Teaching value engineering as a tool for reinforcing applied creativity in a troubled AEC/FM industry: A case of Zambia

Teaching Value Engineering as a Tool for Reinforcing Applied Creativity In a Troubled AEC/FM Industry*: A case of Zambia.*

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Abstract

Conventional design methods that are taught to Engineers do not always take into account the practical constraints associated with resource availability and costs. For example a proposed community self-help constructed facility in rural Zambia, such as a bridge, could result in a reinforced concrete solution, because concrete and steel have always been associated with such structures. The availability and cost of 'usual' materials, in this example, concrete and steel, play a pivotal role in the success and or failure of the delivery of the much needed constructed facilities.

Value Engineering takes a component level approach that addresses practical constraints associated with resource availability and cost. This paper describes an educational requirement specification for engineering curriculum in developing countries that incorporate value engineering techniques as a means of addressing practical design constraints related to Architecture, Engineering, Construction and Facilities Management projects. It further points out areas in the building product lifecycle where various disciplines of construction, are expected to create innovative and robust solutions that suit local conditions.

Key Words: Value Engineering (VE), Architecture Construction, Engineering, Facilities Management, and AEC/FM Zambia.

1.00 Introduction

In a world of changing technologies, transforming economies, shifting demographics and ever-dynamic environment (De Wit and Meyer 1998, 237) business performance plays a pivotal role in fulfilling customer needs. The business of construction in Zambia has not performed well, as can be observed by the infrastructure backlog nation wide (NRB 2003, MPU 2003, Mupuchi 2003). Demand [*expressed as a broad definition of `fit for purpose' that not only concerns the customer, but also implies building stock and societal requirements, including economic criteria (Hendriks and Van der Linden 2003)]* for basic built products such as roads and bridges, water and sanitation facilities, clinics and schools, and sporting facilities is on the increase while supply has largely remained low and unpredictable. Like any worldwide industry, construction expects engineering and building science graduates to be well vest in a myriad of subjects, spanning not only the engineering world of things, but also business, legal, economic and social issues, so that their designs may be exposed to humanities (Cleary and Sun 2003, 52). This meets the construction market requirement of a graduate with highly specialized competencies, critical and analytical thinking skills, and a broad understanding of ones discipline (Popescu and Popescu, 2003, 40). However, the fact that construction has had a negative impact on the welfare of ordinary people (Mupuchi 2003) and the dynamic nature of the business environment demand swift modifications to the education of building students so as to equip them with the evolving challenges (Ibid 2003, 44).

This paper uses a combination of objective and historical research methods to highlight design pitfalls in selected projects as a basis to propose teaching Value Engineering as a tool to address practical constraints associated with resource availability and cost.

2.00 AEC/FM Education in Zambia

A brief history on Engineering education indicates that the University of Zambia commenced engineering training in various disciplines in 1969, at the Great East Road campus. By 1981 the school of the Built Environments was established at the Riverside campus, Kitwe; where Architects and Engineers, *herein called designers*, Quantity Surveyors, Planners and Land Economy Surveyors, *herein collectively called builders,* have been trained since then.

Trades workers are trained at various trade's schools around Zambia. However, there are established national institutions such as the Roads Training School (RTS) that help in the training of local based contractors and other participants of the industry (NRB 2003). For three and half decades the AEC/FM industry has been supplied by thousands of professionals from these institutions. The real values that designers and builders offer to their clients are fundamental technical knowledge, expertise, innovation, initiative, and experience – in other words "brainpower". Plans and specifications, as currently developed, merely are the means of communicating their ideas and concepts (Holness 2003, 24) By no means does this paper strive to investigate the existing curriculum of learning institutions and how they have trained their graduates. However, a read on the plans and specifications for past projects was used to appraise construction education.

2.10 The Production Process of Built Products AEC/FM

Stubbs, O'Brien and Havers (1996, A1-3) reasoned that the production process, usually called ' construction project delivery system' is largely dependent on the stream of time it is being produced (E.g. 6th Century BC or 21st Century), the type of the product, the market structure or regulations of the industry where it is to be produced and the owner / business relationship preferences with the producer. A general rule though is that the production process of the built environment products involve a systematic approach to product delivery, comprising a rational, orderly series of steps that leads to the decision for a given set of conditions (Merritt, Loftin and Ricketts 1996, 1.20). A systematic approach is valuable for routine activities that need to be efficiently organised, for example production, but not suitable for non-routine activities – that is, for doing new things such as innovation (De Wit and Meyer 1998, 155). There exists an organised system of production in the Zambian construction industry.

3.00 Value and the Built Environment Products

Allen (2001, 1557) defines the word value as a fair return or equivalent for something exchanged; *the relative worth, utility or importance of something.* Dell'Isola (1999, xix) defines value as the relationship between function, quality and cost.

The word build means to construct (something) by putting together materials gradually into a composite whole (Allen 2001, 180), while a product is something made that can be sold, produced by a natural or artificial process. A building can therefore be said to be a built product. The user(s) or owner(s) can also call it a value product if its relative worth meets the approval of their set parameters.

3.10 Value Engineering Theory

The theory explained in this paper does not cover the full knowledge one needs to apply value engineering (VE). It merely covers aspects that enable first time readers of VE to appreciate the reasoning behind the paper. According to Mudge (1971,5), value engineering is the systematic application of recognised techniques which identify function of a product or service, establish a monetary value for that function, and provide the necessary function, reliability at the lowest overall cost. An organised process with an impressive history of improving value and quality because it identifies opportunities to remove unnecessary costs while assuring that quality, reliability, performance and other critical factors will meet or exceed the customer's expectation (Dell'Isola 1999,xii).

Value engineering can therefore be subdivided in three components:

- The systematic application of recognised techniques which *identify function of the product or service;*
- An organised effort directed at *analysing the functions of goods and services to achieve those necessary functions* and essential characteristics in the most profitable manner;
- A technique of *removing unnecessary costs while assuring that quality, reliability, performance and other critical factor*s will meet and/or exceed the customer's expectations.

3.20 Origins of Value Engineering

According to Palmer *et al* (1996, 324) value engineering was developed during the Second World War in the United States of America. It began as a search for alternative product components, a shortage of which had developed as a result of the war. Due to the war, however, these alternative components were often equally unavailable. This led to a search not *for alternative components* but *to a means of fulfilling the function of the component by an alternative method.* It was later discovered that this process of '***functional analysis***' produced low cost products, without reducing quality. After the war, the system was maintained as a means of both removing the *unnecessary cost* from the product and improving design.

In a bid to find substitutes that could provide equal or better performance at a lower cost, Lawrence Miles came up with a system called *value analysis* (Kelly 1993,8). Because value analysis, from inception, could serve in assorted branches of enterprise such as engineering, manufacturing and management, the US department of Defence Bureau of ships used the technique and renamed it value engineering, embracing it in their quest to eliminate unnecessary costs of defence systems (Sperling 2001,45).

3.21 The Difference Between Value Engineering And Other Cost Reduction Techniques

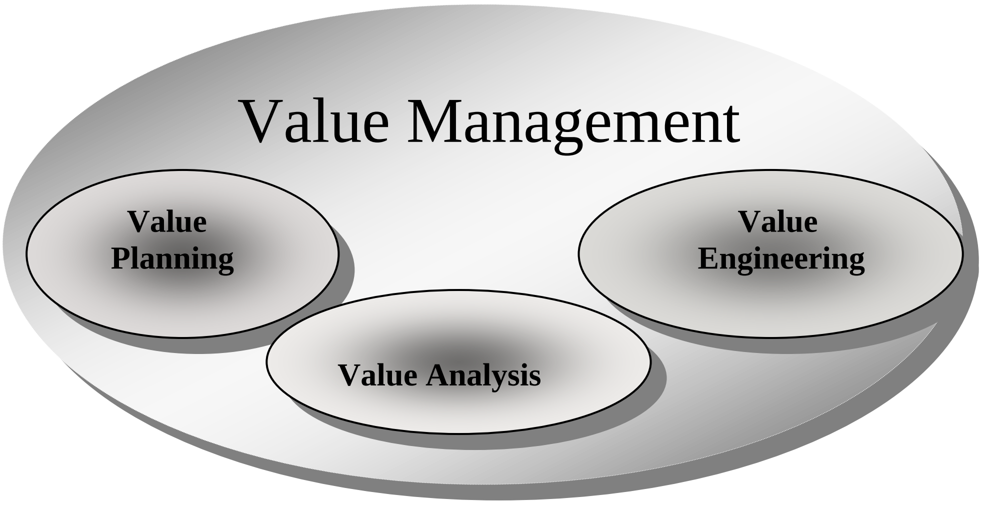
Palmer *et al* (1996) noted the following difference between value engineering and other conventional cost cutting techniques.

- The emphasis in VE is on function, which has to be fulfilled without sacrificing quality;
- VE is a disciplined and organised approach that takes nothing for granted;
- Its utility lies in teamwork.

3.22 The Difference Between Value Engineering and Other Value Techniques

Value Engineering, Value Analysis and Value Planning are embraced in Value Management; which is the term given to a full range of value techniques available (Mc Elligot 1995, 8), as illustrated in figure 1.0 below. Value Management spans the whole process of a project cycle and is not linked with a particular project stage (Watson 1999, 30).

Figure 1.0: Value Management Illustrated



Source: Dell'Isola (1999, xxvi), VE Practical Application.

4.00 Approaches To Value Engineering

Stubbs, O'Brien and Havers (1996, A6-3) stated that VE is accomplished using a team of multidisciplinary individuals using a VE methodology (in a workshop setting) to achieve results. Therefore the team concept and VE methodology are vital to the success of VE. A team concentrates on problem-solving techniques to break through obstacles (Ibid). Figure 2.0 below shows conventional methods of creating value products in the construction industry while figure 3.0 shows the VE approach.

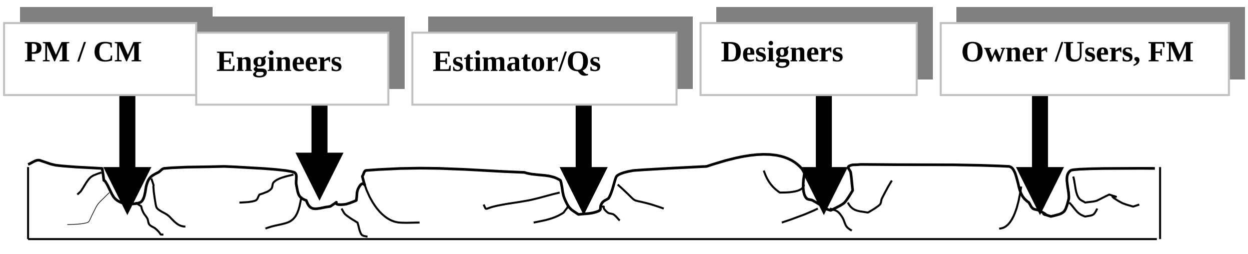


Figure 2.0: Conventional Approach to Creating Value products (*Adopted from* Dell'Isola, 1999).

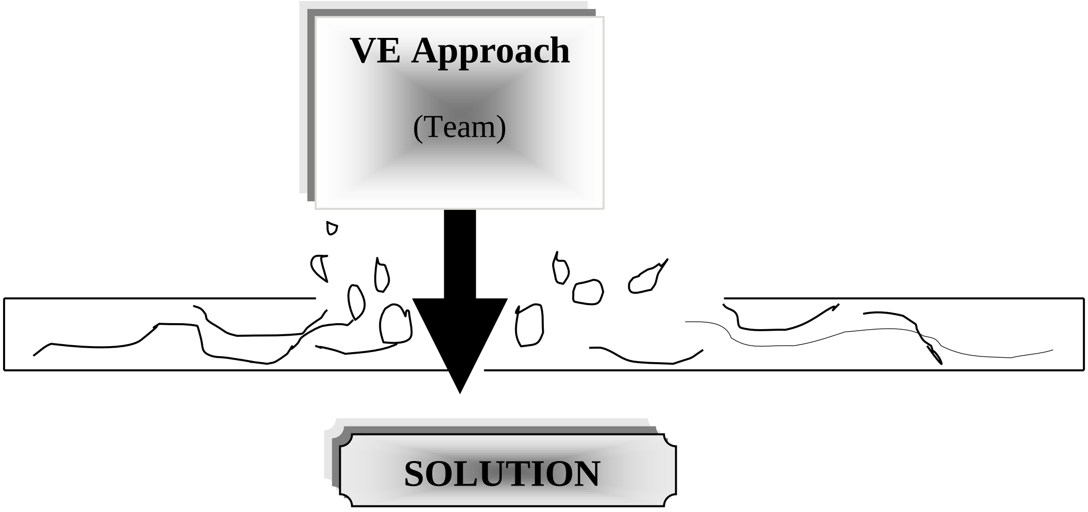


Figure 3.0: Value Engineering Approach to Creating Value products (*Adopted from* Dell'Isola, 1999).

Sperling (2001,45) explains that value studies rely on the synergy of teams to solve a common problem. The search for better value is based on the VE Job plan which is an organised step-by-step problem solving methodology (ibid). The choice of the approach to be used when carrying out a VE exercise is decided by the type and nature of the project, timing of the operation and the make up of the design team (Seeley 1996, 278), smith (1993).

4.10 Techniques Used In Value Engineering

Key to value engineering studies is (i) structured information gathering and sharing (ii) function analysis (CIBOARD 1999). Function analysis promotes a holistic view of products with a view to understand the customers' perspective of the finished product (Seeley 1996, 282). Function analysis is broken-down into (i) functional definition, (ii) valuation and (iii) creation of alternatives, as shown in figure 4.0 below.

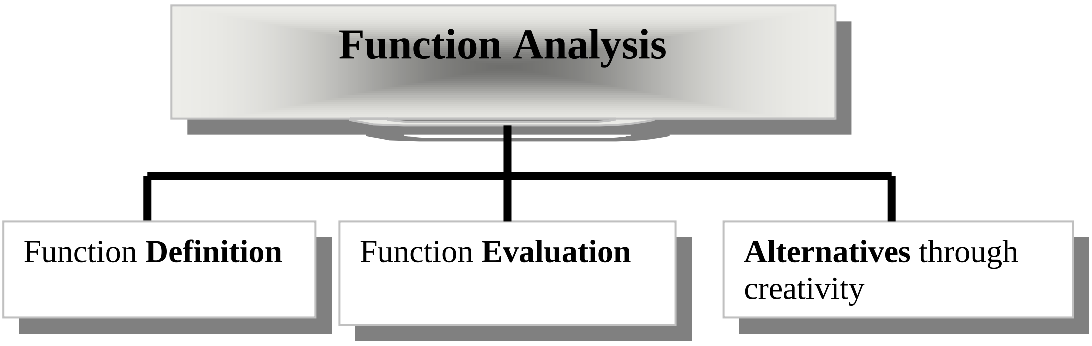


Figure 4.0: Three Basic Stages of Function Analysis (*Adopted*: Sperling 2001)

4.11 Function Definition

The central feature of Mile's work was definition of all functions that the customer requires of the product. These functions were defined only in terms of *one verb* and *one noun.* It is through such a definition that the real function of the item can be understood. The defined functions were then evaluated in terms *of the lowest possible cost* to achieve them and this evaluation was then used as a *means of finding alternatives* that also fulfilled the functions (Ibid). Mile's illustrated his work with an example of an electric motor screen, which needed to perform the following functions. See table below.

	Verb	**Noun**	**Cheapest means of Achieving Function**	**Lowest Cost to Achieve Function**
1.	Exclude	Substance	Sheet Metal	$0.15
2.	Allow	Ventilation	Holes in Metal	$0.15
3.	Facilitate	Maintenance	Spring clip	$0.10
4.	Please	Customer	Paint Metal	$0.10
		Total lowest cost to achieve Function		$0.50

Table 1.0: Function Definition *[Source: Palmer (et al 1996)]*

1. The function of *'exclude substance'* was evaluated on the basis of the cost of a sheet of metal to shield the motor.
2. The function of ' *allow ventilation'* was based on the additional cost of putting holes in the sheet metal.
3. '*Facilitate maintenance'* was evaluated by adding the cost of a spring clip to allow the sheet metal to be removed.
4. '*Please customer'* was based on the cost of painting the metal.

This total lowest cost can therefore be viewed as the *true value of the screen*, since it is *only* this cost that needs to be incurred in order to meet all the functions that the customer requires. In going through this process, Miles cost the functions of the screen based on the lowest possible cost of achieving them; in this case **$0.50.**This lowest cost was then compared to the actual cost of the existing screen; - **$4.75.** This clearly highlighted that much of the cost incurred in producing the screen actually achieved no function.

Mudge (1971) argued that using questions; (i) what is the item (ii) what does it do (iii) what does it cost and (iv) what would that alternative cost, one could define a construction project at the following levels.

- Project level;
- Spaces level;
- Elemental level;
- And component level.

4.12 Function Evaluation And Creating Alternatives

A *by-product* of defining and evaluating function is the ease with which it allows other means of achieving the function to be generated. Meaning function definition result in evaluating functions and later alternatives are formulated in most cases using brainstorming. The aim is either to *reduce cost, increasing function, or reducing cost and increasing function simultaneously* (Sperling 2001,45). Reducing performance while reducing cost is unacceptable because that is cost reduction and not value engineering. The whole process could be carried out using (i) the cherette (ii) The VE Audit (iii) the 40 Hour workshop and many other techniques.

5.00 Research Method

A combination of descriptive and historical research was adopted for this paper. This is because the former attempts to describe systematically a situation, a problem, phenomenon, service or program, or provides information about something (Kumar 1996, 9) while the latter encourages a study of any chain of events if one would inevitably begin to discern certain patterns of rationality and interpret the facts (Leedy, Newby and Ertmer 1997, 173). Reading specifications for past projects as well as observing built facilities was key to gathering strengths and weaknesses in the provision of value built products in Zambia.

5.10 Value Products in AEC/FM Zambia

"An optimist argues that this is the best it can get, and a pessimist agrees with him" Author unknown.

Without doubt, roads (earth or macadam), drainage, bridges (including foot bridges) culverts, clinics, water points, court houses are among the unlimited facilities needed to improve access to production and markets, increase public transport possibilities, and improve the well being of people (MPU 2003, NRB 2003). Such projects are meant to address the problems faced by the poorest members of society especially women, and involve rehabilitation, expansion, construction of new products and or a combination (ibid). In most cases the community is involved.

5.20 A sample of Common Specifications

The following is a miniature sample of the specifications for thirty (30 number) nationwide rural projects with the location averaging approximately 600km from the production centers of materials such as cement and steel products.

- Hollow concrete block work (100mm, 150mm, or 200mm thick) filled solid with plain concrete grade 20-20mm maximum aggregate, 3.5N/mm2 strength bedded in cement sand mortar 1:4;
- Vibrated reinforced concrete grade 25-20mm maximum aggregate tamped around reinforcement;
- Galvanised iron roofing sheets or (Asbestos cement roofing sheets);
- 200mm x 200mm Terra cotta or pre-cast concrete air brick of approved type, including copper gauze backing and building into 200mm walls and render around in cement sand mortar;
- 2M or 1M standard pressed steel doorframe, doubly rebated, supplied with and including 45mm thick standard hollow core flush door.

Adequate as they might have been at initial stages, most communities can no longer afford concrete and steel products because of the ever-escalating prices of inputs plus transportation costs, and to be prescribed such materials as above in most cases leads to abandonment of projects. The problem is compounded by the high rate of depreciation of the local currency (Chonya 2002) and the instability of all economic indicators, with over 26% annual inflation rate at close of 2002 (BOZ, 2003, CSO 2003). Still most engineers and builders find the usual way of specifying projects as the proven way of delivering built products, taking advantage of the established standard of operation as well as materials the world over.

The principles of value engineering however differs with the way projects have been carried out. Among the reasons Dell'Isola (1999) cited as the causers of poor value in general, seven (7 no.) have been extraordinary to the Zambian construction. They include:

- Lack of sufficient data on the functions the owner/user wants or needs and the information on new or old materials, products or processes that can meet these needs, with the required cost range;
- Lack of ideas to develop alternative solutions;
- Temporary circumstances; where urgent design, schedule and delivery, forces decision makers to reach a quick conclusion to satisfy a time requirement without proper regard to good value; for example political projects;
- Honest wrong beliefs; where designers base their decision on what they believe to be true, rather than on real facts, hence impeding good ideas that would otherwise lead to more economical decision or service;
- Habits and attitudes; a form of response – *doing the same things, the same way, under the same conditions*, without asking if it is the best way;
- Lack of Communication and coordination that facilitate discussion of subjects and allowing the expression of opinion without undue concern about acceptability. This is enshrined by the predominantly traditional procurements system used, despite the variety of procurement methods experienced in the Road Sector (NRB, 2002);
- Outdated Standards and Specification, many of which are more than 30 years old.

Technical as the sampled specifications may be, they are unworkable if they are a strain to the communities, meaning more research in the area of alternative means of providing the established functions within a project is concerned. Designers however, cannot embark on such a task if their value engineering skills are shallow or nonexistent.

6.00 Proposed Educational Requirements in Value Engineering

In general, standardising the delivery system of built environments products is beneficial in many ways. However, designers and builders tend to habitually stifle applied creativity when they adopt the same standard for all projects with little regard to the resource constraints that may be peculiar to individual cases. The result has been specifications that are imposed on the communities because of their proven record as opposed to their suitability. In contrast, value engineering encourages robust creativity, by relying on a multidisciplinary team for innovation. Innovation is inherently subversive, rebelling against the status quo and challenging those who are emotionally, intellectually or politically wedded to the current status of affairs (De Wit and Meyer 1998, 155). In this case, the ‘rebellion’ takes place without upsetting the existing institutions of operation as well as national standards. VE therefore enforces the reasoning behind why designers are doing what they are doing so as to create a workable evaluation scheme that could be used to assess the suitability of designs to the local community.

Below are some of the points proposed as part of the educational requirement essential to instill applied creativity in construction:

- A deliberate and detailed insight into the existing general solutions, such as foundation, wall and roofing material so as to ascertain why these solutions are used in the in the first place;
- Detailed Work Breakdown Structures (WBSs) so as to avail every project participant a chance to use their expertise during the matching between design criterion and suggested design solutions. WBS looks at the elemental and component level of a project, a stage where students can commence from and progress to larger units such as space and project;
- Teamwork commencing at colleges so as to encourage multidisciplinary approach to design and construction. Fields of study such as mechanical, electrical, chemical, civil, architecture, and cost engineering are conducted separately in college yet they are mutually inclusive on projects. If integrated efforts from other Engineers are buoyant as early as school, innovation would not be farfetched;
- Brainstorming as a technique of questioning the ‘wheel’ invention. This might sound like reinventing the wheel, as it were, yet in most communities, there is no easy access to modern materials due to exceedingly high cost. Designers might as well revisit alternative means to meet the needs;
- Research and Development on Functional analysis of available products;
- Information systems essential for keeping track of cost studies (Navon 1996). The key issue for the construction industry is not just to do the same thing faster or more efficiently with the help of information systems, but also to actually change what we do and the way we do them, with a view to ensuring value-added services (Holness 2003, 22);

- Most decisions on project or building level are based on necessity for constructed facilities and in most cases are easily justifiably demanded by the communities, e.g. a rural health Center to cover a radius of 50KM. However, such projects demand detailed outlook on materials such as those offered in colleges. This strategy uses the divide and conquer method commonly used in computer sciences;
- VE must be conducted by all professions and project stakeholders, as early as inception stage, as shown in figure 5.00 below, more so on:
  - Materials
    - Local economic and financial conditions
    - Natural resource situation.

Generic Building Product Life Cycle (PMI 1996)

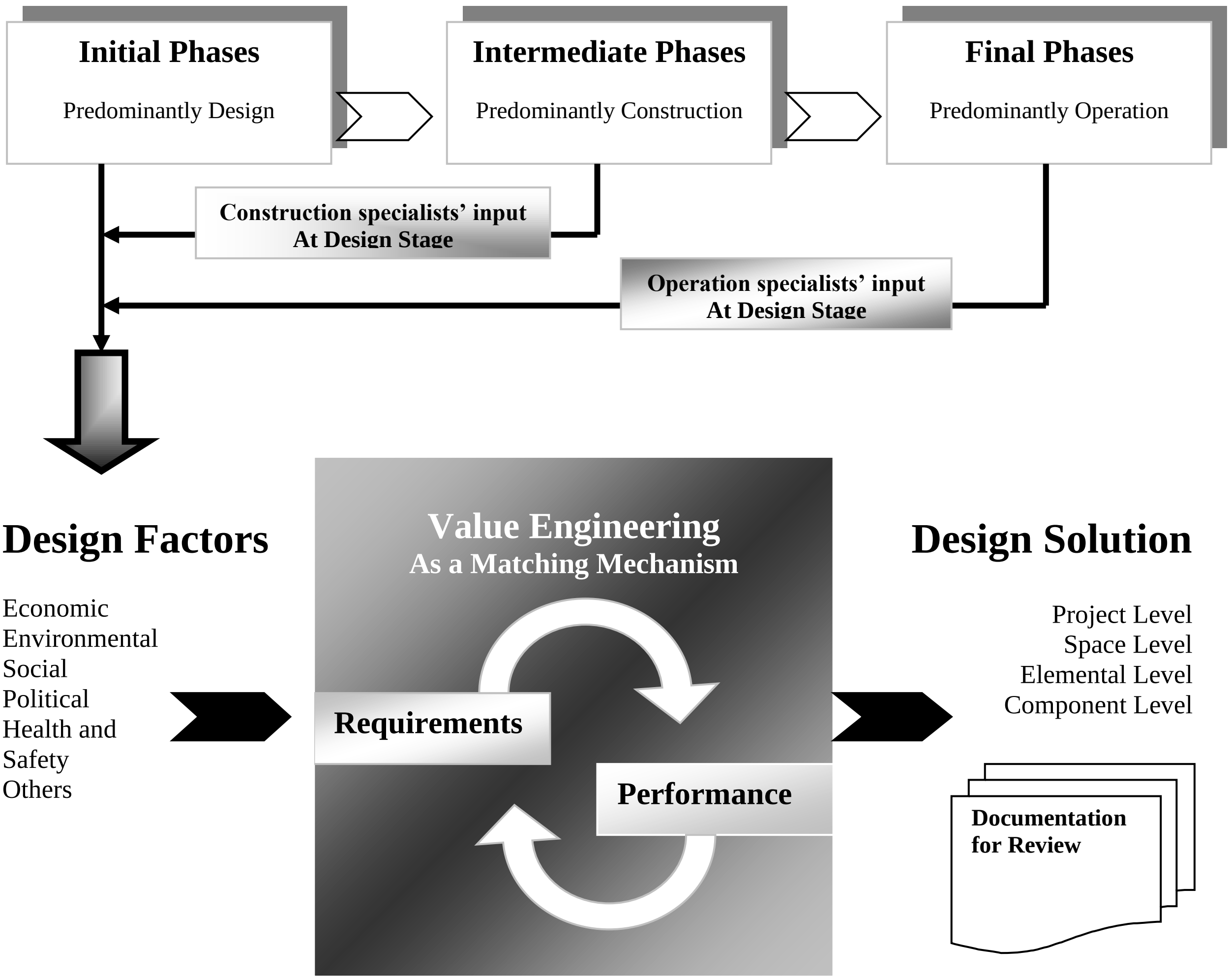


Figure 5.0. Value Engineering as a Matching Mechanism (*Adopted*: Hendriks and Van der Linden 2003).

7.00 Conclusion

Current methods of producing built products may be adequate in lands where economies have kept developing. But adequate is not enough for economically ailing countries. Accepting the tested means of production in construction without reevaluating their suitability prior to use on a project has proved costly to most underdeveloped nations. Robust mechanisms of matching design factors with possible solutions are essential for engineers' innovative designs. Innovation whether in products or strategies, is not a process that can be neatly structured and controlled. In reality innovation requires brooding, tinkering, experimentation, testing and patience, as new ideas grow and take shape. This demands that engineers and builders behave not as planners, but as inventors- searching, experimenting, learning, doubting, and avoiding premature closure and lock in to one course of action (De Wit and Meyer 1998, 155). Value engineering can be used as a tool to achieve such a goal, without upsetting the standardised production systems.

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