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A Methodology for Complex System Quality Model Construction – First level

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Abstract: This paper describes a methodology applied to define the quality model of complex system considering customers' expectations. The aim of this quality model is to monitor system's quality level achieved during development and forecast the future system's quality level in use. This methodology allows to take into account the specificities of the company's industrial sector and customers' expectations all along the system's life cycle. A focus is done on the first level of the model and is illustrated through its application in an aeronautic and defense group.

Keywords: Product Design, Product Quality, Product Reliability, Decision Making

1. INTRODUCTION

During the recent past decades, large companies had to deal with the increasing complexity of systems which they design and manufacture. Complex systems include electronic, mechanical parts and software with a long development phase, involving many engineering fields and potentially, involving hundreds of people. Furthermore, the complex products in the scope of this study have two specificities: they are produced in small series and live on operation for several decades. These specificities increase the difficulty to manage the development of new systems. Product and system will be used indifferently in the rest of this paper.

Complex systems' developments are a succession of decisions and compromises which have impact on future system's characteristics (Herrmann 2015) and thus future system's quality. In fact, some of the decisions might heavily impact the future characteristics of the system, then they have to be taken into account very early in development. Indeed more a design error is discovered late in development, more it will be expensive to correct it.
The use of rigorous processes and quality management methods is crucial to guarantee system's characteristics at the end of the system development process and all along its life. The more the system becomes complex, the more management techniques have to evolve to monitor and control the system development (Lead et al. 2010). Usually, companies take into account three main aspects when a new system, or an evolution of an existing system, is developed: cost, quality and delivery time. Methods and tools used to plan and monitor cost and delay are known and widespread but there are no tools to forecast future system's quality.

Although measurement models are proposed to manage system development (Mendling et al. 2010). Most of those models measure only company's processes efficiencies or some of the product key characteristics. These existing models can't give a suitable response, since complex system development involves intricate processes and very distributed tasks, where processes monitoring is not enough to guarantee that the result will satisfy customer's requirements. Only software development was considered for product quality model prediction. There are no equivalents for complex system. Consequently, direct quality measurements on product are necessary to follow the progress of system development to meet customers' expectations. To address this issue, system quality measurement tool must be developed in order to have a complete view on systems development and to keep the customers' need as a goal.

In this paper we propose a methodology which aims to establish a complex system quality model integrating customers' point of view. The following section 2 is dedicated to the explanation of the needs of companies for such a model. In section 3, there is a review of some existing models with their strengths and weaknesses to answer the problematic previously exposed. Then, the proposed methodology which defines the first level of the product quality model architecture is described in section 4. Section 5 deals with the application of this methodology on an industrial case study.

2. PROBLEM DEFINITION

At the beginning of a system development, there is an expressed customer's need translated, among others, in quality requirements in present case. The customer's need is interpreted through different technical requirements in a collaborative process, requiring several iterations and checking with customer. But, as explained before, complex systems involve several domains of engineering to develop a multitude of subsystems and components. Thereby a single function required by the customer can be split in many technical characteristics for several subsystems developed by various teams (Fellows 2012). Customers' requirements, and consequently future systems quality, are divided in numerous sub goals which have to be evaluated.

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To address this difficulty, a quality model is necessary to evaluate how the progression of system's development along the project meets customers' expectations. The earlier a deviation or a mistake is detected and corrected, the less it costs for the companies (Hoegl 2005). So, to monitor the development and detect potential faults, system engineers are attentive to future system's technical characteristics while quality engineers bring an external view to the development team, taking into account customer's requirements.

System engineers monitor the development using several indicators on future system's technical performances as the power efficiency, the weigh, the failure rate etc. Relevant indicators and methods already exist to forecast the future technical performances (Zaeh 2007) and the company's internal strategy like future production cost of systems (Zhao 2014) or delivery time. However, quality engineers have no indicators to assess the future customers' satisfaction. In fact for the system itself, even if some technical characteristics are monitored, there are no predictive indicators for system's quality. Some models already exist to measure or predict system's features, but they only treat one precise characteristic without making the link between technical characteristic and the quality of the future system. For example, models to predict the future reliability of the system are often used (Johannesson et al. 2013), but they don't give elements to estimate future system's quality. There are no models taking into account all those aspects from the customer's point of view.

Therefore, quality engineers can't have a complete and objective assessment of the future system quality level. An expert knowledge of system development process is necessary to correctly evaluate processes performance on system's final quality. Nevertheless, this last assessment can be enhanced by a set of measurements directly linked to systems' quality, in order to guarantee the good implementation of development and production processes. Those measurements allow to know the quality level reached during the development and to have some objective indicators of the system's development completion. To integrate the constraints of the system and the processes, a system's quality model will allow quality engineers to define relevant quality requirements and system's quality measurements in order to monitor development and production phases. Quality engineers need a quality model which takes into account milestones corresponding to the segmentation of product life cycle in phases (PLC milestones). Thus company's objectives and system's maturity levels can be different in each phase, included the milestones defined with major deliverables such as system architecture design, prototypes, complete design etc.

As a result, the use of the model must be compatible with the segmentation of life cycle in phases covered by the company. At each milestone, the model gives an evaluation of the system's quality level based on the system's characteristics and the processes measurements. The quality engineers could then compare this level with the company's goals derived from the customer's requirements. If the quality level doesn't reach the defined goal at a milestone, the model will help to identify the cause of this gap. If such a gap is identified, quality engineers are notified so they can alert the project managers. Information given by the model will help project managers to take the right decisions about system's design or project organization, in order to reach the quality goal.

3. REVIEW OF EXISTING METHODS AND MODELS

Several methods and models were proposed during the last past decades to take into account system's quality during the development phase. In this section the main methods and models are presented with their relative strengths and weaknesses regarding to the problematic. To start with, quality management methods are presented and then software quality models are exposed.

3.1 Quality Management Methods

In the late 1970s, the ability for industry to improve products' quality and reduce production costs have become essential in order to remain competitive, especially facing Japanese companies (Prajogo 2001). Hence since the 80's, companies have developed Quality Assurance (QA) to identify appropriate techniques and practices to implement and provide products with a high quality level. For this purpose Total Quality Management (TQM) has been defined as quality management system including quality methods and tools taking into account the voice of customers (Oakland 2014). Subsequently, TQM principles have been supplanted by ISO 9000 collection of standards. Most of large companies have a quality management system based on ISO 9001 and 9004 standards. However those methods are often described as informal, as they are not based on defined concepts (Juan 2004), and don't address the needs of all companies (Powell, 1995). In addition, TQM methodology reinforces the idea that quality is achieved by the control of the development and production methods and not the product itself (Kitchenham 1987), whereas the two aspects are still needed for system development management. Methods to control process were thus developed at the expense of direct system measurement models.

To answer this limitation and drive company process, key performance indicators (KPI) as defined in ISO 9004 are more and more used. They can aggregate various indicators influencing performance of process. They are quantifiable metrics and are used by companies to monitor the achievement of their objectives. Nevertheless KPI are high level indicators which are focused on company's internal processes (for instance cost of development, or risk assessments). They are a source of information for making strategic and tactical decisions (ISO 9004:2009) but they are not designed to make direct measurements on a system. Consequently it's not possible to directly represent customer's requirements on product quality using KPI. To do this, it is necessary to develop a specific model taking into account engineering activities influencing product quality.

A common restriction of product quality models is the scope of application. Models developed for quality and project management are usually made to be used in a specific phase of product life cycle (Söderlund 2011). The advantages of these models are that they are very well adapted to the phase for which they were designed. But it is not possible to have a complete view of the product quality all along its life cycle