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Application of Value Engineering in Construction Projects

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Abstract: The current economic conditions have entailed the use of rational method and techniques and research and application of new techniques by utilizing advancements in technology in the field of production as well as in every field. Excess cost control requires to be maintained throughout the project life of building beginning from the initial stages of design. Scrutinizing the project well and considering all possible alternatives particularly in design stage are important for achieving optimum cost. In this study, how the principles of VE (value engineering) are applied in construction projects is explained, and by covering Bregana-Zagreb-Dubrovnik Motorway construction in Croatia by BECHTEL – ENKA joint venture as the sample project, practices of VE in this project are described. The satisfactory results of time and cost saving are achieved by applying value engineering principles through the VE team during the project preparation phase and project revision phase. Approximately 43,000,000$ and 12 months of time were saved in total thanks to all these VE works. This saving provided builder company with 6% financial saving and 17% work time reduction.

Key words: Value engineering, value management, motorway construction.

1. Introduction

VE (value engineering) was developed at General Electric Corp. during World War II and is widely used in industry and government, particularly in areas such as defense, transportation, construction and healthcare. VE is an effective technique for reducing costs, increasing productivity and improving quality. It can be applied to hardware and software; development, production and manufacturing; specifications, standards, contract requirements and other acquisition program documentation; and facilities design and construction. VE is defined as "an analysis of the functions of a program, project, system, product, item of equipment, building, facility, service or supply of an executive agency, performed by qualified agency or contractor personnel, directed at improving performance, reliability, quality, safety and life cycle costs". It may be successfully introduced at any point in the life-cycle of products, systems, or procedures. VE is a technique directed toward analyzing the functions of an item or process to determine "best value", or the best relationship between worth and cost. In other words, "best value" is represented by an item or process that consistently performs the required basic function and has the lowest life-cycle cost. In this context, the application of VE in facilities construction can yield a better value when construction is approached in a manner that incorporates environmentally-sound and energy-efficient practices and materials.

Because "costs" are measurable, "cost reduction" is often thought of as the sole criterion for a VE application and indeed it is primarily addressed in this document. However, the real objective of VE is "value improvement" and that may not result in an immediate cost reduction [1].

VE is a systematic, low-cost approach to assessing the "value" of a project. Typically, VE on projects can be used to gain the following benefits [2]:

- cost reductions;
- time savings (schedule savings);

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- quality improvements;
- isolation of design deficiencies.

The paper of Kemmochi and Koizumi [3] demonstrates that aspects and issues of VE in construction industry by comparing with manufacturing industry and combating these, VE implemented in construction industry must be succinct and propose methods to conduct VE from the viewpoint of construction industry. In a study prepared by Naderpajouh and Afshar [4], a conceptual expert CBR (case-based reasoning) framework is introduced in the paper to form a coherent basis for the provision of practically suitable VE expert models. The proposed framework outlines knowledge entities and their relations in the VE workshop. The model benefits from a fuzzy approach to handle uncertainties in the evaluation phase of the methodology. In the another study, focusing on one component of the ICD (integrated collaborative design) project, the paper reviews existing, reactive value engineering methods and establishes the need for an integrated approach by identifying their inadequacies. A value management context is described which integrates value engineering into continuous design processes. The paper discusses the opportunities for utilizing supplier design expertise by modelling design process information flows [5]. The paper prepared by Palmer and other [6] makes a holistic appraisal of value engineering as used in the United States of America's construction industry by investigating current theory and practice. It evaluates value engineering projects and calculates the savings achieved by them. Omigbodun's paper examines how value engineering contributes to the process of obtaining an optimal solution to the design problem of a building project [7]. Cost minimization in building construction is discussed with examples from the writer's experience on building projects in West Africa and the Middle East.

VE is not cost cutting. VE is a systematic method to improve the "value" of goods or products and services by using an examination of function [8]. Value, as defined, is the ratio of function to cost (Eq. (1)). Value can, therefore, be increased by either improving the function or reducing the cost.

$$\text{Value} = \frac{\text{Function (desired performance)}}{\text{Overall costs}} \quad (1)$$

Reasons for poor value can be that: lack of information, decisions based on wrong beliefs, habitual thinking, negative attitudes, reluctance to seek advice, shortage of time, changing technology, lack of a yardstick for measuring value, old specifications and poor human relations.

Value engineering gets closer to cost control because it looks at ways to reduce costs on specific items or activities. However, it does not look at the total project picture or check the daily performance, it focuses only on specific items in the design, procurement or construction area.

2. Methodology and Approach

VE Job Plan consists of the following sequential phases (Fig. 1).

The value methodology is a systematic process following the Job Plan [2] and is applied by a multidisciplinary team to improve the value of a project through the analysis of functions.

The team leader should have completed at least a 40-hour VE training study and should have additional VE experience as a team member of VE Project studies. Other team members should have attended a one-day VE orientation course prior to being assigned to a team, or alternatively the study may start with a planned one-day VE orientation [9].

3. When to Apply Value Engineering

VE should be performed as early as possible—before commitment of funds approval of systems, services, or design—to maximize results [8]. Contribution of potential savings from VE applications is much greater at earlier stages of a project, as illustrated in Fig. 2. When VE is applied

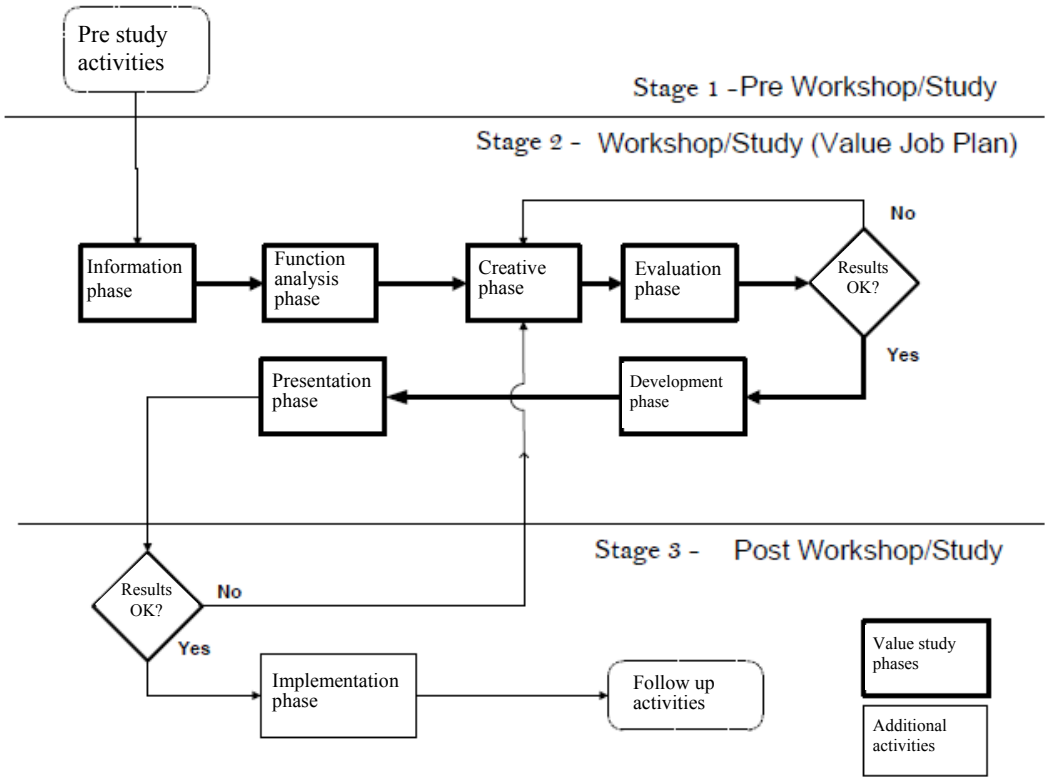

Fig. 1 The job plan [2].

later, two things increase: the investment required to implement any changes and resistance to changes.

VE is neither just good engineering, nor a suggestion programme, nor a routine project or plan review; it is carried out in independent analysis of the project. It must be recognized that VE entails a certain amount of additional expense that must be justified by potential cost saving. Accordingly, the need for a change in criteria, concepts, or plans must be recognized. A distinct opportunity for financial rewards in terms of life-cycle cost savings must warrant the added project engineering cost of a VE effort.

4. Usage of VE in Construction Sector

Companies in the construction sector have a better chance of getting jobs when they use the resources of the country in which they work reasonably, keep their costs at the lowest level and decrease their offer price in comparison with their rivals [10]. But the low offer price is not the only factor for a specific company to get the job. Project must have a high "value". Value has different meanings for the producing company, owner, user or the designer. The builder company tries to finish the construction with the lowest cost to obtain high profit. Owner wants to get the biggest income from the building. User wants to be able to perform his works easily, while the designer gives more importance to his creation's aesthetics or functions.

Purpose, time, quality and cost of every activity that will be realized during the construction process must be determined or estimated beforehand. Owner or user wants to know which feature they will have after the building is completed and with what cost they will have it.

Because construction process has many components such as concept, design and drawing details of the project, construction etc., and it is a long-term production, the risk of completion of construction in time, based on the estimated costs (first investment + usage cost) by providing features

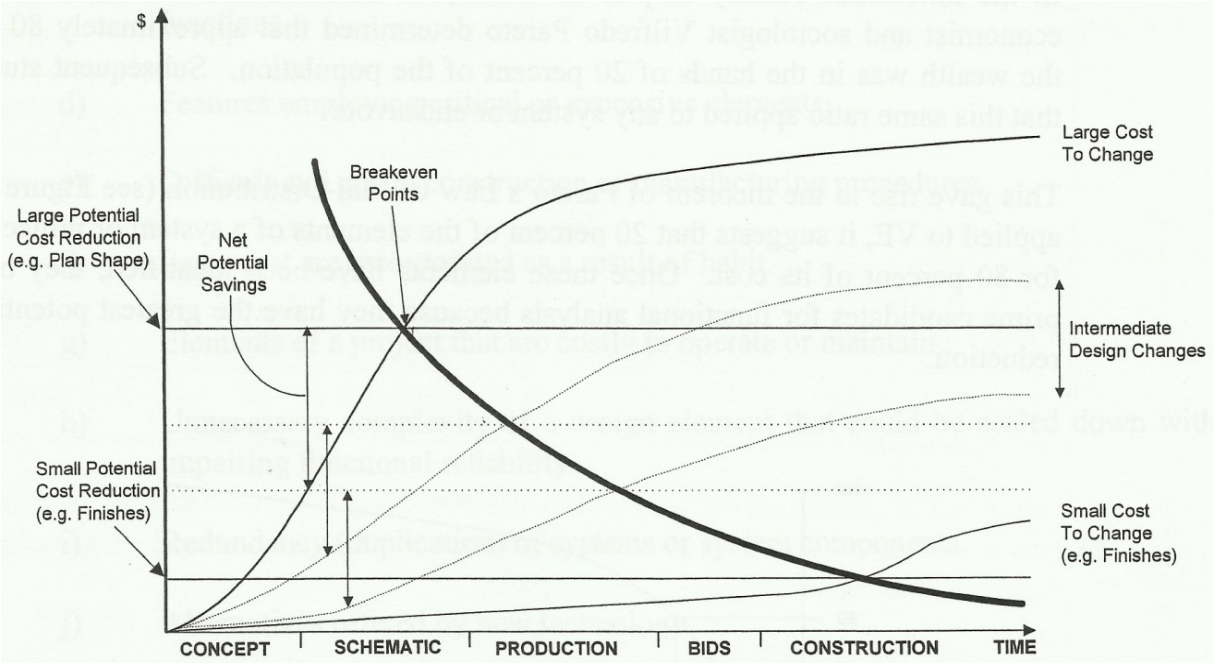

Fig. 2 Potential savings from VE applications [9].

such as quality, durability, usefulness, continuity, feasibility, compliance, image and management convenience, increases.

Suitable precautions are taken by predetermination of problematic areas via various project plannings and scheduling techniques. But none of these methods includes an examination in terms of the "value". After a building is completed or during the construction stage, comparing the building value with the costs that occur during its construction is not thought about. Although many buildings were built with high costs, desired functions were not provided. There is absolutely no direct proportion between a building's costs and provided benefits. In value engineering rationalist evaluation techniques are used considering the target features, and unnecessary costs are determined to be eliminated from the project, so that a building's value is increased and resources (money, material and workforce) are not wasted.

Some methods that increase the value in construction sector are explained as follows.

4.1 Reducing Construction Production Costs

In constructions, especially in functions with high production costs, the costs can be reduced without sacrificing construction's quality or disregarding customer's requests, by using different materials and/or different methods.

Materials, equipments and stipulated production methods in the specification and projects may become old according to current day or be out of date. In case the suggestion of the contractor for making changes is accepted by the employer, a much more economical solution will be provided for both sides. Carrying out production with better quality by using the suggested methods, in other words improving the quality may be a more economical solution [11].

4.2 Finishing the Job before Time Schedule

Finishing the job earlier provides economical benefits in term of reducing general costs. By comparing the cost of job acceleration and the reduced general costs, it can be decided to complete the job earlier.

It may not be necessary to accelerate the production speed to finish a job earlier. It may be possible to start earlier.

For such a condition to exist, these conditions may

be considered to happen:

- finishing the project designing before the schedule, especially for the jobs at the beginning;
- having the units ready in the worksite for usage beforehand, which are necessary for operation;
- obtaining necessary construction permits and making construction site deliveries before the delivery of projects which are necessary to start the job earlier;
- providing pre-financing before advance payment;
- having the necessary personnel ready for the start-up in a short time at the worksite;
- using a subcontractor at the start of the job if necessary.

Usually, finishing the job earlier results in additional costs. The additional cost should be less than the cost reduction in total due to finishing the job earlier. Finishing the job earlier as the result of scheduling to an earlier date with the decision of management is out of the scope of value engineering. In case of such a demand, the contractor will have right to claim.

4.3 Quality Improvement and Correction

Quality and value are related with each other one-to-one. Job is not being in compliance in terms of own quality of production and measurement tolerances as defined by the specifications results in these, in general terms:

(1) In terms of production quality:

- determination of project drawing/production and repair method for reconstruction or repair of defects that occur in productions within guarantee period;
- realization of product repair/reconstruction;
- giving guarantee period for performed repair process/reconstruction.

(2) In terms of measurement tolerances:

- reconstruction of products with the abovementioned methods;
- reconstruction of products that are damaged because of reconstruction process;
- In case the mistakes are out of tolerance values but very close to such values, product can be accepted by the employer. But there may be deductions for last payments in return for excellence in addition to acceptance approval in the quality control minutes. The amounts deducted in return for excellence can be huge.

As it can be understood from the results, additional costs with significant amounts can be in question. Moreover, company will experience a loss of prestige. The most economical production is the production carried out at the quality level demanded on the specifications.

4.4 Reducing Mistakes and Deficiencies in Project Drawings to Minimum

Quality of the projects is one of the factors that affect construction's quality most. The effect of the projects with errors which are not suitable for application on the construction process is negative, while projects without errors or with small errors are suitable for application have positive effect at the same force. It is obligatory to control the drawn projects during the phase of drawing and before the application. One of the methods, applied to reducing project design and drawing errors to minimum or zero is designing three dimensional projects. Therefore, the mistakes, which may occur in the architecture or carrying system, will be prevented from the start.

Thanks to some of the current computer programmes, three dimensional drawings can be prepared and with material and unit definitions, quantity lists can be obtained automatically based on these drawings in order to determine material quantities to be used, with zero mistakes.

One of the methods reducing project preparation time to minimum is simultaneous engineering application. In simultaneous engineering, it is taken as a basis to simultaneously form the projects, which are formed classically with consecutive stages and with the participation of all project partners. So that the mistakes in project drawing can be prevented and time

will be saved by avoiding making returns to previous stages because of project mistakes.

Material and measurement tables in the sheets shall be prepared without any mistake as they are the most important guides for the works of implementers. Reinforced concrete iron lists, tables taken as a basis for topographic works, excavation-filling diagrams steel production sheets and tables can be shown as examples.

Using the most economical sizes and systems for construction elements during project designing, contributes to reach suitable values in terms of costs. With this purpose, optimization methods that minimize construction costs can be used during the design.

5. Changes in Croatia Highway Project to Accelerate the Job and to Reduce the Costs

In this publication, the VE works carried out during the application of Croatia Highway Project, the joint venture between BECHTEL Company from USA and ENKA from Turkey will be explained. The related project was carried out at two different routes:

Section I: Between Bregana - Zagreb (Jankomir) (Fig. 3). In this route the existing old road was repaired and reconstructed in some areas.

Section II: Because the Section II was not constructed by BECHTEL-ENKA joint venture, details of Section II can not be given. Section III: Here, a new road was made between Basilijevo-Otocac-Sveti Rok (Fig. 4).

Value engineering studies were carried out for various activities in Croatia Highway Project. The information about at what degree some activities accelerated the job and how much cost benefit was obtained is written below. The information on provided time and costs for some activities is not given. Because the related activities are VE studies that are carried out during project preparation stage. Project time and costs provided at the beginning were determined considering the effects of these studies. The activities for which time and cost reduction information is provided are VE studies that are carried out after the project began.

These are the activities that reduce the costs and accelerate the jobs applied on Croatia Highway Project:

The length of climbing forms used on viaduct feet are produced 4 m as standard. The climbing forms were produced as 5 m instead of 4 m by placing special

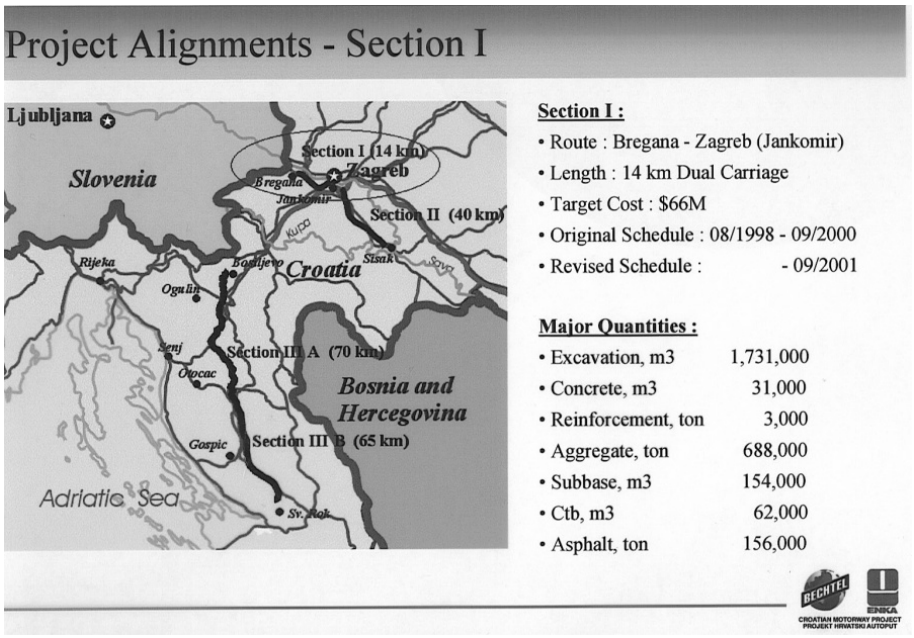

Fig. 3 Croatia highway project: Route 1.

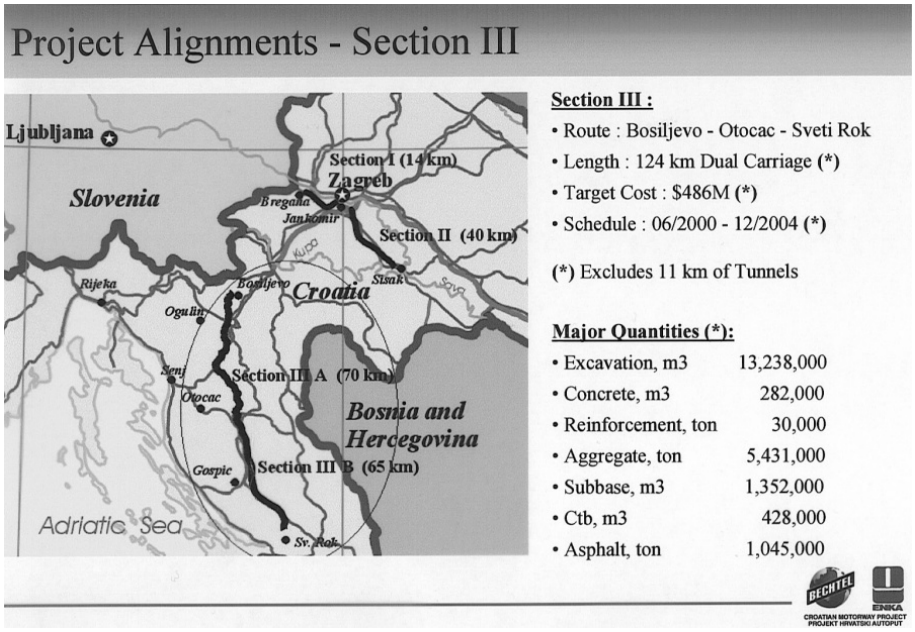

Fig. 4 Croatia highway project: route 2.

order to production company for this project (Fig. 5). As the number of viaducts is high along the way, the special production's cost loss is at a degree that can be ignored. By bringing the length of climbing forms to 5 m, molding workmanship and iron workmanship amount was reduced and job speed increased. Also, iron overlapping number is reduced, which provided savings for the production company. Obtained total cost benefit is $40,000 and construction time was reduced about one month.

A serious time reduction was provided by making germination with spraying method instead of vegetal earth and germination in splits and fillings.

Time is saved without price change by making supporting wall instead of gabion which requires long production time.

In two bridges with 60 m of opening which require special girder production, $200,000 cost reduction is obtained by using hammer beam (Fig. 6) and production time was shortened for one month.

In the area where two bridges were built which was critical in terms of job schedule, elevation is reduced for shortening and, therefore, production time was reduced. This situation made it possible to carry out earth works faster, with shorter transportation distance. The reduction in job amount provided the construction company with $1,200,000 cost saving and job's time was reduced about two months.

As required by the production method of concrete channels on both sides of the road, it had to be done before asphalt works. In this project, the places where channel was needed to be made were separated by using cold joints, therefore asphalt works were carried out beforehand without waiting for the production of concrete channels and job was accelerated.PEHD (polyethylene high density) pipe system works were carried out instead of concrete pipe system

Fig. 5 Usage of climbing form in construction of viaduct feet [11].

Fig. 6 Hammer beam application on the bridge [11].

for drainage systems with pipe (Fig. 7). Thanks to applied method, a significant reduction was obtained in drainage works which last long and therefore the following works became faster.

Two wild animal passages were built as cast-in-place concrete arch instead of prefabricated building to reduce high cost due to distance of transportation and $1,540,000 cost-saving was provided (Fig. 8).

The length of Modruš Bridge whose length reached 2,500 m was built as three separate bridges according to change of profile length, and total length was shortened for 850 m. Thanks to this change, the production time was shortened for four months and the construction company obtained $24,500,000 profit.

The open tunnel whose length reached 440 m was completely cancelled as the result of changing the horizontal and vertical routes, and 75,000 m^3 concrete was saved. As the result of this change, $15,400,000 cost benefit was obtained and the required job time was shortened for four months.

Emergency stop lanes are not used much, therefore, they are exposed to less corrosion, consequently different types of asphalt were used for emergency stop lanes and main road. Asphalts of these two types of lanes are applied separately by leaving cold joint. Emergency stop lanes are not continuous, therefore requires turning back which results in time losses. In this project, two separate asphalt facilities were used for different asphalt types and production was carried out simultaneously (Fig. 9). Therefore, quality was increased while workmanship was reduced by saving elastic band, cleaning and necessary cutting processes for cold joint production.

6. Results

Competition among the companies in construction sector increases day by day. Companies in competition are addressing their customers with innovations, conveniences, low prices and quality to

Fig. 7 Application of PEHD pipe system in drainage works [11].

Fig. 8 Passage-bridge construction for the passage of wild animals [11].

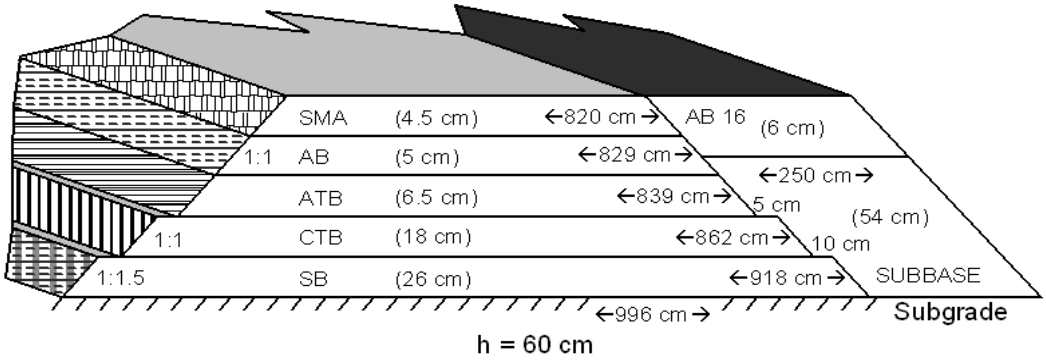

Fig. 9 Highway upper structure section example.

SMA : special mastic asphalt;
AB : asphalt binder / binder;
ATB : asphalt treated base;
CTB : cement treated base.
SB : subbase.

compete with each other. But these mentioned factors are not creating sharp steps for competition, as they are subject to laws, standards and specifications. VE is one of the leading methods for competition by getting free from these elements. VE application directly affects each element in quality-time-cost triangle.

In this project, approximately $43,000,000 and 12 months of time were saved in total thanks to all these VE works. This saving provided builder company with 6% financial saving and 17% work time reduction.

All of the changes were carried out according to demands of field directorates controlled by project manager, technical examination of engineering director and approval of the management. Subject concerns whole technical management.

7. Conclusions

Success of a project, deciding on where and how a project will be built, completion of the structure according to desired design and building quality, within determined time and cost limits, are all possible with good estimations and solutions. Realism of estimations is completely in direct proportion to success. Carrying out correct estimations is closely based on the knowledge level of the team. Value engineer assumes regulating and analyzing duties to increase the value of the project while preventing unnecessary costs.

It is not possible to apply VE on each project a company produces. Much more successful value engineering studies can be carried out on complex and big projects which have high potential of restoring the investment. Of course value engineering works have a cost, therefore this project shall be big enough to meet this cost and obtain profit.

The purpose of value engineering is not just reducing the costs, increasing the design standards, making it easier to build the project and saving time and money. VE must create a balance between all the needs of the project.

Purpose of VE shall be determined in direction of company purposes. Every person that joins for VE shall be embraced. There should be no one in the team who thinks in the opposite of project management, or who is suspicious in the benefits of VE.

The highest performance in VE is achieved especially when the purpose is mainly increasing the value rather than reducing the costs.

Production methods developed with VE are carried out to reduce the costs of a product without sacrificing the quality, keeping the cost fixed by increasing the quality or shortening the production time. It shall be never forgotten that VE works are not just the savings

of contractor but also savings that are made in the project in direction of the contractor's and the customer's interests. Contractor's own saving is a kind of economical saving.

When the projects in the world are taken into account for which VE is used; we can see that most of them are applied on civil engineering constructions. Because analyses show that contribution of potential savings from VE applications is much greater at earlier stages of a project. For example, USA Highway Administration added VE into their specifications as an obligation.

When VE applications are regularly carried out in Turkish construction sector, it will be seen that the competition between the companies will increase and prices will become lower. More importantly, systematic working and the quality will increase in addition to them. When contractor quality and customer satisfaction increase, Turkish civil engineering sector will be able to advance much further.

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