

# SYSTEMIC QUALITY MODEL FOR SYSTEM DEVELOPMENT PROCESS: CASE STUDY<sup>1</sup>

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## Abstract

*Information, as the main asset of an organization, has been an incentive to building and use many Information Systems in order to satisfy a variety of needs. The heady growth of the Information Systems development has resulted in an industry with serious productivity and quality problems. There is a real need to focus on quality as a means of increasing its own productivity and its competitiveness. This explains why so many models have been designed to evaluate the process for developing Systems (CMM, PSP, BOOTSTRAP) and International Standards (SPICE) to ensure efficient quality management in this area.*

*The objective of this paper is to design, study and propose a model with a systemic approach, which would make it possible to estimate the level of quality present in the Systems development process. We also describe its application in a case study.*

**Keywords:** Information Systems, development process, quality model, process quality, systemic quality.

## Introduction

It is quite usual nowadays to focus on Quality as a means of increasing competitiveness in business (Hoyle 1998). Many industrial sectors have made numerous efforts to create incentives to improve the quality of their products. In many organizations quality has been achieved through trial and error, while others have attained it by implementing a Quality prediction and design process (Hoyle 1998).

Quality must be present in any customer targeted product or service. Organizations have therefore had to adopt standards and improve many of their processes to attain levels of acceptance in international markets. Organizations that develop Information Systems (IS) are no exception. They must offer very high quality products to remain competitive in a global market like today's. This situation leads developers to seek solutions to obtain quality products. They have to define the quality attributes of their products and also see that the software product development process is improved.

This article proposes a quality model with a systemic approach that enables its level to be estimated in the systems development process. We shall start by briefly describing the quality characteristics as the basis for defining the quality of systems with a systemic focus. Then we shall analyze the model proposed, and finally, in order to evaluate the model, we shall describe the application of the model and analyze the results.

## Theoretical framework

Quality is “any function or feature of a product or service that is necessary to meet a client’s needs or make it suitable for use” (Hoyle 1998). There are many features for determining Quality (Hoyle 1998). The features must be specified in order for Quality to be controlled, ensured, improved, oriented and proven. They are used as parameters to establish the requirements in many of the standards developed by the International Organization for Standardization (ISO) (ISO/IEC, 1998) such as ISO 9000, ISO 9001, ISO 9002 and ISO 9003. When the value of these features is quantified or qualified, one speaks in terms of Quality requirements.

For the Systems area, the former division between the product and the service does not apply. This is because, when considering the Systems as a process and a product, the service can be considered part of the product. This makes it harder to measure the Quality in this discipline. The metrics (numeral information) are indirect measurements of non-quantifiable

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properties (Voas 1999). The problem lies in the fact that many people still see metrics as absolute predictions for achieving Quality, which is not entirely true since metrics serve as a guide for achieving it.

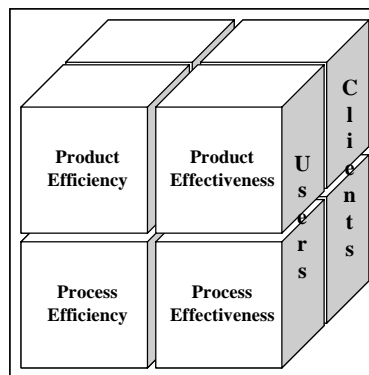
**Quality of Information Systems**

In this article, the term IS centers on software implementation, i.e. this plus the hardware and the organization under which it operates, and conceived as a whole made up of a process and a product. The foregoing is partially based on the idea expressed by Kobryn that satisfactory Systems projects tend to be associated with sound processes and robust architectures (Kobryn 1999). Furthermore, greater emphasis will be placed on the process than on the product; which does not mean that the latter loses importance, but that due to the complexity of the subject, we shall only refer to the systems development process in this article.

Quality of Information Systems (QIS) can be defined as the design of specifications written in the most effective manner possible (Boehm 1978). This term means adjusting them, as effectively as possible, to the true requirements of the business (or the user), by the time the System comes into operation (Hoyle 1998). QIS is a factor of competitiveness in Systems companies since they have to satisfy their clients’ needs in order to remain in the market and attain superiority and leadership. Therefore, another type of approach is proposed in order to satisfy the client, through which standardization is carried out on the Systems Process and Product. It is known as the Quality Matrix (Callaos & Callaos 1993) and is described below.

**Quality matrix: relationship between quality and efficiency, effectiveness and efficacy.**

The definition of Total Quality in the development of Information Systems covers the Systemic Quality Matrix shown in Figure 1, which consists of four types of Quality: product-efficiency, product-effectiveness, process-efficiency and process-effectiveness, without taking into account the client and/or user dimension. This division is justified in one sense because a project includes both efficiency and effectiveness; and in another because the System conceived (the product) is different from the System of human activities (the process) through which the System-product is designed (Rojas and Pérez 1995; Callaos and Callaos 1993). In using these approaches, the other tends to be ignored, which is why it is advantageous to apply the Quality Matrix in Systems.



**Figure 1. Global Systemic Quality Matrix (Callaos and Callaos 1993).**

**Model formulation**

A wide range of models is available for evaluating the quality of the software development process, such as: Personal Software Process (PSP) (Humphrey 1997), CMM (Baltzer et al. 1993), BOOTSTRAP (Engelbart and Engelbart 1990) and SPICE (ISO/IEC, 1998). None of these options explicitly considers the characteristics inherent in the development of Software Systems, such as process efficiency and process effectiveness for instance. The conflict arises because there is no process or product oriented model that supports the Systemic Quality proposed by Callaos & Callaos (1993). The solution proposed seeks to establish a model that integrates the Systemic Quality approach with the features present in the SPICE process model. The model proposed has a complex structure defined by level, where each higher level is made up of lower level elements. This structure is described following and shown in Figure 2.

**Level 0: Life Cycles.** As with the SPICE process model, three Life Cycles are considered. These are shown below:

- *Primary Life Cycle* is made up of two categories: Customer–Supplier and Engineering.
- *Support Life Cycle*, only contains the Support category.
- *Organizational Life Cycle* is composed of the Management and Organizational categories.

The inter-relationship between these cycles guarantees the quality of the Information Systems development process as far as all the areas characteristic of an organization’s operations are concerned.

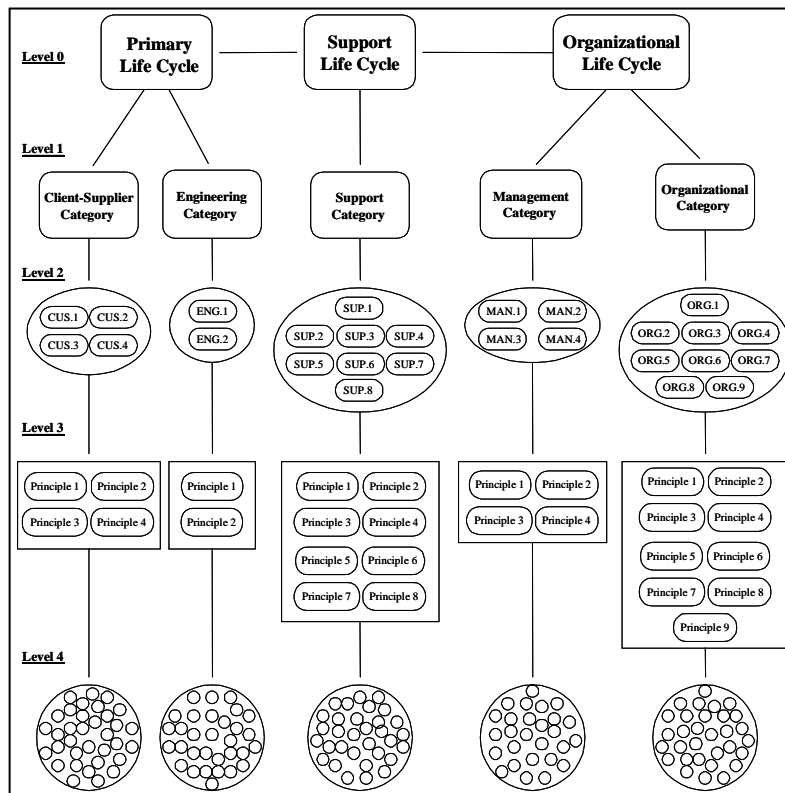


Figure 2. Structure of the model for evaluating process quality.

**Level 1: Category.** This model covers five categories of process, in accordance with SPICE. These are given below:

- *Customer-Supplier Category (CUS)* is made up of processes that have an impact on the client, support the development and transition of the Software to the client, and give the correct operation and use of the software product or service.
- *Engineering Category (ENG)* consists of processes that directly specify, implement or maintain the software product, its relation to the System and documentation on it.
- *Support Category (SUP)* consists of processes that can be used by any of the processes (including Support ones) at several levels of the acquisition Life Cycle.
- *Management Category (MAN)* consists of processes that contain practices of a generic nature that can be used by anyone managing any kind of project or process, within a Primary Life Cycle.
- *Organizational Category (ORG)* contains processes that establish the organization’s commercial goals and develop process, product and resource goods (values) that will help the organization attain the goals set in the projects.

**Level 2: Processes.** Each category has a set of characteristic processes that define the key areas to be met to achieve, ensure, maintain and control quality. Each process has an identifier associated with it that distinguishes it unequivocally. Table 1 shows the processes associated with each category.

Table 1. Processes for each category of model.

CATEGORY	PROCESSES	
Customer-Supplier	CUS.1 System or Product Acquisition Process	CUS.2 Supply Process
	CUS.3 Requirements Bidding Process	CUS.4 Operation
Engineering	ENG.1 Development	ENG.2 Software and Systems Maintenance
Support	SUP.1 Documentation	SUP.2 Configuration Management
	SUP.3 Quality Assurance Process	SUP.4 Verification
	SUP.5 Validation	SUP.6 Joint Review
	SUP.7 Auditing	SUP.8 Problem Solving Process
Management	MAN.1 Management	MAN.2 Project Management
	MAN.3 Quality Management	MAN.4 Risk Management
Organizational	ORG.1 Organizational Alignment	ORG.2 Change Management
	ORG.3 Process Set-up Process	ORG.4 Process Evaluation Process
	ORG.5 Improvement	ORG.6 Infrastructure Process
	ORG.7 Measurement Process	ORG.8 Re-use Process

**Level 3: Principles.** Each process has a Principle (P) associated with it, which is defined as an abstract and generic feature of the organization that serves as an indicator to determine the levels of quality in the development of Information Systems.

**Level 4: Base Practices.** A set of Base Practices (BP) is defined as a set of guidelines to be implemented by the organization in order to attain a principle; where each of these BP supports one or more dimensions of the Systemic Quality Matrix.

It should be noted that it was necessary to reasonably increase the number of BP present in the SPICE (ISO/IEC 1998) processes model, in order to ensure that the new model would maintain a balance in the dimension of the Quality Matrix process. **This balance is achieved by adding the BP that support the effectiveness of the process, since the model proposed by SPICE pays more attention to process efficiency than to process effectiveness** (Pérez et al. 1999). The BP added to the model were defined taking into account different factors that influence the effectiveness of the process. The factors indicated below were gathered through a bibliographical study on the subject conducted by different organizations (Silva 1996; Padrón 1998; Porras 2000): Technological variables, Organizational culture, Organizational change management, Group behavior (Leadership profiles, Communication standard, Influence strategies and Decision-making) and Organizational structure. The model has a total of 338 Base Practices. The Table 2 shows the number of BP that were proposed to balance the dimensions process-efficiency and process-effectiveness fixed by the Systemic Quality Matrix (Rojas and Pérez 1995; Callaos and Callaos 1993)

**Table 2. Number of BP to balance the process-efficiency and process-effectiveness dimensions.**

Total Number of Base Practices related to the process dimensions: 283	
Base Practiques of process-efficiency dimension: Total number: 148 – Proposed: 7	Base Practiques of process-effectiveness dimension: Total number: 135 – Proposed: 51

It is important to mention that **the increase in BP led to the birth of a new Process associated with the Organizational Category, known as Change Management (ORG.2). The purpose of this process is to plan, implement and control change when it is necessary to adapt to the environment outside the organization or when an improvement is necessary due to internal demands.** Figure 3 shows the Base Practices that make up this Process.

Identify and set up the best platform for the change	Maintain the impetus by providing resources for the change. Create a support system for the change agents, develop new techniques, competences and abilities and, lastly, strengthen new behaviors	Overcome resistance to change by encouraging the members of the organization to take part and show interest in planning and implementing change
Create willingness to change by disseminating information on the reason behind the change	Develop political support by evaluating the change agent, identifying stakeholders and influencing them	Manage the transition by taking into account the planning of organizational structures and activities
Turn intentions into real efforts by applying the change strategy	Develop a strategy for the change process	Focus the organization when it is going in the new direction, i.e. make the changes achieved permanent
Create a vision that provides an image of the future and the ways of adapting to it		

**Figure 3. BP that make up the change management process. Adapted from (Álvarez 2000).**

The model had to be evaluated through a case study which is described in the next section.

## Case study

In order to validate the proposed quality model, the model was applied to the two organizations. Not only did this enable the model proposed to be evaluated, but it also allowed the quality of the development process for Systems present in each organization to be estimated. The general features of companies are as follows:

- **Organization A:** characterized by being a small company, specializing in the development of automation solutions for the telecommunications industry. Its field of action is centered on the development of products and services for small and medium enterprises, through open, ready-to-run software packages.
- **Organization B:** is a large company that has become consolidated over the years and specializes in the financial area. The field of action of systems development is limited to one departmental unit.

In order to gather information for the study, some questionnaires (Álvarez 2000) were designed and validated as follows: measurement of the existence or absence of the process is determined from a series of questions corresponding to the BP which are intended to measure the level of satisfaction for each process, category and life cycle (primary, support, organizational) defined in the organization to be evaluated. The Figure 4 shown the outline of the questionnaires and a question example.

So the questionnaire covers three life cycles in keeping with the quality model proposed. There are five categories in line with the correspondence in the model. The key areas are equivalent to the processes associated with each category and serve as a connecting point between BP and the questions on the questionnaire. All the questions on the questionnaire were coded according to the following categories: YES, NO, N/A (Not Applicable), D/K (Don't Know). Therefore the answers corresponding to YES or NO were coded from one to zero respectively. The other two categories will only be counted to

determine the degree of applicability of the questionnaires (D/A) and the information present in the company (D/K). For the initial loading of the results on management, a basic table was defined which, for each questionnaire, contains general information on the person answering the questionnaire and the replies to each question.

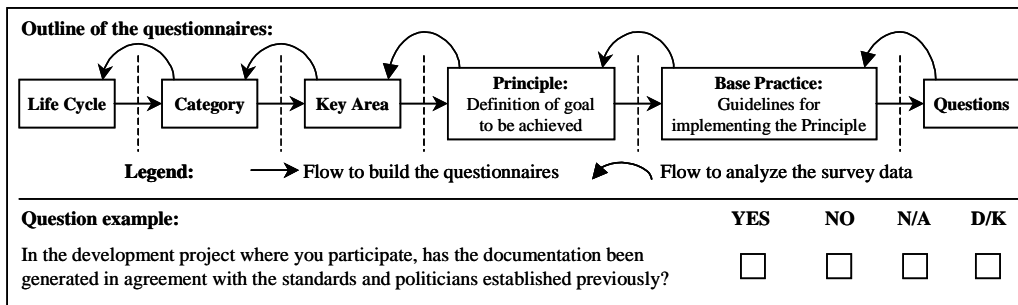


Figure 4. Outline of the questionnaires and a question example.

A pilot test was carried out with one Project Leader, one Analysts, and one Manager from each organisation, for the purposes of obtaining detailed feedback on the clarity of the questions and the overall comprehensibility of the instrument. The result of this pilot study led to some adjustments to the format of the questionnaire and terminology used. Before applying the questionnaire, the appropriate reliability test was conducted and the reliability value obtained was 0.659, showing that the internal consistency of the questionnaire is fairly reasonable (Hernández et al. 1998). Three categories of people were surveyed into the two organizations using the questionnaire: Analysts, Project Leaders and Managers.

**Method of analyzing the results: interpretation algorithm**

Once the questionnaire has been developed, validated and applied, the method for analyzing the data is defined. For this particular case an algorithm was implemented that will be used to interpret the results obtained from applying the questionnaire that was designed based on the algorithm proposed by Vásquez (Vásquez 1997). Figure 5 shows the interpretation algorithm used to analyze the results of the case study. It is important to stand out that the acceptability and conformity percentages were established according to the appreciations of the participant organizations in the case study and of the research team, on the base of the DESMET method (Kitchenham et al. 1996) it recommends for this study type.

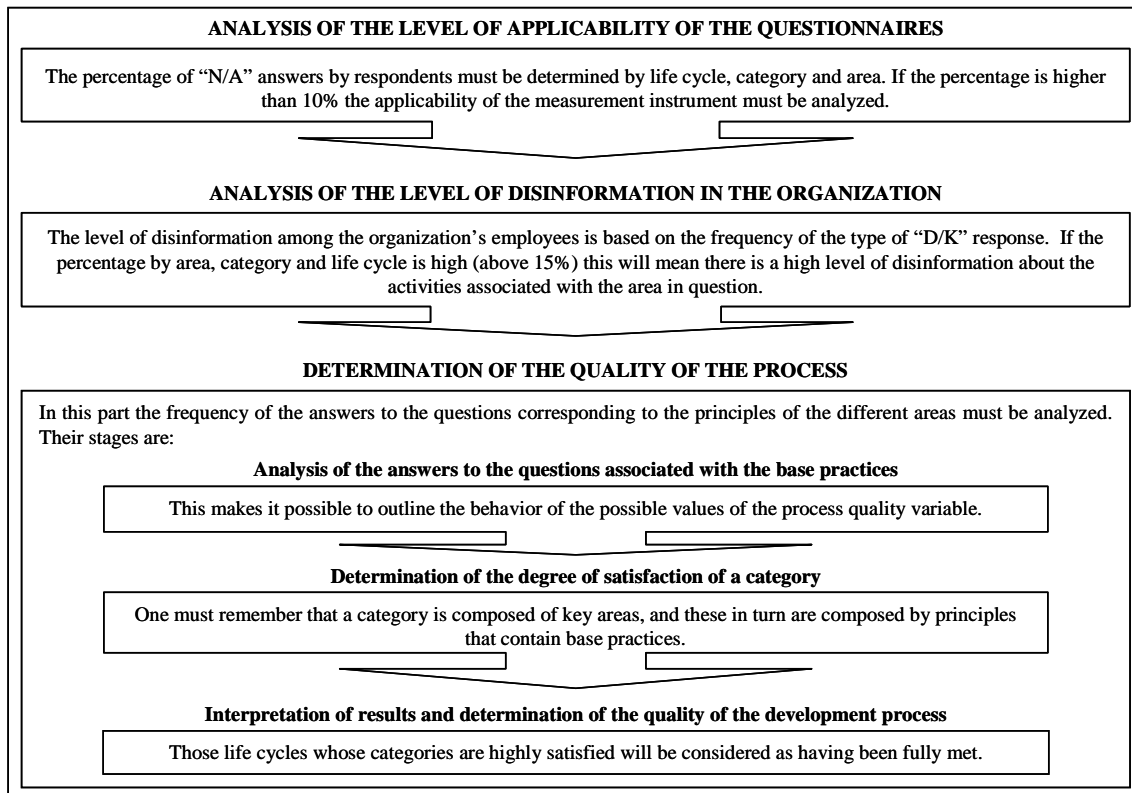


Figure 5. Algorithm interpreting the results of the case study. Adapted from (Álvarez 2000).

In the next section we shall discuss the results obtained through implementing the field study and the application of the analysis method.

## Results analysis

### Level of applicability of the instrument

The analysis of the percentage of 'N/A' replies answered by the respondents, by life cycle, by category and by area, meant the questionnaire had a high level of applicability in the organizations where it was applied, given the fact that the percentages were below 10%.

### Level of dissemination of information in the organization

Based on the analysis of the percentage of 'D/K' replies, there is obviously a greater degree of disinformation in organization "B" than in organization "A", none of the percentages of 'D/K' answers exceeded 10%. It can therefore be concluded that the higher the level of abstraction, in general, the better the level of information on the processes related to each of the life cycles. The results shown in the left side of Figure 4 were obtained based on the calculation of the percentages corresponding to the different types of answer, and the total answers to the questionnaire.

These results make it possible to predict the general behavior of the variable observed by this research (Process Quality). One can intuitively see then that probably the process for Organization "A" lacks quality since it has a high percentage of "NO" answers (70.8%). On the other hand, organization "B" cannot be subject to predictions because of the low degree of variability between the "YES" and "NO" responses, 50.0% and 41.2%, respectively.

### Determination of the degree of satisfaction of a category

The right side of Figure 6 shows the following:

- Organization "A" has implemented the Customer-Supplier (CUS), Engineering (ENG) and Management (MAN) categories, though not effectively. The Support (SUP) and Organizational (ORG) categories have still not been implemented.
- Organization "B" has implemented the Customer-Supplier (CUS) and Engineering (ENG) categories, since the level of satisfaction of both are above 75%. Even though they were implemented, the Support (SUP) and Management (MAN) categories have some effectiveness problems, and the Organizational (ORG) category has not been implemented.

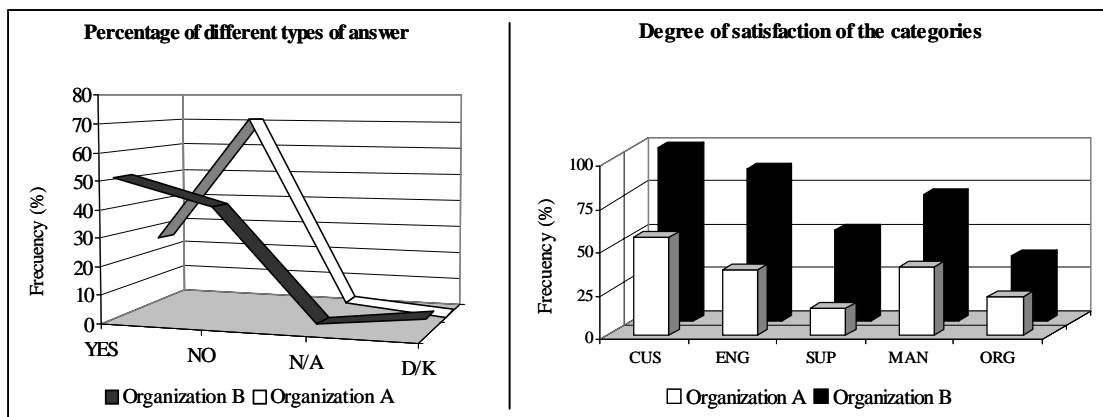


Figure 6. Percentage of different types of answer and degree of satisfaction of the categories.

### Interpretation of results and determination of the quality of the development process

The above analyses are summarized as follows:

Organization "A" lacks quality in the development process since none of its categories is fully satisfied. This implies that there is anarchy in the way the projects are implemented, leading to unpredictable results as far as implementation time and the results obtained are concerned.

Organization "B" has a basic type of quality, since the Customer-Supplier and Engineering categories are met, meaning that

## Conclusions

The difficulty in measuring quality has been ascertained and the efforts made to evaluate the quality of the systems development process described. The research shows that none of the models based on the process supports or fosters the Systemic Quality approach; consequently the model proposed is one based on the SPICE model, which would integrate its process model with the Systemic Quality approach.

An exploratory type study is carried out in two Venezuelan companies that develop Systems, using a questionnaire specifically designed for this research. Descriptive and Qualitative analysis statistics are used to analyze the data.

The information obtained enabled the systems development process to be improved in the organizations selected, and in all those interested in estimating the level of quality present in the Systems development process.

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## References

- Álvarez, A., *Modelo para la Evaluación de la Calidad del Proceso de Desarrollo de Sistemas*, Caracas, Venezuela: Universidad Simón Bolívar, 2000.
- Baltzer, A., Daryanani, S., and Díaz S., *Modelo de Capacidad de Madurez (CMM) del SEI*, Madrid, España: Addison Wesley Iberoamericana, 1993.
- Boehm, B. W., *Characteristics of Software Quality*, New York, New York: North Holland, 1978.
- Callaos, N. and Callaos, B., "Designing with Systemic Total Quality", in *International Conference on Information Systems*, N. Callaos and B. Sánchez (eds.), International Institute of Informatics and Systemics, Orlando, 1993, pp. 548-560.
- Engelbart, D., and Engelbart, C., "Bootstrapping and the Handbook Cycle", *Telematics and Informatics* (7:1), January 1990, pp. 27-32.
- Hernández, R., Fernández, C., and Baptista, P., *Metodología de la investigación*, México D.F., México: Mc Graw-Hill Interamericana, 1998.
- Hoyle, D., *Manual de Sistemas de Calidad*, Madrid, España: Editorial Paraninfo, 1998.
- Humphrey, W., *Introduction to the Personal Software Process*, Cambridge, Massachusetts: Addison Wesley Longman, Inc., 1997.
- International Organization for Standardization, Software Process Assessment, TR 15504, on-line, WG 10: Software Process Assessment, <http://www.sqi.gu.edu.au/spice/>.
- Kitchenham, B., Linkman, S., and Law, D. "DESMET: A method for Evaluating Software Engineering Methods and Tools", *Technical Report [ISSN 13 53-7776] (TR96:09)*, Department of Computer Science, Keele University, 1996, pp.1-67.
- Kobryn, C., "UML 2001: A Standardization Odyssey", *Communication of the ACM* (42:10), October, 1999, pp. 29-37.
- Padrón, J.Y., *Efectividad en el desarrollo de los SI: Administración del cambio y estructura organizacional*, Caracas, Venezuela: Universidad Simón Bolívar, 1998.
- Pérez, M., Rojas T., Ortega, M., and Caldera, A. "Toward Systemic Quality: Case study", in *4Th Squad Meeting*, Squad, Porlamar, Venezuela, July 1999, <http://www.lisi.usb.ve/publicaciones>.
- Porras, L.O., *La cultura de la organización y el proceso de desarrollo y mantenimiento de sistemas de información*, Caracas, Venezuela: Universidad Simón Bolívar, 2000.
- Rojas, T. and Pérez, M., "Improvement in the Development of Information Systems by increasing its Process Effectiveness", in *InterSymp '95 - 5th International Symposium on Systems Research, Informatics and Cybernetics*, N. Callaos y B. Sánchez (eds.), International Institute of Informatics and Systemics, Baden-Baden, 1995, pp. 36-42, <http://www.lisi.usb.ve/publicaciones>.
- Silva, M., *Factores incidentes en la efectividad del proceso de desarrollo de Sistemas de Información*, Caracas, Venezuela: Universidad Simón Bolívar, 1996.
- Vásquez, J., *Método evolutivo de madurez organizacional en relación al proceso de desarrollo de software*, Caracas, Venezuela: Universidad Simón Bolívar, 1997.
- Voas, J., "Software Quality's Eight Greatest Myths", *IEEE Software* (16:5), September/October, 1999, pp. 740-745.