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Function analysis: going forward in value analysis

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Abstract

Stakeholders are key elements of complex technical projects. They can determine orientation, evolution and success of the project. They can cause uncertainties, changes in objectives and lead the project to failure. In this context, it is always more important to involve them in project decisions. Value Analysis (VA) is a means to introduce management and decision-making in design of complex projects, based on stakeholder needs. A method named Function Analysis aims at identifying and treating functions that the system has to complete. However, this functional approach does not allow some non-functional attributes to be included in the design phases. This is a lack identified by some engineering companies. The proposed paper aims at identifying the challenges encountered by the Stakeholder approaches to translate their needs into non-functional dimensions to deal with VA practices to design technical solutions. The research methodology combines a classical bibliographical analysis on VA that led us to show FA limits. Thus, we propose a Stakeholder-based "Non-Functional Analysis" to determine the non-functional attributes to characterize for the design of complex projects, and an industrial company's feedback practices on a case study. This will allow practitioners to have a systems approach to Value in the context of a VA but it will also allow scientists to compare theory and lack of practice around the identification and characterization of the needs of a set of stakeholders.

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1. Introduction

Value Analysis (VA) is the framework used in this research study. Indeed, Function Analysis (FA) represents the heart of VA: functions are used to address technical Stakeholders' requirements with quantitative indicators. Stakeholders are key elements of a complex technical project: they are able to lead a project to failure, or success. Thus, integrating stakeholders multiple points of view is one of the priority of project management and design. Euro Contrôle Project (ECP), the consulting branch of Assystem group, uses VA as a tool of decision-making in early phases of complex technical projects as infrastructure ones. This method seems to be well adapted with a systemic view of systems able to treat their management and design dimensions. In this context, our research aims at demonstrating that today there is a gap to deal with non-functional aspects of VA that are expressed by qualitative indicators. Non-functional requirements considered in this paper are social, political and environmental needs expressed by stakeholders. The research methodology is firstly based on a state of the art of Value Analysis approach. This allows us to show that there is a lack in one of the key phases of VA: Functional Analysis (FA) meets the functional needs of Stakeholders by forgetting to include other aspects. Thus, we propose a "Non-Functional Analysis" based on the Stakeholders to overcome this lack. A case study is developed, based on the observations of a company: it will bring us to highlight that this approach could make it possible to respond to our problem although it could still be improved.

2. Literature review

This section will present the VA approach, its main steps and limits.

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2.1. Value Analysis: toward a Stakeholder-centered approach

According to [1], "As it was originally conceived, VA was defined and applied as a cost-cutting tool, in order to make products more competitive". However, this scope "was early identified as limiting further developments and applications of the concept[...], if no extra effort was made to take the concept into other levels of management and, consequently, of business", always according to [1]. Today, this approach has two names depending on its use: on one hand, VA is currently used to re-design a system to make it evolved, on the other hand Value Engineering (VE) is concerned with new systems", as suggested by [2]. We will only use the term of Value Analysis (VA) in this paper to report re-design of a system. Despite the polysemous nature of the concept of Value [3], French Association for Value Analysis (AFAV) standards [4] define Value as the "measure which expresses how well an organization, project, or product satisfies stakeholders' needs in relation to the resources consumed".

The expressed needs are met and processed in a functional form: Function Analysis (FA) is used and this is the heart of the VA methods [5]. However, this seems to be very reductive since some attributes cannot be expressed in a functional form. For instance, the function "to be aesthetically beautiful" does not make sense. Likewise, although resources are mentioned, in practice it most often comes down to cost analysis. This is a second limitation to the stated definition.

If we are interested in the temporal evolution of VA standards (the 1995 European standard [6] versus the 2014 French standard [4] for example), we can notice that we have moved from a method centered on the consumer / user of a product / system to a method that is interested in various stakeholders of a larger project. Personal and ideological changes seem to be the cause: people want the lowest possible social and environmental impacts for themselves but also for society as a whole.

Many applications based on this concept of Value and this methodology have led many practitioners and academics to theorize and apply new concepts and methods [1]. [7] Demonstrates that a VA approach can be used to support a contextual design centered on cultures while [8] shows that VA may evolve to obtain a management tool to introduce Stakeholders' preoccupations on complex projects. Thus, we can say that VA is a very flexible method able to adapt to challenges of the practitioners based on workshops that permit Stakeholders involvement. Collaborative design makes it possible to make compromises and lead to successful projects.

We can see that despite a theoretical and normative approach allowing to integrate Value in a systemic way to support decision-making as well as numerous research works, in practice, the method is not yet fully adapted. The question that is then asked is therefore how can we integrate resources other than financial? To do this, we will first look at the process that is used by detailing its different stages.

2.2. Different steps of a Value Analysis

In this section, we will describe the approach used to manage and design a complex project and more precisely to make decisions in a conceptual phase of a technical project. VA is an organized method with different stages adapted to the project. Based on the experience of practitioners, we propose the division described below, into 5 parts:

- Identification of Stakeholders: AFAV standards AFAV standards recommend having a systemic viewpoint of the projects to identify all Stakeholders and the ecosystem in which they live (economic, social and ecological dimensions) [4]. Thus, practitioners have to adapt the constitution of the group of Stakeholders according to the project and the context associated with the multidisciplinarity as an objective
- Identification of Stakeholders needs: According to the French Association for Value Analysis (AFAV) [9], the formulation of the need to be satisfied aims at defining qualitatively and quantitatively expectations of the project. With a more practical approach, [10] shows that "one of the many ways to understand users' needs, as consumers, is studying their specific functional and emotional needs and, consequently, transforming those into product attributes or functionalities". A classical Function Analysis (FA) is not sufficient to translate Stakeholders' needs to a product or a system. Environmental and social needs are hard to translate in terms of functions. Thus, studying these attributes, it is to say what is not easy to translate by functionalities seems to be crucial to have a complete viewpoint of how to satisfy the needs or wants of Stakeholders. After studying the stakeholders and their needs, the next steps consist in studying "the relation between the satisfaction of needs and wants and the resources utilized", according to [1]: it is the manner to determine the "value" of a solution proposed.
- Function Analysis: As documented by [1], "function analysis methods […] are well documented in existing literature". We will not describe each manner to proceed but we have to highlight that there are two complementary "approaches to function analysis: (i) the functional need analysis (or external function analysis), related to use or esteem functions; and, (ii) the technical function analysis (or internal function analysis) related to product functions", [1]. To summarize the FA, [11] describes this method as the set of techniques which make it possible to identify and quantify the real needs. However, the FA does not have a Stakeholder-based approach: it is a "techno-centered" one, based on functionalities all along the life cycle of the product/system.
- Solutions finding: Based on needs and their functional formulations, the working group undertakes a collaborative design session. Firstly, solutions have to be defined without any restrictions: the creativity process is important to have many points of view. According to [9], "The object of this process is to propose, with a view to their comparative analysis, sets of concepts constituting solutions, that is to say answers likely to satisfy the requirements of the functional expression of the need for the VA product". Characteristics of each solution "must be developed with a degree of definition allowing them to be compared in terms of value", for project Stakeholders [9].
- Decision-making: According to [9] recommendations, the working group of VA approach contributes with sharing "all the information, […] allowing the decision-maker to decide on the follow-up to be given to the AV action and to prepare,

if necessary, the implementation of the chosen solution". In our case, the decision-maker corresponds to the project manager that has to decide what seem to be the best of the solutions presented by the working group.

To conclude with these different steps, [1] summarizes VA with a figure that could be interpreted as: "what makes value is how a system responds to attributes (utility and emotional), service functions (use and esteem) and product functions (hard-technological and soft-cultural)".
Table 1 summarizes main steps of VA and their characteristics, adapted from [1, 5, 7]:

Table 1. Main steps of a generic VA approach and their characteristics.

Steps	Stakeholders' involvement	Functional or non-functional characteristics	Type of indicators associated
Identification of Stakeholders	Decision-maker and VA leader	N/A	N/A
Identification of the needs	Workshops	Both	Quantitative and qualitative
Function Analysis	Workshops	Functional	Mainly quantitative
Solutions finding	Workshops	Both	Quantitative and qualitative
Decision-making	Decision-maker, based on group recommendations	Both	Quantitative and qualitative

2.3. Main findings of the literature review

We have shown through the literature review that VA is mainly based on Function Analysis (FA), which helps designers determine what functionality a system should enable. It helps practitioners to determine technical attributes of the system, based on quantitative indicators. We showed that in a complex project, Stakeholders are a key element to ensure a project also. Working groups are used to involve these Stakeholders and they determine solutions and compare these together. If the FA helps Stakeholders to compare technical solutions to design a system based on functionalities and quantitative indicators, what is not captured by functionalities, it is to say for instance social or ecological indicators, expressed qualitatively, seem to have a limited impact on the system design. It is underlined by the fact that some studies aim at involving these issues to FA: one approach studied by [11, 12] is using Life Cycle Assessment (LCA), the most known methodology of ecological impact accounting. Indeed, LCA permits to quantify supposed ecological impacts of a proposed solution. However, it is also mainly based on feedback: the quantification associated seems to be limited by the number or access to previous existing data. Thus, LCA is a technical-based approach that seems not to be a real solution to introduce environmental aspects with indicators in early phases of decision-making. Despite these studies, only ecological dimensions seem to be included with a technology-based approach. As described by the literature, there is an imbalance between AF based on quantitative indicators which helps to determine technical solutions put in place and the lack of research and consensus to integrate non-functional dimensions expressed by qualitative indicators. Thus, we introduce the concept of "non-functional analysis" as a way to complete FA by introducing non-functional criteria.

2.4. Proposition of using a Non-Functional Analysis

To have strongest indicators based on Stakeholders, we propose to undertake a "Non-Functional Analysis" (NFA) approach as following:

- A Stakeholder-based approach: Integration of Stakeholder expectations is at the center of designers preoccupation today. Whatever the mean used, they are a key element. Workshops seem to be adapted to a collaborative design and it is well known in VA approaches. Problems and system representation should be accessible by stakeholders. The indicators used to compare solutions must also focus on the Stakeholders: the latter must understand why and what these indicators are. This should be based on exchanges between stakeholders leading to consensus.
- An experience-based approach: The experience of VA practitioners could be represented by a database to integrate qualitative indicators: a system for comparing experiences should be set up not only to exchange between practitioners but also to implement a scientific vision of perceived value.

After having shown that FA is incomplete to support a Stakeholder-based approach via the literature and having proposed a way to complete the approach, we will now illustrate it through the case study presented below. Indeed, the case study will allow us to show that the Stakeholder approach makes it possible to move from a value that is perceived as functional to a broader value.

3. Case study

We propose to analyze how companies are using the approach, based on Euro Contrôle Project (ECP)'s experience. The case described hereafter were used by [8] to demonstrate that a VA approach should be used to integrate Sustainable aspects in early decisions of complex technical projects. We will have an approach centered on indicators to show how the VA is carried out in an industrial case. This case study was used in the company for training purposes. Thus, it has been built to be representative of a typical Value Analysis study, as achieved in ECP and prevents confidentiality aspects.

3.1. Case description

The case study concerns the design of transportation solutions between two cities A and B far from about twenty kilometers each other. The project's aim is to find some technical solutions to link up A to B globally more efficiently. Existing small roads between A and B are overload and a highway exists near to B from North to South without any exit to lay out B. Furthermore, some residential subdivisions were built on the outskirts of both cities; a river is situated at few hundred meters of A and B South's limits, and there is a mountain to the North. These topological constraints do not let us think about an "easy" solution. The consulting company is asked by the government to determine what technical solutions could answer this problem and how to compare them.

3.2. Value Analysis

In this section, we will apply the different steps described in the literature review section with a focus on the indicators used in each of these steps.

- Identification of Stakeholders: It refers to the definition of "who are the different Stakeholders" of the technical project. It is based on previous studies as topographical or socioeconomic ones. In this case, the Government, which led the study supported by ECP, determined around fifteen Stakeholders as citizens of the two cities, workers that have to schedule every day, etc. This step does not require any indicators: it does not consist in an evaluation.
- Identification of Stakeholders needs: After having identified the Stakeholders, it is crucial to know what they really need, and to characterise it. Each Stakeholder needs are expressed and discussed in a group of work. Some needs are expressed by functionalities (it is to say what the system has to do) and others which are expressed by other means such as "the system does not pollute": this type of need is not functional. This step requires indicators to determine 1) a level of technical performance for the system: technical solutions will be discussed in next section based on functionalities (it is to say the Function Analysis) and 2) a level of no technical performance as the "beauty" of the system or his potential to pollute for instance (We will name it Non-Functional Analysis to show the difference with FA). Latter is discussed as soon as this step by determining the challenges encountered by various Stakeholders with a system of consensus around a workshop. Indicators used are linked to personal perceptions and are collectively discussed to determine the different expected performance levels. Thus, it can be determined through consensus that the "beauty" of the project (that has social impacts) is more important than the level of pollution produced by the utilization phase of the project (55% vs 45% of Stakeholders preferences). This example shows the importance of having Stakeholder-based indicators to determine what really matters. If it is the Government, the main financier and decision-maker in the project, which opposes one of the solutions based on the non-functional aspect, the project can be optimized but will never succeed.
- Function Analysis: Linking A and B corresponds e.g. to transport people and facilitate exchanges. These are functions that the system of transportation has to permit. It corresponds respectively to cities expectations and Government's one. Functions are characterized and ranked by "order of importance" by Stakeholders for each step of the life cycle of the system. The most important function is "to transport people" that is noted with 65% of the importance of the project while "to facilitate exchanges" have 35% of Stakeholders preferences in this example. Contrary to the non-functional approach, the FA permits to determine a level of technical performance: the system has to transport at least 1,000 persons per hour for instance. Despite the fact that this level of performance could be discussed, it permits to have a strong indicator to compare different solutions.
- Solutions finding: After having determined a panel of solutions during the workshop, solutions have to be evaluated. The first evaluation consists in the level of technical performance: each solution is confronted with his theoretical performance. At this step, some solutions can be judged as satisfying and be deleted. For example, the idea to link the two cities with airplanes is not realistic according to the Stakeholders due to the space to design the system. The second approach consists in judging the solutions according to non-functional attributes of the Stakeholders. Another time, the group of work permits trade-offs and determines a level of satisfaction of each solution despite the fact that it is based on the perception of each Stakeholder and the indicators seem to be less strong.
- Decision-making: Based on above-mentioned evaluations, the solutions are compared and a classification is made according to the group of work. Thus, indicators based on technical performance and indicators based on a perception are compared with each other. They are used to model a diagram representing the classification of global "value creation" for each solution. The diagram is used as a support of the group of work to explain their approach and recommend solutions at the final decision-maker, the Government in this example.

3.3. Main findings of the case study

Through this case study based on ECP's experience, we have highlighted that with an industrial approach, FA is completed by a Stakeholder-based approach to determine non-technical indicators to evaluate solutions of a problematic. Thus, solutions are compared according to quantitative indicators that are determined by a level of technical performance and qualitative indicators based on human perception that reflect non-technical aspects.

Despite a quietly clear approach (due to ECP's experience) described in this paper, to design a complex system in its early phases represents a challenge to combine a technical approach based on "strong indicators" and a human approach based on collective works. It seems that some studies in the context of VA should be conducted to determine what should be indicators to integrate non-functional attributes into the design project. A catalog of non-functional indicators could be created to support VA practitioners in the non-functional analysis phase of VA but it would also serve to focus on the perception of value that is not only based on technical or financial aspects, in the context of system design. In the next section, we will discuss the highlighted gap and our proposition based on industrial application of a VA approach.

4. Discussions

Firstly, we showed that VA is a method mainly studied with a functional-centered approach. In fact, FA is "considered to be the core" of VA approaches, according to [5]. It helps in determining technical solutions based on functions that the system has to address. In a second time, it has been highlighted that VA is an adaptable method able to support technical complex projects design. A company-based approach shows advantages to take into account Stakeholders in VA approach by a non-functional approach. In this part, we will discuss in

one hand some limits of actually applied VA and an approach mainly based on FA and in other hand, we will discuss our proposed solution to support a Non-Functional Analysis.

4.1. Comparison between the literature review and the practical approach

In this part, we will compare a classical VA centered on FA as described on the literature review and an industrial approach based on Stakeholders to integrate non-functional dimensions to design a complex system. We have seen that Stakeholders are key elements. We have made the hypothesis that they must be at the center of design decisions: the perceived value of the non-functional attributes of the project is as important as the technical response to the problem raised, to facilitate the acceptance of the solution.
With a theoretical approach, we saw that VA through FA is able to integrate technical approach into design with indicators based on a level of performance. In fact, functions help designers to determine what could be solutions to address some Stakeholders' requirements. At the same time, VA is a collaborative approach, based on facilitating the success of a project. Thus, we can notice a limit to take into account Stakeholders' perception in a FA. Indeed, as highlighted in [1, 6], not only the technical solution of a problematic is important but designers of a system have to take into account contexts such as historical, cultural, etc.
With a practical approach, we have seen that Stakeholders are the center of the design approach: not only VA is made with a group of work but also with a "Non-Function Analysis" that aims at considering dimensions as social or ecological that are not expressed by a functional one. This approach is combined to a classical FA to have a systemic view of the system. Thus, Stakeholders' involvement and their perceptions are integrated into the design process. But when integrating perception, an important gap consists in supporting decisions with indicators to compare many solutions, including qualitative indicators linked with perceptions. To deal with non-functional aspects, authors propose to use a Non-Functional Analysis as described earlier.

4.2. Recommendation for practitioners

In this section, we will make some recommendations based on earlier observations. We have seen that VA is mainly based on FA but also that it is difficult to involve Stakeholders and their perceptions into indicators and decision-making tools. As highlighted during the case study, an extended approach based on Stakeholders, the Non-Functional Analysis could help designers of complex technical projects. Indeed, NFA aims at taking into account Stakeholders and their perception and at having return on experience (REX) based on earlier projects. Dimensions highlighted are not only technical and economic ones (FA) but also human, social and societal ones, linked to society's evolutions. Despite the fact that VA norms as [9] insist on the fact that a VA have to be systemic, applications of the recommendations are often partial as highlighted by [2]. Thus, authors recommend to particularly studying non-functional aspects that could lead to project success or failure. The proposed Non-Functional Analysis should be developed and formalized to facilitate VA practitioners' approach.

5. Conclusion and future works

It has been seen that some limits exist in VA approach, mainly based on a Function Analysis: technical requirements are integrated despite the need to have a systemic view of them. Indeed, the practical approach based on ECP experience showed that this approach is not sufficient: Stakeholders want a more global vision of projects with a socio-environmental approach. In this context, we have made some recommendations for practitioners. These recommendations have to be completed and tested with other concrete cases and an implementation of indicators have to be undertaken. Proposed NFA consists in analyzing Stakeholders' perceptions but also to have return on experience as a base of work for practitioners and scientists. Thus, we could say that Function Analysis translates technical solutions for a complex technical project while Non-Functional Analysis, introduced in this paper, could treat Stakeholders' perception of solutions. Different indicators are used to compare these solutions: on the one hand, FA uses quantitative indicators (technical response of the solution) and on the other hand, NFA uses Stakeholder approaches, based on qualitative approaches. Practitioners and scientists should exchange views in order to have a tool to integrate all the dimensions of Value.

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