These columns of ICJ offer an opportunity to the engineering fraternity to express their views on the current practices in design, construction and management being followed in the industry.

To share your opinion with our readers, you may send in your inputs in about 1500 words via E-mail to editor@icjonline.com

IT-propelled value engineering in construction

V.N.Heggade

Value engineering is a methodology which tries to reduce cost by improving functionality through lesser consumption of energy. The author feels that information technology can integrate the compartmentalised nature of the construction industry and play the role of 'incredible facilitator or enabler' in both knowledge management and value engineering.

In the words of Alwin Toffler, the author of 'Third Wave' and 'Future Shock', the advancement of civilisation is categorised by three phases, namely, agricultural revolution, pre-industrial revolution and post-industrial revolution. The post-industrial revolution may be called as 'IT revolution'. Each revolution, made the life styles, behavioural aspects and human idiosyncrasies of the previous revolution obsolete and the rate of obsolescence is accelerated with successive revolutions.

While the impact of information technology (IT) revolution on aerospace engineering, manufacturing and process industries has been phenomenal in the last decade or so, the construction industry, despite being the second oldest profession of the world, largely remained outside the domain of application of digital technologies.

There is likely to be significant shift in the construction paradigm from the 'fast track construction" practised in the last decade to conservation of energy in terms of manpower, machinery, materials and money, as there is an apprehension that the inherent inadequacies of over consumption of energy that is invariably called for in the fast track construction may lead to premature deterioration of the structures. However, the nature of fast track construction has necessitated the use of IT in a fragmented manner in the organised construction sector.

The compartmentalised nature of tender, design, purchasing and construction process has given rise to 'islands of automation', in the construction industry. However, the envisaged paradigm shift to conservation of energy will warrant at each of the above process stages 'value engineering' propelled by 'knowledge management'. This is where IT can play the role of 'incredible facilitator or enabler' in both knowledge management and value engineering.

Value engineering

"Value engineering is a methodology used to analyse the function of the goods and services and to obtain the required functions of the user at the lowest total cost without reducing the necessary quality of performance"[1]. Many a time, value engineering (VE) is confused with cost cutting exercises in construction industry. The essential difference between conventional cost cutting and VE is that it involves reducing the cost by improving the functionality through lesser consumption of energy in terms of manpower, materials and machines.

In the initial stages VE was used by production engineers for reducing the cost of manufacture. However, it was found that the benefit of VE is much greater if multi-disciplinary teams of engineers were involved which would also influence the design team, that is normally the case in construction.

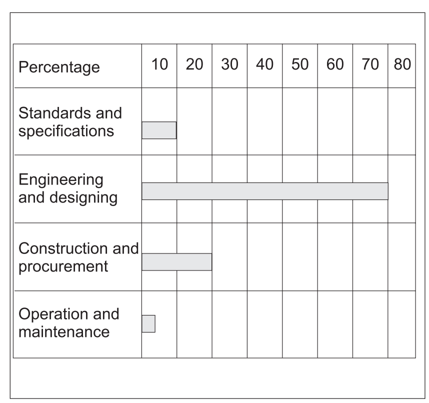


Fig 1 Influence on project cost generation

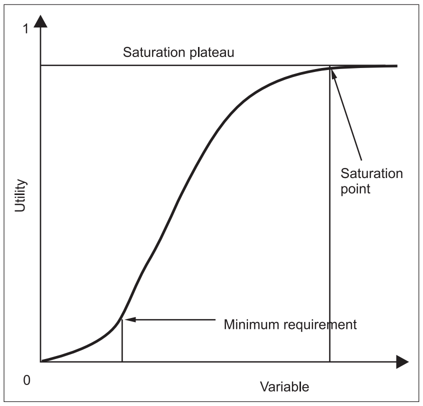


Fig 2 Law of diminishing returns[2]

Since the objective function of VE is reduction in cost, it is imperative to examine the cost generation pattern in the construction industry.

Fig 1 shows that in a typical construction project, 10 percent of the project cost is created by the agency's standards and specifications, 70 percent of the project cost is created by designing and engineering, 20 percent is generated by procurement of construction and perhaps rest is ideally due to maintenance. Ironically, even when 70 percent of the project cost is due to designing and engineering, the expenditure allocated for the design effort is the smallest.

It is of importance to recognise that by proper VE, there could be substantial savings, say to the tune of 20 percent of 70 percent of the project cost at engineering stage and 10 percent of 20 percent of the project cost at construction and procurement stage.

However, for VE to be effective, the design of the organisation structure shall be such that constant interaction between engineering, construction and procurement process is enabled and the approach should be "project-based design approach" (PBDA). As a consequence of mechanisation, the design of permanent structure is, to a large extent, dictated by the construction system and enabling structure design which has to be a specialised function in itself as the same calls for an understanding of plant and machinery. Thus, the currently practised 'design and build organisation" structure in premier organisations like Larsen & Toubro Ltd (L&T) and Gammon India Ltd (GIL), etc, is most suited for VE in construction projects. In the contracting firms where the engineering departments are not fully developed and have to depend upon outside consultants, VE is not practicable as the strength of different sections are not complemented with each other and there is a tendency for the contractor and consultant to position themselves on different sides of the divide.

Standards and specifications

Specifications are the description of the properties of the object being designed. They are usually expressed as numbers or measures. The design specifications articulate, in a numerical or measurable way, design requirements, which provide the basis for evaluating the targets in the design process.

The specifications formulated by the owners or consulting agencies, usually refers to the standards and codes. However, many times, it is observed that Indian standards and codes are on the conservative side and result in unnecessary waste. The dilemma of the code-makers is that they have to cater for both petty unqualified contractors and sophisticated contractors in a generalised manner. In such cases, it is always prudent to change certain clauses of the codes under the sections "Special conditions of the contract" keeping in view the profile of contractors participating in the construction project. This effort of VE has been successfully implemented by the Maharashtra State Road Development Corporation (MSRDC) recently in the construction of a series of flyovers in Mumbai, which resulted in unexpected reduction in cost of the flyovers.

The use of recent advances in construction technology and building materials in the design is illustrated by some of the following pioneering works in India wherein the author's company (GIL) was involved.

- Development of precast segmental cantilever construction practised in the seventies by GIL which is much more complicated than the presently practised span by span segmental constructions.
- The design and construction of first cable-stayed bridge in India (Akkar bridge in Sikkim) in the eighties.

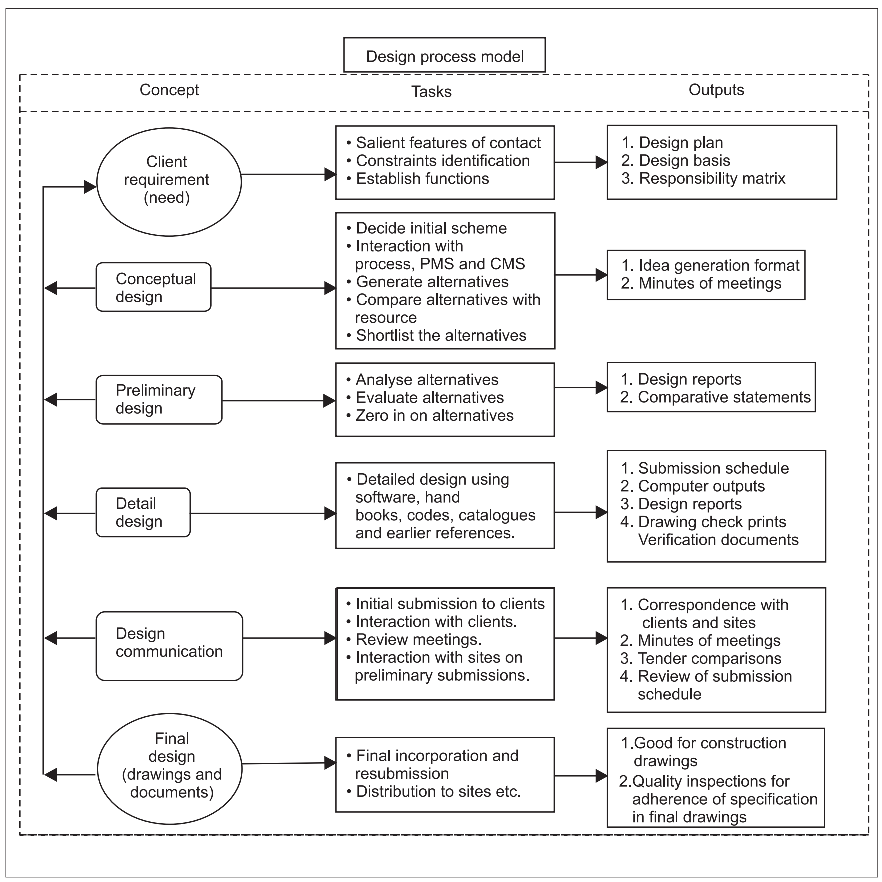


Fig 3 Design process model[2]

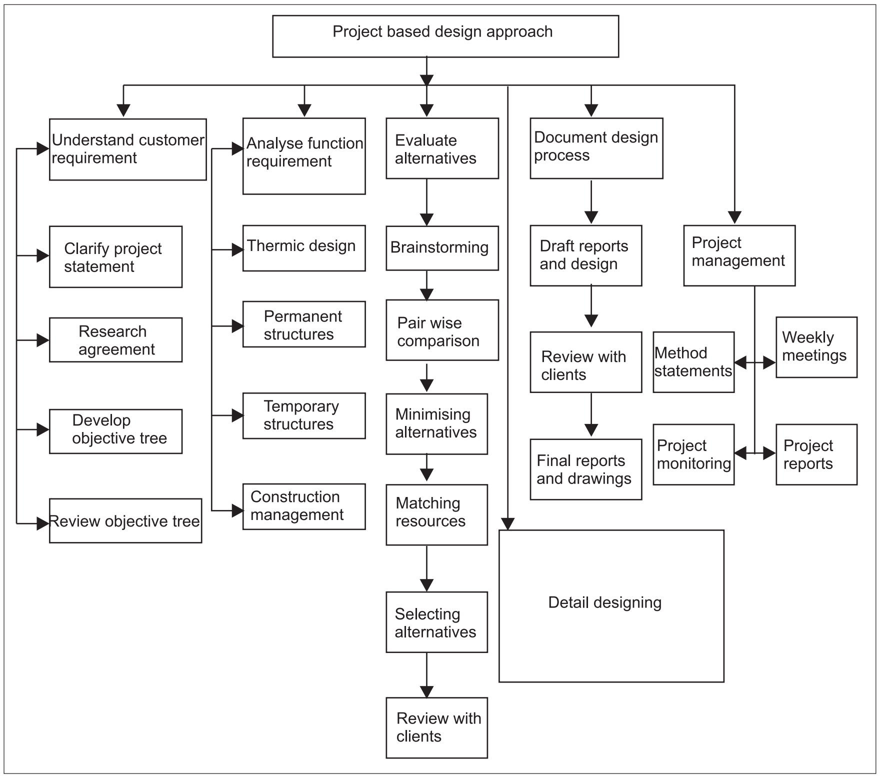


Fig 4 Project-based design approach[3]

- The externally prestressed cast in-situ bridge in Sringeri in the late eighties and precast segmental construction for Noida bridge.
- The use of high performance concrete (HPC) upto M 75 in JJ hospital flyover, Mumbai.

The Indian standards and codal provisions were not available for the particular type of construction when the above jobs were designed and executed.

The notions that the design leniency is overcome by superior mechanised construction abroad, and the potential constructional deficiencies have to be overcome by enforcing safeguards and higher factor of safety during specification formulation in our country have cost the country several millions of rupees.

Thus, determining a range over which a 'measure', 'factors of safeties (FOS)", or 'safeguard' is relevant to a design and deciding how much improvement is worthwhile is "value engineering". The futility of provision of more FOSs and other safeguards can be explained by the law of diminishing returns as shown in *Fig* 2.

In *Fig* 2 the utility or a value of a design gain is plotted on the vertical axis over a normalised range from '0' to '1'. The level or the cost of the attribute being measured is shown on the abscissa. For example, consider using cement content in the concrete. The cement content below 250 kg/m^3 of concrete will perhaps fail to produce required alkalinity around the reinforcement, which is required to resist corrosive deterioration of concrete. The cement content of more than 450 kg/m^3 of concrete does not help in improving the quality of the concrete and rather is vulnerable from cracking point of view. However, by increasing cement content from 250-kg/m^3 upto 450 kg/m^3 of concrete, the strength can be improved. This kind of behaviour where until some minimum level is realised, and also above the saturation plateau no meaningful benefit is obtained, is very much applicable to factors of safeties and other safeguards provided in "the specifications".

Detailed engineering

A typical "design process" to be adopted in any value engineered, design and build organisation is depicted in the design process model shown in *Fig* 3.

For effective VE to be carried out for each construction project, the project-based design approach (PBDA) is of paramount importance as shown in *Fig* 4.

After having understood the customer requirement, analysis of functional requirements are carried out and the departments to be involved like design, process, construction systems and execution are identified. In the design department, various alternatives are worked out through idea generation format and it is discussed in brainstorming session alongwith the other department involved, *Fig* 5.

The various alternatives are compared pair-wise, matching with the resources of construction system department and plants and machinery departments, such as whether any formworks, gantries, cranes and other plants suiting for the proposed construction is readily available and if not how the permanent structure design shall be changed to suit the available resources. After having brainstormed the various alternatives keeping the cost-reduction in view, a proposal is conceptualised. It is a universally recognised fact that the changes in design, once the concept is finalised increase the cost of the project exponentially. By the adoption of PBDA, the cost of the project is generally reduced at least by 15 to 20 percent of the cost generated by engineering due to the following reasons:

(i) Time saved in avoiding wrong alternatives in detailed design.

Alternatives	Feasibility	Constructibility	Resource availability	Duration	Cost implication	Total
1. Well foundation						
2. Pile foundation						
3. Open foundation						
4. Continuous beam						
5. Simply supported beam						
6.						
7.						
8.						

1. For the different alternatives, points are given out of 10 scale
2. Ideally option with the maximum number of points in 'Total' column shall be selected for the final proposal
3. However, normally minimum cost option is chosen

Fig 5 Idea generation format

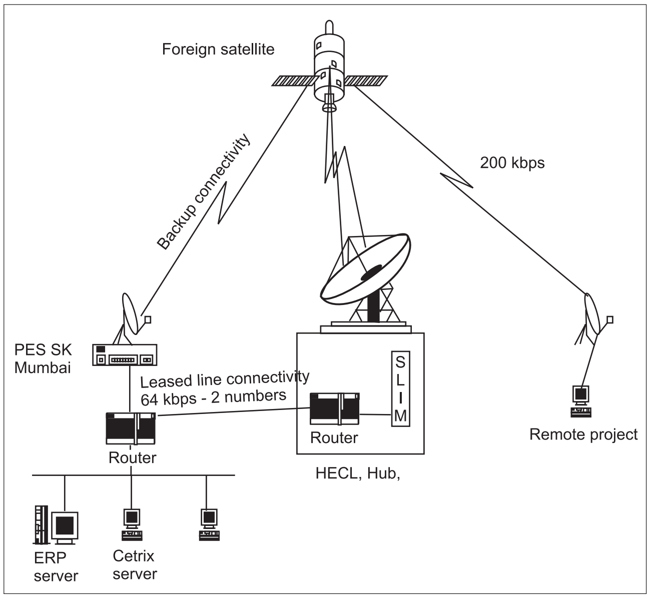


Fig 6 Connectivity using LAN

(ii) Transparency in decision making helps ensure the process is repeatable.

(iii) The ability to absorb the thought process of others is made feasible.

(iv) The designer can defend the decisions made in discussions with management and clients.

(v) Designers with no previous experience can carry out feasible evaluation of alternative concepts.

(vi) The process of concept selection stimulates new concepts or encourages combination of concepts.

The process of concept selection among the alternatives during the idea generation stage can involve various quantitative techniques like: criteria ranking and weighing in matrix form, datum method and decision trees based on probability, etc. Also, available formworks, staging material, launching and erection systems, plant and machinery, require a database, which should be easily available and retrievable to the concerned departments. This can be achieved by computerisation and networking across the company.

Procurement and construction

In a typical construction environment the various projects, which are at remote places, are controlled and monitored by project co-coordinators or integrators who are stationed at the headquarters. Each project is managed by a project manager supported by engineers, accounts and department stores. The construction process model enclosed at the end, explains the typical construction process involving various stages from planning to controlling.

The control budget is the only tool through which the project co-coordinator, stationed at headquarters, can use for reducing costs at sites. As soon as the job is secured, it is ideal that the project manager himself prepares the 'control budget' and 'cash flow' supported by project scheduling, ABC analysis, schedule of rates and rate analysis. Based on the schedule, it is normally the responsibility of the project co-coordinator stationed at headquarters to organise plants and equipment, materials, staffing, bought-out items and recoupment in time. Monitoring and controlling by way of corrective and preventive measures essential in this regard.

In the entire construction process, the documents, data and information has to flow from remotely located sites to headquarters, *Fig* 6, and thus information has to be processed to become knowledge for decision making using a local area network (LAN) across the different departments. The premier construction companies have gone in for enterprise information portal (EIP) and enterprise resource planning (ERP) programs for such integration.

However, as on date as a part of the EIP or ERP implementation, IT has been exploited to the extent of the mapping of the existing system and automating the same, which only helps in speedy access and retrievability of information or data. But the decision-making is deferred to judgement based on information and experience.

There is a large scope for utilising the data collected from various sites and integrated at headquarters, using quantitative techniques such as linear programming, learning curves, probability distribution (decision trees), waiting lines, quality control charts, work sampling and line of balance method, etc in construction industry.

If these quantitative techniques are complemented with judgement and experience, the quality of the decision-making gets enhanced culminating in considerable reduction in cost during the procurement and construction stage. *Fig* 7 encapsulates the construction process model.

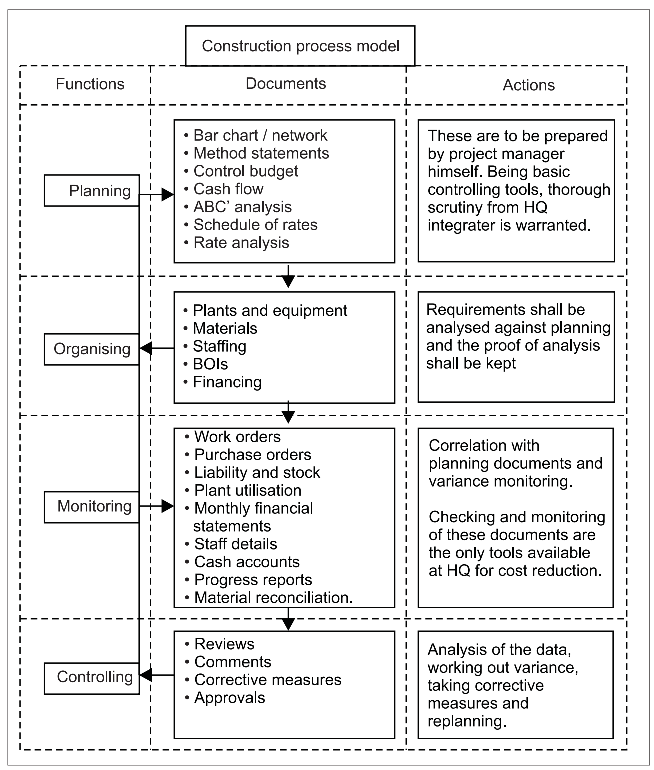


Fig 7 Construction process model

Conclusions

Use of IT in construction is a recent development. So far, its limited use created "islands of automation" especially at the headquarters level being supported by server based network. The popularity of any technology depends upon the economic considerations. IT-propelled VE will certainly help in reducing the cost of construction projects. Hitherto, IT was used for automating the existing system through which accessibility and retrievability of data was hastened, but not for imbibing quantitative techniques. Earlier the quantitative techniques were not popular in construction execution because of their inbuilt tedium. IT shall enable the use of quantitative techniques, which certainly will enhance the quality of decision making.

VE and cost creation pattern in construction projects reveal some interesting facts that need to be addressed at appropriate fora by decision-making authorities.

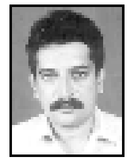
(i) The engineering and designing contribute to 70 percent of the project cost generation; VE exercise at this stage may save up to 15 percent of the 70 percent project cost. However the expenditure budgeted for the same in terms of capital layout and remuneration is meagre, thereby reducing the quality.

(ii) There is an urgent need for designers and code makers to catch up with the advances made in the construction technology and building materials in the country. The notion that the potential construction deficiencies have to be made up by provision of higher FOSs and other safe guards is no longer applicable and in fact are resulting in uneconomical and in aesthetic structures.

(iii) For successful implementation of VE, design and build contracts, and organisation structures have to be encouraged.

References

1. HURST, KEN *Engineering Design Principles*, John Wiley & Sons. Inc.
2. DYM, CLIVE. L. and LITTLE, PATTRIK, *Engineering Design-A Project Based Introduction*, John Wiley & Sons. Inc.
3. HEGGADE, V.N. Raichur natural draught cooling towers - Units 5 and 6, *Journal of Indian Concrete Institute*, July-September 2000, Vol 1, No 2.
4. REDDI, S. A. Value Engineering and cable stayed bridges, *Proceedings of International Conference of Indian Institute of Bridge Engineering*, 19-21, November, 1999, Hyderabad.
5. REDDI, S. A. Value engineering for bridge projects, *Conference PrOceedings of Advances and Innovations in Bridge Engineering*, Indian Institute of Technology Madras, August 1999, Chennai.
6. HEGGADE, V.N. Systems approach to durable concrete (An obvious solution), *National Seminar on Concrete for Infrastructure*, Indian Concrete Institute (Mumbai Chapter), October 22-24, 1999, Mumbai.



Mr V.N. Heggade has around 18 years experience in designing bridges, aqueducts, industrial structures and marine structures, in addition to construction management, including site execution, as project manager. Presently, Mr Heggade is the deputy general manager of Gammon India limited and heads its technical management section. He is a member of various national and international institutions.

• • •