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Balancing Value in Complex Systems Development

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Abstract. The analysis of alternatives during the concept exploration must support the transformation of a need into a balanced design, must be able to reconcile the differences in the present set of physical and functional requirements and must evaluate the operational scenarios in terms of several attributes. However, the analysis of alternatives in the early stages of complex systems development is poorly structured and characterized by not sufficient detail for the assessment of the initially identified needs. The understanding of the relationship between the preferences of stakeholders and potential solutions for the systemic analysis of alternative designs is one of the most important activities in pursuit of information that can distinguish good from bad solutions. The evaluation of the system properties during the project requires the ability to analyze and map the architecture value space to find the best solutions. Thus, decisions made early in the development of a program should be supported by systems engineering analysis, involving teams of users, purchasers and others involved in the project, namely the stakeholders. In this paper are discussed several value dimensions and implications for the systems development to achieve and balancing value in complex system development.

Keywords. Complex systems, value, development, stakeholders, analysis of alternatives

1 Introduction

The analysis of alternatives during the exploration of concepts must support the transformation of a necessity in a balanced design, be able to reconcile the differences in the set of physical and functional requirements and evaluate the operational scenarios in terms of several attributes. In this way, a major part of the system engineer's role is to provide information that the system manager can use to make the right decisions.

According to Keeney [11] individuals are concerned with values. Therefore, these values should direct efforts in decision making, i.e., they must be part of the effort and time that is spent on decisions. But this is not the normal route followed. Instead, decision making, often focusing on the choice between alternatives. In fact, it is common to characterize a decision problem by the alternatives available.

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Thus, understanding how value is identified, planned and delivered is vital for developing systems for success.

In this paper are discussed several value dimensions and implications for the systems development to achieve the balancing value in complex system development.

2 Value

According to Keeney [11], Dominguez [5], INCOSE [8] companies considered leaders began to emphasize the perceived value, believing it to be, instead of consumer satisfaction, the driver of customer loyalty. So, the first step to understand the implications and dimensions of perceived value to the systems development is to have a clear understanding of concepts related to value.

In literature, there are many definitions of value. Johansson *et al.* [10] propose that the value can be quantified in terms of product quality, Q; service, S; selling price, SP, and lead time, LT; according to Equation 1.

$$Value = \frac{Q * S}{SP * LT} \qquad (1)$$

Park [16] proposes that the value can be based on product functionality (F) and cost (C):

$$Value = \frac{F}{C} \qquad (2)$$

To Downen [6] value is a term often only loosely defined in vague terms by the ratio between benefits and costs, and thus is problematic to make it operational in practical applications.

Mandelbaum and Reed [14] emphasize that the relationship between the value or utility of an item and its real cost represents his concept of value. The highest value is represented by a product with an essential quality with the lowest total cost and that will perform reliably the required function in the desired time and place.

In this context, the product value is expressed by a relationship between its utility (U) and cost (C), as modeled by Equation 3.

$$Value = \frac{U}{C} \qquad (3)$$

3 Perception of Value

Briggs, Reinig and Vreede [3] proposed a causal theory that was written originally to explain the mechanisms that could give rise to responses of satisfaction and dissatisfaction of the product. The authors argue that the cognitive mechanisms that give rise to satisfaction responses may also give rise to the perception of value for an object, and that the satisfaction response is integral to perceptions of value.

Like satisfaction, perceptions of value may arise from the mechanisms of mind that relate to goal attainment. A goal is a state or outcome that an individual desires to attain [13].

Zeithaml [18] finds that the perceived value is the total consumer evaluation of the utility of a product based on perceptions of what is received (benefits) and what is given (sacrifices).

Despite variations, the various authors cited above seem to converge on the concept that perceived customer value is linked to the use or utility of the product or service. Thus, the perceived value is related to customer perception and involves the notion of exchange of benefits for sacrifices.

Dominguez [5] adds that some aspects of the analysis of perceived value are:

i. Timing dimension, i.e., it can vary with the time of evaluation;

ii. External an internal view to the company. According to Zeithaml [18], it may have differences between the expectations of customers regarding the value of the product attributes and perceptions of the company about those expectations.

iii. Nature of the market. Customers may define value differently depending on the nature belong to different markets.

iv. Personal dimension. The purchase decision always involves people who may have different views of value, according to their own perceptions

v. Supply chain coverage. Companies must operate in the entire value chain, seeking partnerships with suppliers, dealers and distributors, to maximize the value delivered by the chain to the customer.

According to these literature definitions, the perception of value υ can be represented by the ratio between the benefits received by the customer *i* in the evaluation time ($\beta_i(t)$) and the sacrifices given by the customer *i* in the evaluation time ($S_i(t)$), as written in the Equation 4.

$$\upsilon = \frac{\sum_{i=1}^{n} \beta_i(t)}{\sum_{i=1}^{n} S_i(t)} \tag{4}$$

4 System Value in the Development

Chase [4] notes it is difficult to quantify value, particularly within the context of product development, because there are many perspectives on value. These perspectives depict the complexity of value, which is seen differently by the business customer, end user, shareholder, employee, etc. Each of these will typically have a different perspective on what is valuable.

To Downen [6] despite to seemingly quantitative nature of value definitions, all of them involve qualitative parameters such as quality, function, benefit need, and levels of satisfaction..

Hallander and Stanke [7] consider that the value of a system includes the evaluation of multiple dimensions and implications throughout its life cycle. These value dimensions include aspects such as performance, cost and time. Another concern that arises in developing new systems is large technological uncertainties. From this account, the risk, therefore, becomes another dimension of value. Chase [4] adds that these dimensions should be considered as evaluation criteria for solutions effectiveness.

If the value, as a function of the attributes of the system, was estimated, the value of a proposed solution can be calculated from the variables related to each of the attributes that characterize it.

In this line, Shinko [17] states that a measure of effectiveness of a system describes the systemic objectives achievement in a quantitative way. Thus, each system has its own measures of effectiveness.

Based on all information collected by the various authors referred to here, Equation 5 for the system would be:

$$\upsilon_{system} = \sum_{i=1}^{n} \upsilon_i(\chi_d) + \sum_{i=1}^{n} \upsilon_i(\chi_c) + \sum_{i=1}^{n} \upsilon_i(\chi_r) + \sum_{i=1}^{n} \upsilon_i(\chi_s) \qquad (5)$$

where, υ_{system} is the system value, $\upsilon_i(\chi_d)$ is the value of the performance attribute χ_d related to the valuer *i*, $\upsilon_i(\chi_c)$ is the value of the cost attribute χ_c related to the valuer *i*, $\upsilon_i(\chi_r)$ is the value of the risk attribute χ_r related to the valuer *i*, and $\upsilon_i(\chi_s)$ is the value of the schedule attribute χ_s related to the valuer *i*. All of the value assessment evaluated at a determinate moment to *n* valuers.

Therefore, the value of system architecture is strongly associated with the personal value related to the attributes that characterize the architecture of a system. Thus, the system value regarding the attributes should be considered as a measure of effectiveness in assessing the value of the solutions of the problem presented.

5 The Value Context in Complex System Development

The INCOSE [8] postulates that the main challenge for the industry in the XXI Century involves identifying and delivering value to all stakeholders. This challenge is compounded by geographical and philosophical distance between all stakeholders in the development of a system, despite the need for collaboration between them.

In this way, when considering the perspective of stakeholders during the development of new systems can be identified a variety of interests. These interests are usually related to performance, development time and delivery, system cost or price and, therefore, risks of development.

Lemon Bowitz, Burn and Hackney [12] suggest that the successful development of a system is strongly related to perceptions of stakeholders in the value of the project and their relationships with the development team.

Thus, in a systemic way, measures of effectiveness should be established based on perceived value, i.e. the relationship between the attributes of a system and the needs of stakeholders in its development.

Keeney [11] states that the value-centered thinking is a philosophy to guide decision makers. It has three main ideas: starting with the establishment of values, use these values to generate better alternatives, and use them to evaluate these alternatives. The author points out a way for the analysis of alternatives that begins with values, rather than starting with alternatives, i.e. start with the objectives of stakeholders and decision makers and use them to generate better alternatives. Finally, the author demand to use values to evaluate the alternatives generated by the technique of multiple objective decision analysis.

On the other hand, Murmam et al. [15] propose a creation value system for the development process with activities, inputs and outputs. Figure 1 illustrates this structure with three distinct stages: the value identification, the value proposition, and the value delivery.

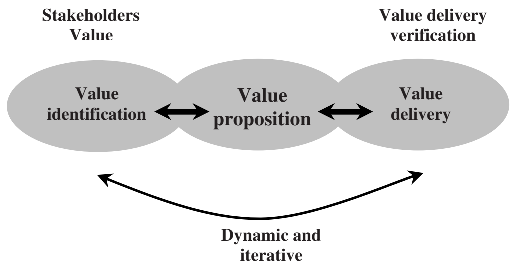

Figure 1 – Value creation process [15].

Thus, it becomes important to improve the goals, needs, direct or indirect interests, of the technical definitions, and programmatic constraints during the early stages of complex systems development. Thus, if the selection criteria are correct and well defined, those involved in the project can do analysis to better understand the design space and then choose one that best balance the satisfaction with the architecture chosen according to the needs be met.

The assumptions below detail the changes proposed for balancing the perception of stakeholders value in developing a complex system.

Assumption 1: A better understanding of the problem to be solved can be accomplished through the study of all internal and external interfaces of the system being developed. Several systemic values come from various areas such as technical, political, social and financial can be incorporated to the development through analysis of stakeholders. Thus, communication and information exchange can be accomplished in a more appropriate way, following the requirements of a new governance in system development.

Assumption 2: Most of the value that will be delivered to the stakeholders is defined at early development stage by the architecture that will be selected among the proposals. Thus, the main objective of this premise is to drawn the proposed concepts from the values identified in the systemic stakeholder analysis. For this, all the tasks of proposing requirements, functional analysis, synthesis, design and definition of figures of merit for characterizing the system should be based on stakeholder satisfaction, i.e. the value given by the stakeholders to these characteristics.

Assumption 3: The purpose of the third premise is to set the solution analysis of effectiveness based on the evaluation of the importance placed by stakeholders at every critical parameter of the various proposed architectures, namely the valuation of the attributes of the system of special interests identified. The architecture analysis must be performed based on the perception of value, i.e., in evaluating the impact of the attributes of the architecture, measured by the figures of merit of the system on the needs of stakeholders during the development.

6 Balancing Value in Complex Systems Development

The central goal of this paradigm shift in systems development at an early stage of exploration of concepts is to balance the satisfaction of stakeholders with respect to the system figures of merit, as opposed to the position of performing a direct analysis of the attributes that characterize the system. This satisfaction is the basis for enhancing the confidence of stakeholders in delivering value in the long run in complex system development.

Figure 2 illustrates the relationships between stakeholders interests, a systemic solution, and their figures of merit that characterizes the perceived value relationship, used as a measure of effectiveness that, consequently, model the evaluation in delivering value decision.

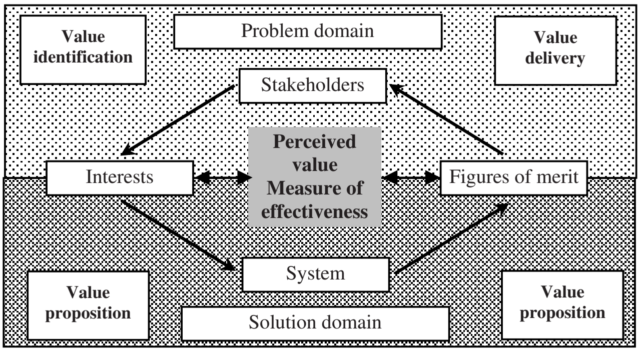

Figure 2 – Value criation in complex system development [1].

Thus, it is proposed that during the definition of a system is more appropriate, natural and palpable evaluate a solution by the total value perceived by stakeholders, as a practical way they will give financial, technical, political and social support to the development of the system.

Changing the perceived value of the attribute with the value given by the stakeholders for the performance, cost, risk and schedule attributes and introducing a weight for each value factor, the Equation 5 becomes:

$$\begin{aligned} \upsilon_{stk} = & \sum_{i=1}^{n} \omega_{psi} \times \upsilon_{psi}\left(\varphi_p, \eta_{si}\right) + \sum_{i=1}^{n} \omega_{csi} \times \upsilon_{csi}\left(\varphi_c, \eta_{si}\right) \\ & + \sum_{i=1}^{n} \omega_{rsi} \times \upsilon_{rsi}\left(\varphi_r, \eta_{si}\right) + \sum_{i=1}^{n} \omega_{ssi} \times \upsilon_{ssi}\left(\varphi_s, \eta_{si}\right) \end{aligned} \tag{6}$$

where, υ_{stk} is the stakeholders's system value, υ_{psi} is the value of the performance figure of merit φ_p related to the i stakeholder interest η_{si}; υ_{csi} is the value of the cost figure of merit φ_c related to the i stakeholder interest η_{si}; υ_{rsi} is the value of the risk figure of merit φ_r related to the i stakeholder interest η_{si}; υ_{ssi} is the value of the schedule figure of merit φ_s related to the i stakeholder interest η_{si}; ω_{psi}, ω_{csi}, ω_{rsi}, and ω_{ssi} are the weight factors for each value factor for the Equation 6.

The proposed methodology seeks to highlight the importance placed by stakeholders to the properties of a system early in development, namely through the relationship between attributes and interests, characterizing the perceived value of the stakeholders. In this way, the Equation 6 capture the elements to get a better balancing of the value given by stakeholders of the system for the analysis of alternative architectures in the development of complex systems. Traditional methodologies provide only a partial picture of these elements and their interactions.

Thus, explain to people how the systems produce tangible stakeholder's value benefits should become a major task for all actors involved in the complex systems development.

8 Conclusions

One of the most difficult aspects of the product development process is to recognize, understand and manage the development work in a way that maximizes the product's success. This is particularly important for complex systems [2].

The main objective of the analysis of architectures has been to meet the demands associated with high performance in a cost-effective long-term and low-risk, i.e., the common is the optimization of these parameters directly. In other words, the traditional analysis does not focus its efforts on balancing stakeholder satisfaction in developing a system with respect to its attributes, but in balancing the attributes that characterize the system architecture.

Based on results achieved in [1] is indeed possible to balance the stakeholder satisfaction with the attributes of an architecture. This owes to the fact that attributes can be evaluated in a specific manner according to the interests involved, i.e., through the perceived value of each stakeholder with respect to the attribute. Thus, a figure of merit of a system can be evaluated differently according to the perception of who is evaluating.

The approach seems to be closer to the reality lived nowadays regarding the improvement of the quality of decisions made within the various centers of development of complex systems, harmonizing political, budgetary, programmatic and technical decisions, that by definition, are taken at different levels of society.

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