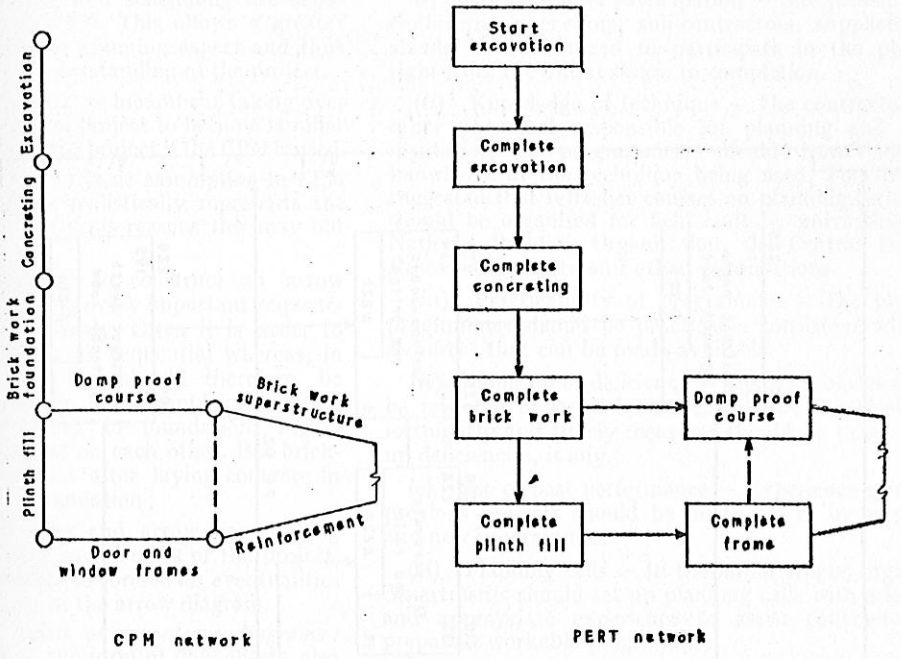


Fig 5 CPM and PERT networks

The milestone chart was an improvement on the bar chart, but it still had one great deficiency; namely that it did not clearly indicate the interdependencies between events.

Network methods: An extension of the milestone chart was the network where the events are connected by arrows in logical sequence. The milestone chart in *Fig* 3 is shown in the form of a network diagram in *Fig* 4. It will thus be seen that for each event there is a fixed sequence of construction, *viz.*, event 4 cannot be started before the completion of events 2 and 3.

CPM and PERT networks — In any network the stress can be laid either on the event or on the activity. When the stress is laid on an event, the network is called Project Evaluation and Review Technique (PERT). Whereas, an activity oriented network is called Critical Path Method (CPM). Both are shown in *Fig* 5. The other main difference between CPM and PERT is that the former does not take into account the uncertainties involved in the estimation of time for the execution of activities while the PERT does. In other words in CPM, single estimation of time is considered while in PERT three-time estimation is invariably considered for an activity. Generally in building works, single-time estimation for any activity is considered, hence it is proposed to discuss the merits and limitations of CPM only.

Merits of critical path method — The critical path method of planning has the following merits over bar charts:

(*i*) When using CPM, the interrelationship of all operations is clearly seen, *Fig* 5. On the contrary the normal bar chart does not do this and consequently requires the dependence of one operation upon another to be remembered by the project manager. This is not only difficult, but almost impossible on large projects.

(*ii*) Using CPM in case of delays, critical operations require particular attention. However, when bar charts are used on a large project many activities tend to be 'crashed' unnecessarily as it is not possible to remember which activities are interdependent.

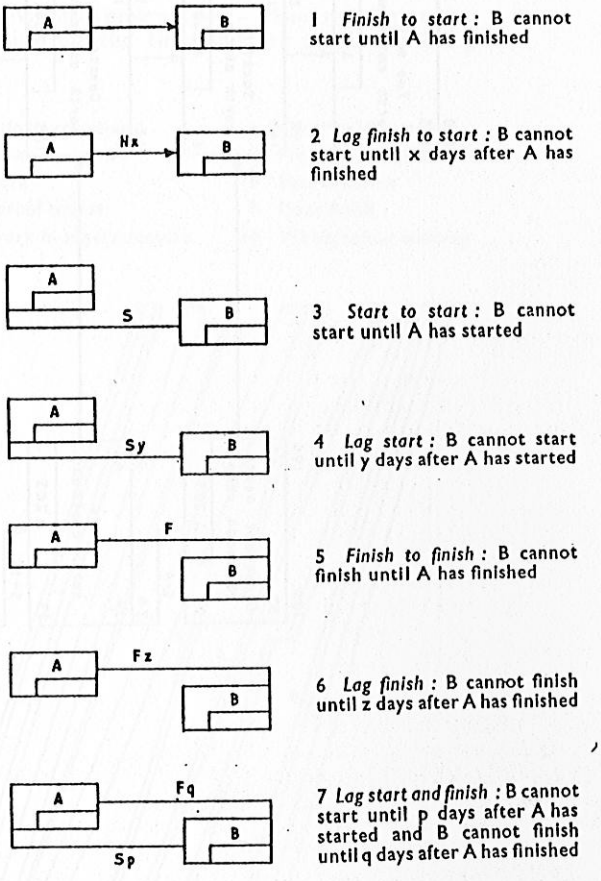


Fig 6 Unique logic conventions for precedence diagrams

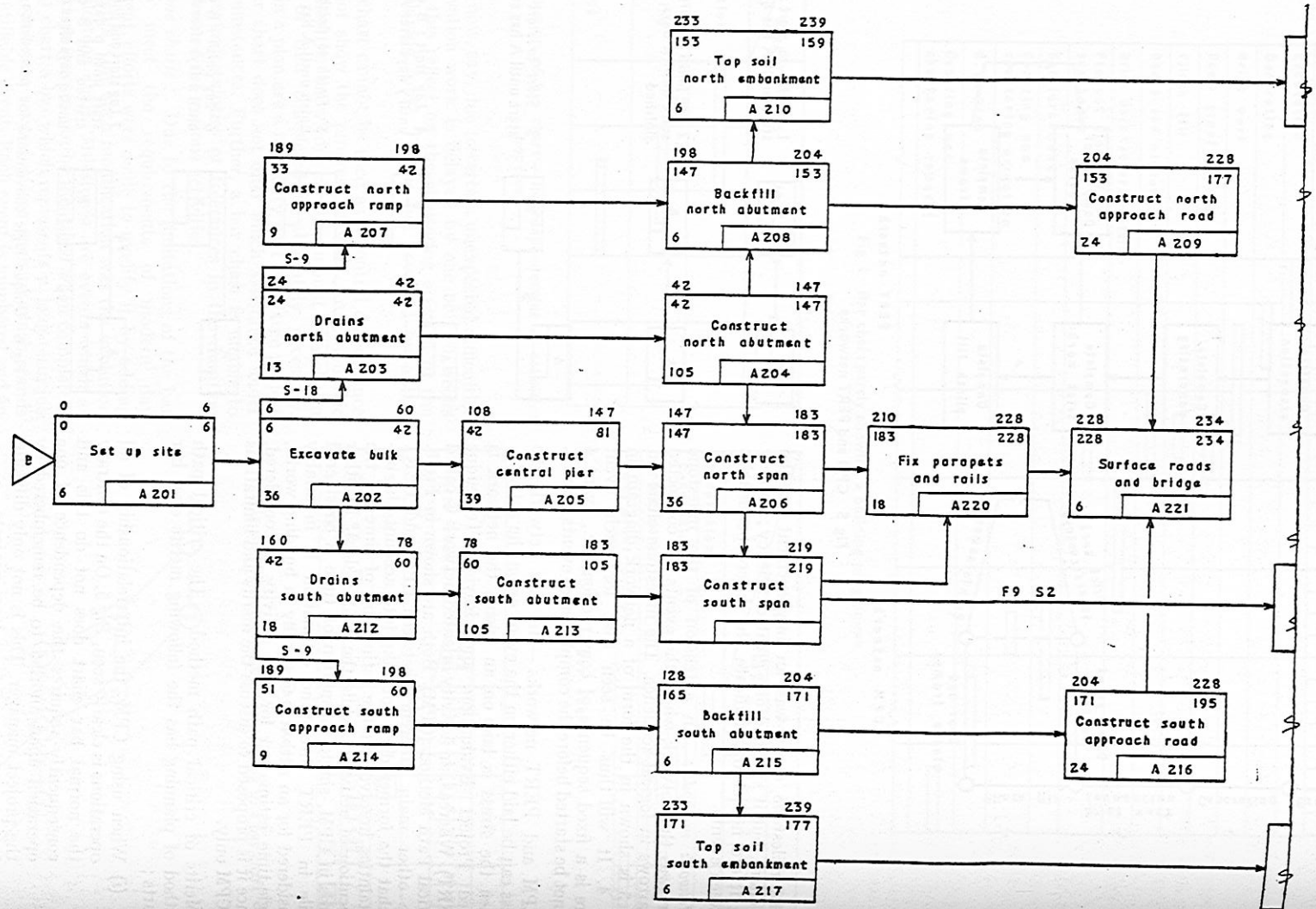


Fig 7 Precedence diagram for the construction of a bridge

(iii) Planning, analysing and scheduling are separated when using CPM. This allows a greater concentration on the planning aspect and thus leads to a clearer understanding of the project.

(iv) It is far easier for a new incumbent taking over a partially completed project to become familiar with the progress of the project if the CPM is used.

Limitations of CPM — The basic assumption in CPM is that the arrow diagram realistically represents the construction project. For various reasons this may not always be true because

(i) firstly, it is difficult to construct an arrow diagram which depicts every important sequencing relationship properly. Often it is easier to show two activities as sequential whereas, in fact, they overlap and should therefore, be broken down further. For example, concreting and laying brickwork in foundation, *Fig* 5 are shown dependent on each other. But brickwork can be started after laying concrete in certain section of foundation;

(ii) secondly, as planning and arrow-diagramming is done at the very early stages of the project, it is often impossible to foresee all eventualities and allow for them in the arrow diagram.

Networks using flow charts or precedence diagrams: Networks can be drawn in the form of flow charts, also known as precedence diagrams as an alternative method to a more conventional CPM network. When using these flow charts the activities are usually represented by rectangles and the relationship between activities is shown by a line linking them. Flow charts or precedence diagram networks eliminate the first limitation of CPM, since the sequencing relationship between various activities is done properly as will be seen in unique logic conventions, *Fig* 6. These are used in flow charts (precedence diagrams) networks.

The construction programme for a bridge in the form of precedence diagram is shown in *Fig* 7. It can be seen that various events are represented more rationally. For example events A202 and A203 indicate that the latter cannot start until 18 days after the former has started.

Line of balance technique: The line of balance, *Fig* 8 is a planning technique which is suitable for repetitive construction. The main advantage of this method is that it gives a better indication of the dependence of one activity on another. It is very useful during the progress of a project, because it is immediately obvious when corrective action needs to be taken.

Line of balance schedules are series of inclined bar-lines, one for each trade. The big difference between line of balance schedules and a traditional bar chart is that the schedules are inclined at different angles to denote the rate of working of the various trades, they thus clearly indicate the relationship of manpower allocation and speed of working of one trade against another, highlighting the risk of collision courses and unbalanced manpower allocation. Schedules can also be used to programme plant utilisation and materials delivery.

To provide a margin for error and to ensure that one trade does not interfere with another, time buffers are normally inserted between the trade schedules. The last schedule in the diagram, represents the handover schedule of the building components.

Requirements for success in planning techniques

There are certain essential requirements which should be adhered to in practice for the planning techniques to be successful. These are:

(i) Site personnel participation — Site personnel like engineers, supervisors, sub-contractors, suppliers, etc., should be encouraged to participate in the planning right from the initial stages to completion.

(ii) Knowledge of technique — The contractors and other personnel responsible for planning and implementation of programmes, should have adequate knowledge of the technique being used. For this it is suggested that refresher courses on planning techniques should be organised for field staff by universities, the National Building Organisation, the Central Building Research Institute and other organisations.

(iii) Practicability of programmes — The planning programmes should be practicable consistent with the resources that can be made available.

(iv) Filling up of deficiency — Actual progress should be reported at small intervals of time, say weekly or fortnightly and timely measures should be taken to fill up deficiencies, if any.

(v) Use of past performance — Experience gained in previous projects should be made use of in preparing any new programmes.

(vi) Planning cells — In the initial stages, organised departments should set up planning cells with adequate and appropriate experience to assist contractors in preparing workable programmes.

(vii) Support from higher level — It is essential to have the support of higher levels of management for adoption of modern planning techniques.

(viii) Revision of programme — Planning programmes need revision all the time and are constantly being

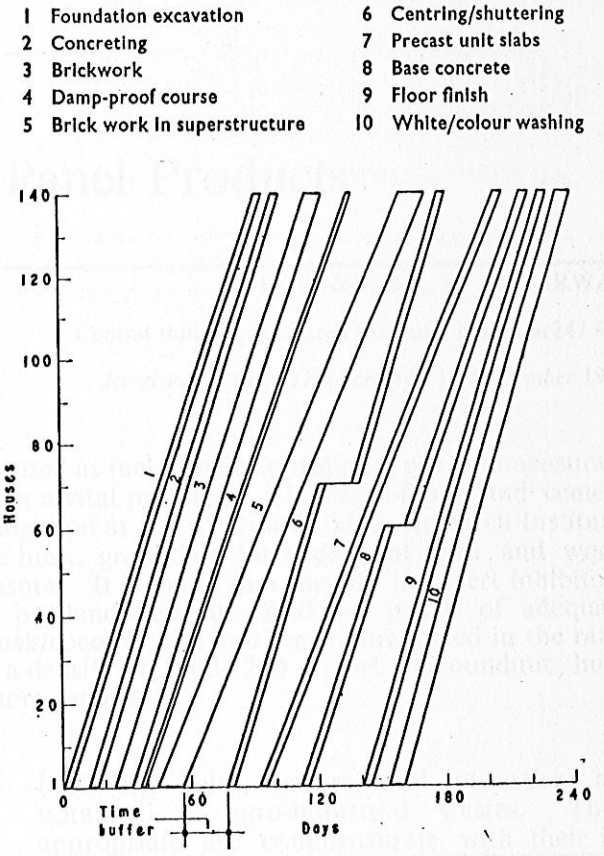


Fig 8 Line of balance programme for one hundred and forty houses showing schedules of critical activities

done so even in developed countries where these techniques are widely used. Such revisions should not be taken as failures, but should be considered in a positive manner, since based on experience gained in implementation, better workable programmes can be planned.

Conclusion

Bar and milestone charts have basic limitations as compared with CPM, precedence diagrams and line of balance method of planning techniques. For repetitive construction like those of housing, the line of balance method is most appropriate and its use should, therefore, be encouraged.

Participation of site personnel, adequate knowledge of techniques, practicability of programmes, use of past performance records, timely action for filling up deficiencies, setting up of planning cells, etc, are the essential factors for success in use of planning techniques and should therefore be given full consideration.

Acknowledgment

The authors are grateful to Dr S. K. Misra, Scientist Coordinator, for his valuable suggestions made in the course of preparation of the paper. The paper is published here by the kind permission of the Director, Central Building Research Institute, Roorkee.

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Printed and published by Col C. L. Proudfoot (Retd.) for The Concrete Association of India, a Division of The Associated Cement Companies Limited, at 'Cement House', 121, Maharshi Karve Road, Bombay 400 020 and printed at The Times of India Press, Bombay, India.