

## How functional value analysis unlocks the design paradox and will result in novel and cost-effective process engineering solutions

### Abstract

"Functional Value Analysis involves identifying clearly what each of the individual elements of a venture, project, product or service actually do. It is directed towards analyzing the functions or objectives to improve value through the optimization of whole life cycle costs. Value is defined as the ratio between function required (no less, no more) and the cost of achieving it. It can be considered as a yardstick for achieving the completeness of a product."

**Keywords:** Design paradox, design process, project management focus, functional value analysis, examples, learning points.

### HOE 'N FUNKSIONELE WAARDE-ANALISE DIE ONTWERP-PARADOKS ONTSLUIT EN 'N UNIEKE EN KOSTE-EFFEKTIEWE PROSES-ORDENING EN PROBLEEM-OPLOSSING TOT GEVOLG HET

### Samevatting

Wanneer 'n ontwerper gekonfronteer word met 'n probleem-ontwerp, lê die veld braak vir 'n verskeidenheid van moontlike opsies. Tog is hy steeds in die duister oor wat die uiteindelijke oplossing en resultaat sal wees. In hierdie geval kan die ontwerper alle moontlike weë navors om die antwoord op sy probleem te vind en die toepasbaarheid te evalueer op grond van sy eie kriteria en ervaring van wat die beste keuse vir die besondere behoefte sou wees. Dit is die ideale beginpunt vir die maksimale benutting van alle beskikbare kreatiwiteitsbronne wat kan lei tot die beste oplossing vir 'n probleem-ontwerp.

**Sleutelwoorde:** Ontwerpproses, projékbestuur, funksionele waarde-analise.

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<sup>1</sup> This paper was read at the 15th International Cost Engineering Congress, Rotterdam, April 1998. Mr. J. Janssen is affiliated with Shell International Chemicals (The Netherlands).

## 1. The design paradox

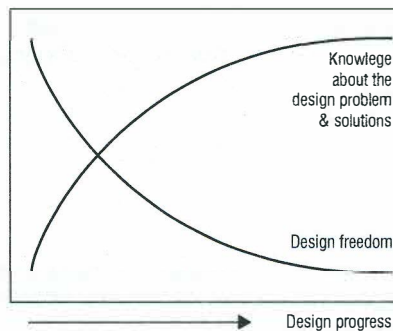
Whenever a designer is confronted with a new design problem all options are open and little is known about possible solutions and the eventual result. In such a case the designer can explore all possible avenues to arrive at a solution and to evaluate its applicability, using his own criteria and experience to judge the most suitable fit to the design criterion. It is the ideal starting situation to maximize utilization of all available creativity that can lead to the optimum design solution.

The only limitations are the perceived definition and boundaries of the design problem and the solution generation power (capabilities) of the designer. Following the route covered by the designer it becomes obvious that very soon he will be trapped within his own solution path thereby limiting the number of possible solutions.

His perception of the design problem inevitably blocks certain alternative solution routes and subsequently options that in turn should be considered but are rejected because they do not align with the developing solution path. This is of the inherent design paradox that plays a role in the mind of the individual designer. In addition the paradox deepens if we consider the environment that is allowing the designer to perform his act of creation. Outside circumstances will force the designer to stay within cost constraints and this conflicts with his own desire for a good quality design solution. Inevitably the designer feels trapped and he would welcome the opportunity to redo the design process with the knowledge gained during the design. A total recycle would of course allow him maximum design freedom but introduce delay and increased costs.

**FIGURE 1**

The design paradox



## 2. The design process

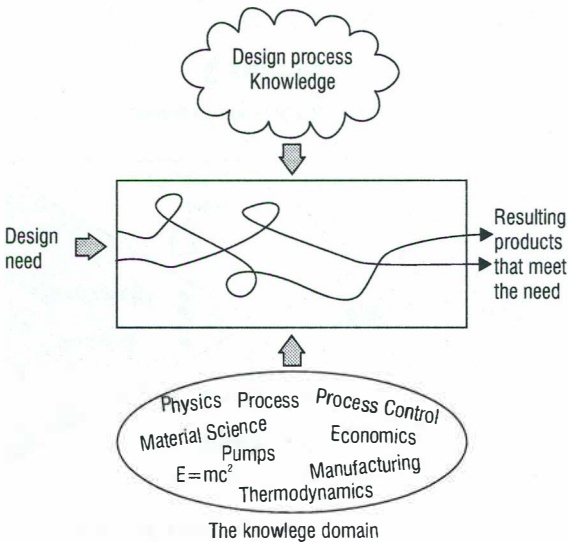
When we consider the act of creation that plays a dominant role in every design process it is obvious that this is difficult to describe because it remains hidden inside the brains of the designer.

However what we can do is take a more holistic approach to the overall design process. By doing so we can define a number of entities that encompass the overall process: "The Design Need", "The Design Process Path", "The Design Process Knowledge", "The Knowledge Domain", and finally "The Resulting Product That Meets The Need".

When considering these entities it becomes clear that to improve the end result of the design process the only thing one can do is to improve the quality and the interaction between the different entities of the overall process.

**FIGURE 2**

The design process



The deliverability of the design process will, as in many interacting processes, be mainly determined by the weakest link in the chain.

This is where Functional Value Analysis will help because it provides an extra dimension that will improve the interaction between the different elements of the design process. The additional attributes named Function and Value will shed a new light on the design process path and provide a new direction to the designer.

Before expanding on the Function Value Analysis approach I would like to discuss another constraint that is often experienced as a hindrance by the designer.

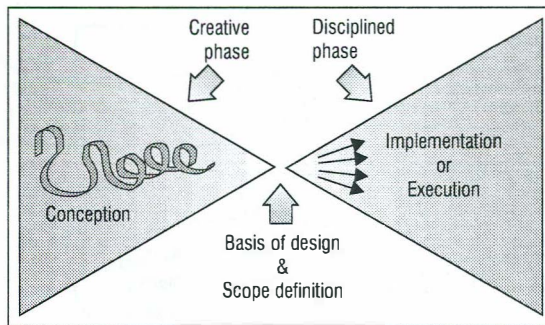
### 3. Project management focus

In every design process we can distinguish two different domains: the creative phase and the execution or implementation phase. Elements of the creative phase have been discussed above however the execution or implementation phase is governed by a completely different focus.

In this phase the main emphasis is on the optimum utilization of resources within financial and time constraints to produce the end product. This phase is regulated by design rules, procedures, planning and in many cases it will also control the funds and time window for the creation phase.

**FIGURE 3**

The main design progress domains



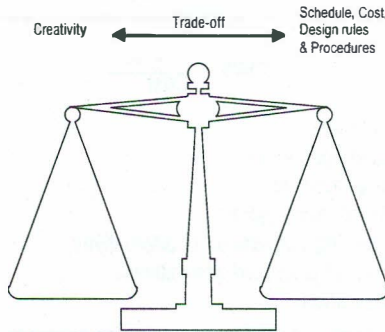
It is the delicate balance between design freedom and available resources that will create a conflict of interest in the mind of the project manager. The main objective in the opinion of the project manager will be to get the job done i.e. delivering an agreed scope of work within the available time and within the given budget.

He would like to contain any deviation from his perception of the fixed scope that will deliver the end product.

There is also a natural tendency to exercise his span of control and curtain off as soon as possible the outcome of the conceptual design phase. Such an approach will enable him to commence implementing the project without the thread of continuous change.

Elements of some of these fields of tension are shown below.

**FIGURE 4**  
Project management focus  
or  
The balance between the creative and  
implementation phases



It is obvious that the interest of the stakeholders is best served by an improvement of the overall profitability of the venture or to maximize the effectiveness of investment with respect to project objectives. This is where Functional Value Analysis will provide the ideal vehicle to ensure an adequate solution to the apparently conflicting requirements of all parties involved.

#### 4. Functional value analysis

Functional Value Analysis involves identifying clearly what each of the individual elements of a venture, project, product or service actually do. It is directed towards analyzing the functions or objectives to improve value through optimization of whole life cycle costs.

Value is not an absolute measure, but a balance between conflicting requirements.

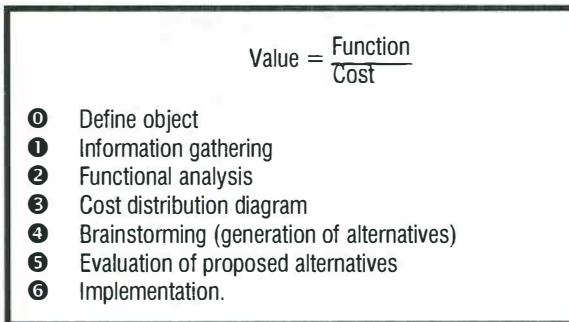
Value is defined as the ratio between function required (no less, no more) and the cost of achieving it. It can be considered as a yardstick for achieving the completeness of a product.

Function can be defined as the capacity of a venture, project, product or service to satisfy a need.

Unlike traditional approaches Functional Value Analysis does not only evaluate expenditure as a consideration. It really relates to the basic requirements of the venture.

Functional Value Analysis is a practical, structured and creative method, which is performed by a multidisciplinary team in which all the relevant project interests are represented.

**Figure 5:** Functional Value Analysis



A facilitator is needed to lead the team through the various stages of a Functional Value Analysis that typically contains the following steps:

Definition of the object and agreeing on the "Terms Of Reference" for the exercise

- ◇ Information gathering
- ◇ Functional analysis
- ◇ Functional cost distribution diagram
- ◇ Brainstorming (generation of alternatives)
- ◇ Evaluation of proposed alternatives
- ◇ Implementation.

The total exercise will take about 6-8 weeks and it can already be carried out as soon as an initial scope and very first capital estimate of the project are known.

## 5. Examples

Functional Value Analysis can be applied during every stage in a project and two extreme examples will be given below.

Firstly an application of Functional Value Analysis during the early scouting phase of a project and secondly an example when Functional Value Analysis is applied when project definition is already well advanced.

The first example refers to the case of an effluent water treating plant that was considered for a repeat design of a new chemical production facility. As starting point an existing unit could serve as reference design, and this consisted of a wet air oxidation unit.

In such a unit the effluent water is being mixed with compressed air and the mixture is passed through a reactor operating at a temperature of about 220<sup>o</sup> C and at a pressure of about 200 Bar. At these conditions the hydrocarbons and organic salts present in the effluent water are oxidized resulting in reaction heat which is partly recovered. The treated water is separated from the carbon dioxide formed during the reaction together with the excess air after which the water is further passed through a biotreater. Given the above description of the unit and its operating conditions it will be obvious that it is a complex and expensive plant.

During the functional analysis of above unit it became apparent that the proper function of the unit was to separate the dissolved hydrocarbons and organic salts from the water, and this function in turn could be formulated as separating the water from the aqueous effluent. With this true functionality for the unit a completely different design was proposed consisting of a freeze concentration unit which is a proven technology in the production of concentrated orange juice. Pilot experiments confirmed its suitability for this particular aqueous effluent resulting in a completely different design for the unit with a saving of 70% compared to the reference design.

The second example refers to applying Functional Value Analysis when again for a repeat design existing P&ID's were scrutinized before the design was handed over to the EPC Contractor. In this case the Terms Of Reference for the Functional Value Analysis team stressed in particular to examine the instrumentation and control requirements of the design. Although the exercise had to be completed within an extremely short time period of only a few weeks, the team was able to propose modifications to the existing design that were not limited to the instrumentation

and process control domain, but resulted in the elimination of certain requirements e.g. spare pumps. The reductions of other equipment items were also brought about. The resulting savings in this case were 7% of the total project costs.

## 6. Learning points

Based on more than 10 years of Functional Value Analysis application in Process Engineering design the following learning points can be given:

- ◆ Having an existing design/plant available as a reference point is a prerequisite for a successful Functional Value Analysis exercise and it also is the only way to demonstrate the real savings or resulting improvements of the venture.
- ◆ Whenever there is a big incentive to reduce cost in order to improve project profitability this can be seen as an effective driving force that influences the success of the Functional Value Analysis.
- ◆ An experienced facilitator and a balanced team composition with experienced, imaginative and challenging people will have better end result. Avoid a too homogeneous team.
- ◆ Full support of the team by higher management is essential.
- ◆ A structured approach is required to get full contribution of all parties and this will maximize the outcome of the Functional Value Analysis exercise.
- ◆ Tight project schedule constraints have a negative effect on the Functional Value Analysis results.
- ◆ Application of Functional Value Analysis during the scouting phase has shown to be able to result in savings up to 70%. Even when carried out on projects near the EPC phase savings up to 5% are possible.
- ◆ The best results are obtained if you can get closest to the true functionality of the project or venture.
- ◆ Functional Value Analysis exercise should be part of normal Project Management procedures.
- ◆ Incorporate findings of previous Functional Value Analysis studies into the standard design practices.