# ERP Software Quality Using Paraconsistent Logic

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**Abstract.** This study shows the perception of users regarding the ERP software (Enterprise Resource Planning). We used ISO/IEC 9126-1 for the evaluation of quality questions. As a decision-making tool, we used the Paraconsistent Annotated Evidential Logic E$\tau$, assisting software factories in which quality item to invest in ERP order to improve the production process and consequently their final product.

**Keywords:** Software Quality · ISO 9126-1 · ERP · Paraconsistent Logic

## 1 Introduction

In the decade of the 90s of last century, the implementation of ERP software (Enterprise Resource Planning) was presented as a major focus of investments related to the use of information technology in enterprises [1], which sought to gain competitive advantage through cost reduction and product differentiation by using these systems.

Thus, it was necessary to integrate business processes of companies with ERP was originally built. As the use of the ERP among companies gets more popular, the concern about the quality arises [2], as there are in the market several software development centers of this segment.

The question of this research is: how can IT users assess existing quality aspects in ERPs?

This research proposes to evaluate the perception of the user regarding the quality of ERP, based on ISO / IEC 9126 [3] and apply Paraconsistent Annotated Evidential Logic E$\tau$, with the focus on helping you software factory in which quality characteristic should invest to improve production process of ERP software and user satisfaction.

The research is relevant because it is motivated by the difficulties encountered by small and medium-sized software companies with limited financial resources O'Brien [4] to implement international standards. It helps to verify that the ERP meets the quality standards established by the standard ISO/IEC 9126 through Paraconsistent Logic, which analyzes the responses of IT experts that are often inaccurate or contradictory and that, if verified by other methods, will not have adequate accuracy for decision making. Thus, this work demonstrates that there are reasonable solutions for this niche of software market to work with quality in its products.

# 2 Literature Review

## 2.1 Software Quality

Some thoughts on quality: for Deming [5], product quality has a purpose: satisfying the customer. Crosby [6] states that "quality is the accordance to requirements".

There are many international norms and frameworks on software quality. We present them briefly:

ISO 12207 was created in order to standardize the quality of various types of life cycle of existing softwares in Software Engineering (Pressman 2014). It is divided into: Primary Processes, Organizational Support and additional information on ISO/IEC 12207.

CMMI (Capability Maturity Model Integration) is an approach of process improvement that helps in the development of products, services and procurement. It has five levels of maturity: 1 - Initial, 2 - Managed, 3 - Defined, 4 - Quantitatively Managed and 5 - Optimized, details at: www.cmmiinstitute.com.

ISO/IEC 15504 or SPICE, includes a reference model in two dimensions: the Process Dimension, divided into five big categories: Customer - Supplier, Engineering, Support, Management and Organization and Capacity Dimension, divided into six levels: Incomplete, Realized, Managed, Established, Predictable or Optimized.

Both of the norms above mentioned, including ISO 9126, have some points to note:

- Years are necessary for process improvement, organizational changes, employees training and putting the standards cited in practice completely;
- Significant investment in specific training for human resources;
- Greater investment in consulting for internal audits aimed at validation of requirements specified in each ISO;
- Revalidation of certification constantly achieved in software factories, which also generate investments.

Observing the aspects shown above, the small and medium-sized software factories don't have financial resources for implementation of norms in software quality, which makes their competition in the global market in which they are impossible. To attenuate this problem, the use of Paraconsistent Logic along with ISO 9126 is suggested, which doesn't replace the international standards mentioned, but contributes to the study, requiring significant financial investment to assess in which aspects the ERP needs to adapt, assisting companies in this decision making.

## 2.2 ISO/IEC 9126-1

It is divided into four regulations, but for this study we used only Part 1: Quality model. The ISO/IEC 9126-1 presents six groups that assess quality to the software, as shown in Table 1 below [3]:

Table 1: Characteristics of Software Quality according to ISO/IEC 9126-1

| Characteristics | Description |
|---|---|
| F1-Funcionality | Functions that meet the explicit and implicit needs for the purpose to which the product is intended. |
| F2-Reliability | Performance is maintained under prescribed conditions over time |
| F3-Usability | It highlights the ease of using the software. |
| F4-Eficiency | The resources and time involved are compatible with the level of performance required for the product. |
| F5-Maintainability | It points out if there's ease for corrections and updates. |
| F6-Portability | It uses multi-platforms and little effort to adapt. |

### 2.3 ERP - Enterprise Resource Planning

The ERP arose from the confluence of factors such as: integration of transnational companies requiring a unique and real-time treatment of information; tendency towards substitution of functional structures by structures anchored in processes; and integration of various information systems into a single system.

It maintains a unique and consistent flow of information across the enterprise in a single database and it shows transactions made by the company, designing scenarios of its business processes [4].

It offers a set of programs that connect and incorporate the administrative procedures or data generated by other applications [7].

Also, ERP integrates the company's management, improving decision making and allowing real-time monitoring [1].

### 2.4 Paraconsistent Annotated Evidential Logic Eτ (Logic Eτ)

Roughly speaking, Paraconsistent logics are logics that can serve as underlying logic of theories in which there are formulas $A$ and $A$ (the negation of $A$) both true without being trivial [8]. There are infinitely many paraconsistente systems. In this work we consider the Paraconsistent Annotated Evidential Logic Eτ.

The atomic formulas of the language of the Logic E$\tau$ are of the type $p_{?\mu??? \lambda?}$, in which $p$ is a proposition and e $(\mu, \lambda) \in [0, 1]$ is the real unitary closed interval.

$p_{(\mu,\lambda)}$ can be intuitively read as: "The favorable evidence of $p$ is $\mu$ and the contrary evidence is $\lambda$" [9]. For instance, $p(1.0, 0.0)$ can be read as a true proposition, $p(0.0, 1.0)$ as false, p(1.0, 1.0) as inconsistent, $p(0.0, 0.0)$ as paracomplete, and $p(0.5, 0.5)$ as an indefinite proposition [10]. Also we introduce the following concepts: Uncertainty degree: $G_{un}(\mu, \lambda) = \mu + \lambda - 1$ $(0 \leq \mu, \lambda \leq 1)$ and Certainty degree: $G_{ce}(\mu, \lambda) = \mu - \lambda$ $(0 \leq \mu, \lambda \leq 1)$ [11].

An order relation is defined on [0, 1]: $(\mu_1, \lambda_1) \leq (\mu_2, \lambda_2) \Leftrightarrow \mu_1 \leq \mu_2$ and $\lambda_2 \leq \lambda_1$, constituting a lattice that will be symbolized by $\tau$.

With the uncertainty and certainty degrees we can get the following 12 output states Table 2 extreme states, and non-extreme states. It is worth observed that this division can be modified according to each application [12].

Table 2: Extreme and non-extreme states

| **Extreme states** | **Symbol** | **Non-extreme states** | **Symbol** |
|---|---|---|---|
| True | V | Quasi-true tending to Inconsistent | QV→T |
| False | F | Quasi-true tending to Paracomplete | QV→⊥ |
| Inconsistent | T | Quasi-false tending to Inconsistent | QF→ T |
| Paracomplete | ⊥ | Quasi-false tending to Paracomplete | QF→⊥ |
| | | Quasi-inconsistent tending to True | QT→V |
| | | Quasi-inconsistent tending to False | QT→F |
| | | Quasi-paracomplete tending to True | Q⊥→V |
| | | Quasi-paracomplete tending to False | Q⊥→F |

Some additional control values are:
$V_{scct}$ = maximum value of uncertainty control = $Ft_{un}$
$V_{scc}$ = maximum value of certainty control = $Ft_{ce}$
$V_{icct}$ = minimum value of uncertainty control = $-Ft_{un}$
$V_{icc}$ = minimum value of certainty control = $-Ft_{ce}$
All states are represented in the next Figure (Fig.1).

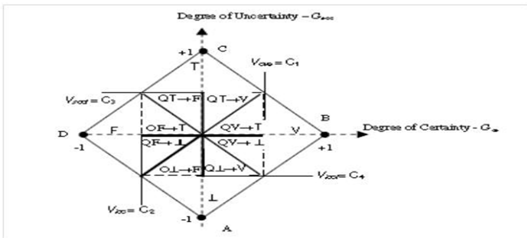


Fig. 1: Extreme and Non-extreme states

From data standardization experts and the same being submitted - Aces rules Paraconsistent Logic, the graph of Figure 1 is generated and from the ordered pairs indicated in the graph, the analysis can be performed using the Table 2.

## 3 Methodology

We forwarded an online questionnaire to thirty IT users of the ERP in daily operations, where we dealt with questions about the perception of users regarding the six characteristics of ISO 9126-1 shown in Table 1.

Answers from all requested users were obtained and the results were grouped by expert teams (Final Users, System Analysts and IT managers) where we obtained quantitative data.

From these data, we used the Logic Eτ to support the Software Factories in deciding in which quality feature related to the ISO 9126-1 to invest efforts in correcting problems in order to, consequently, improve the product and get satisfaction of ERP customers.

Below, procedures for the application of Logic Eτ:

a) Definition of Proposition: To start the study, we went to the following statement: There were problems in the quality of ERP software.

b) Factors for expert analysis: The factors used for the analysis of respondents were the same as listed in Table 1, from the ISO / IEC 9126.

c) Sections for expert analysis: The sections, asked in accordance to each factor, are related as shown in Table 3:

Table 3: Factors and Sections used in structuring the database

| **Factors** | | **Sections** |
|---|---|---|
| F1 | Functionality | **S1** - Do the functions that the ERP contemplate meet the current needs? |
| F2 | Reliability | **S1** - Does the ERP maintain its performance level (does not freeze) even in critical situations? |
| F3 | Efficiency | **S1** - Is the performance level vs response time of the ERP balanced? |
| F4 | Usability | **S1** - Is the effort required for the use of the ERP irrelevant, is the software easy to learn and operate? |
| F5 | Maintainability | **S1** - It is necessary to make great effort to upgrade or to perform maintenance on the ERP? |
| F6 | Portability | **S1** – Does the ERP work in multiplatforms like: Windows, Linux, Os2, SQL, Oracle, DB2, etc? |

d) Definition of expert groups: The questionnaire was sent to 3 groups of IT specialists: Final Users, System Analysts and IT managers, (thus following assessment standard ISO/IEC 9126-1), where each group had ten replies, totaling thirty ERP users interviewed.

e) User responses: Each quality factor was evaluated by ERP users about the positive and negative aspects ($\mu$, $\lambda$) ranging from 0 to 1.

f) Assigning weights to the responses of experts: a weight ”2” was assigned to the answers of the final user group, as this is the central axis of the research.

g) Database construction: From Table 3, the responses of experts were grouped according to their group and the data were normalized by arithmetic average and distributed among each type of specialty, as shown in Table 3:

With data from Table 4, we drew the favorable and contrary evidence from experts on the factors (F1 to F6). The rules of Maximum and Minimum have been applied.

Table 4: Data collection from experts

| **FACTORS** | **SECTIONS** | **G1: Users** | | | | | | **G2: System Analysts** | | | | | | **G3: IT Managers** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | E1 | | E2 | | E3 | | E4 | | E5 | | E6 | | E7 | | E8 | | E | |
| | | $\mu$ | $\lambda$ | $\mu$ | $\lambda$ | $\mu$ | $\lambda$ | $\mu$ | $\lambda$ | $\mu$ | $\lambda$ | $\mu$ | $\lambda$ | $\mu$ | $\lambda$ | $\mu$ | $\lambda$ | $\mu$ | $\lambda$ |
| **F1** | **S1** | 0.8 | 0.2 | 0.7 | 0.3 | 0.7 | 0.3 | 0.9 | 0.1 | 0.7 | 0.3 | 0.8 | 0.2 | 0.4 | 0.4 | 0.6 | 0.8 | 0.6 | 0.3 |
| **F2** | **S1** | 0.9 | 0.1 | 0.6 | 0.4 | 0.5 | 0.7 | 0.5 | 0.1 | 0.8 | 0.2 | 0.8 | 0.2 | 0.5 | 0.5 | 0.5 | 0.6 | 0.5 | 0.7 |
| **F3** | **S1** | 0.9 | 0.1 | 0.5 | 0.5 | 0.6 | 0.3 | 0.6 | 0.1 | 0.4 | 0.3 | 0.8 | 0.2 | 0.6 | 0.6 | 0.7 | 0.3 | 0.7 | 0.3 |
| **F4** | **S1** | 0.8 | 0.2 | 0.5 | 0.5 | 0.6 | 0.4 | 0.4 | 0.7 | 0.5 | 0.1 | 0.8 | 0.2 | 0.7 | 0.3 | 0.5 | 0.5 | 0.5 | 0.4 |
| **F5** | **S1** | 0.3 | 0.7 | 0.3 | 0.7 | 1 | 0 | 0.5 | 0.5 | 0.6 | 0.3 | 0.9 | 0.1 | 0.5 | 0.3 | 0.9 | 0 | 0.9 | 0 |
| **F6** | **S1** | 0.8 | 0.2 | 0.5 | 0.5 | 0.8 | 0.2 | 0.7 | 0.2 | 0 | 0 | 0.9 | 0.1 | 0.5 | 0.7 | 0.1 | 0.9 | 0.1 | 0.2 |

h) Maximization and Minimization rules: We used the rules of Max and Min to the evidence of experts for each factor and section identified.

## 4 Analysis and Discussion

We have favorable or contrary evidence relating to software quality characteristics, if there is a certainty degree equal or greater than 0,6. The certainty degree is defined as: $G_{ce} = \mu - \lambda$

The division criterion adopted was:

$G_{ce} \geq 0{,}6 \rightarrow$ Truth (T), the valued software can be considered of good quality;

$G_{ce} \leq -0{,}6 \rightarrow$ False (F), the valued software has no good quality; and $-0.6 < G_{ce} < 0.6$. Region between Truth and False is called DOUBT, where the amount of data presented was inconclusive to determine whether the software factor has good quality or not.

We applied the Max and Min rules to the data of Table 4, below on Table 5.

Observing the degree of favorable and contrary evidence resulting from the application of MAX (OR) and MIN (AND) rules to the evidence of the experts, it is noted that the degree of certainty ($G_{ce}$) to F1 (functionality) is $G_{ce}$ 0.6 experts say ERP meets the quality questions herein. When analyzing the F2 factor (reliability) the $G_{ce}$ showed 0.0, which means experts have not reached a conclusion.

For the F3 factor (efficiency), the presented $G_{ce}$ 0.4, ie, experts report that the ERP does not offer good response times and uses many computational resources.

Regarding the F4 factor (usability), the $G_{ce} = 0.0$, that is, the experts have not reached a conclusion.

Regarding the F5 factor (Maintainability) the $G_{ce}$ presented -0.7, meaning the maintenance of ERP is for bug fixes, product enhancements or version migration which are complex to run.

Table 5: Evidence degrees resulting from the application of Max and Min rules

| **Factors** | **Sections** | Number of lines: 6 | | Control Value:≥ 0,6 | | |
|---|---|---|---|---|---|---|
| | | **Max and Min between groups** | | **Conclusions** | | |
| | | $\mu_{1R}$ | $\lambda_{2R}$ | **Gce** | **G**$_{contr}$ | **Decision** |
| F1 | S1 | 0,9 | 0,3 | 0,6 | 0,2 | True |
| F2 | S1 | 0,5 | 0,2 | 0,0 | -0,3 | Paracomplete |
| F3 | S1 | 0,7 | 0,3 | 0,4 | 0,0 | False |
| F4 | S1 | 0 | 0 | 0,0 | -1 | Paracomplete |
| F5 | S1 | 0,2 | 0,9 | -0,7 | 0,1 | False |
| F6 | S1 | 0,8 | 0 | 0,8 | -0,2 | True |

Finally, for the F6 factor (Portability), the $G_{ce}$ showed 0.8, in which experts agree that ERP can work in computer multi-platform, showing no significant problems.

On the Unit Square in the Cartesian Plane, adapted from Abe [10], we are presented the coordinates and abscissas from Table 5 (Figure 2).

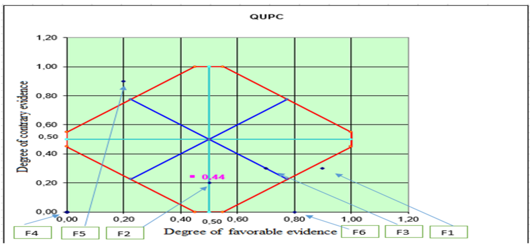


Fig. 2: Unit Square in the Cartesian Plane (USPC)

For factors F2 and F4 there were doubts among the experts; in order to clarify them, stricter criteria for evaluation is needed, i.e., for a safer and more reliable decision, it may be necessary to increase the Requirement Level or to use a larger number of experts in the search, or to even consider the given evidence in terms of each expert's weight.

## 5 Conclusion

After applying the Logic Eτ, it was noted that the Factors F3 (Efficiency) and F5 (Maintainability) require significant improvements related to quality of ERP software, according to ERP users questioned.

With this research, it was possible to identify and assess the user perception, supported by ISO/IEC 9126, as ERP softwares are characterized in the aspect of quality.

It was from the Logic Eτ that it was assessed that among the six quality traits studied, two of them - Efficiency and Maintainability - must be reviewed and better structured by software factories.

Software Factories, knowing their vulnerability among the groups studied by ISO 9126, will benefit from the results, reducing rework and domestic spending on their projects, and their potential customers will not be affected by unscheduled stoppages caused by defects in the ERP, avoiding financial losses of this type of incident and consequently increasing satisfaction with the services provided.

In resume, the Logic Eτ was essential to eliminate the contradictions, assisting the management of software factories in which quality characteristics to invest, thus improving its processes and therefore its ERP software products, reaching then the goals at the beginning this study.

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