WORK-TASK: COMPUTER SYSTEM FOR SHORT AND MEDIUM-TERM PRODUCTION PLANNING AND CONTROL

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ABSTRACT

This work aims at presenting a computer system developed to integrate the preparation stages of medium-term plan, constraint identification and analysis, and short-term plan. The computer system proposed in this study is strongly based on the Last Planner system, designed for production planning.

The system is developed on the basis of a 16-month research project. A bibliographic review was conducted on production planning and control areas. This literature review showed that there are few systems designed to implement the concepts and principles of the Last Planner, freely available for construction companies.

The Work-Task allows the development of short and medium-term planning through weekly spreadsheets, graphics and reports. The system also permits constraint controlling and indicates the problems to be solved so that the planned tasks can be executed on schedule. The constraints are stored in a module of the program called C.A.S (Constraint Analysis System) and may be viewed, edited, and controlled to avoid interruptions. The purpose is to facilitate the implementation of concepts and principles of the *Last Planner* system within civil construction companies.

KEY WORDS

Last planner system, production planning, control, constraint, information system.

INTRODUCTION

Last Planner production planning methodology has been diffused through Brazil during the last ten years. In this period, papers were published in different national and international congresses reporting the different experiences of various researchers.

In Brazil, this methodology is generally implemented through electronic spreadsheets, a fact that can be initially explained by their ease of use by most professionals involved in production planning. Second, computational systems following the Last Planner approach are not easily found in the building industry: they were normally developed by scholars and are

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generally sold through consulting services. Obviously, this discourages the use of such solutions due to the necessary investments related to system acquisition.

However, the use of electronic spreadsheets can harm the diffusion of concepts associated to Last Planner due to a low efficiency in planning preparation, even more if the spreadsheet demands the filling out of a large number of fields. In spreadsheets, it is easier to lose data from copy-paste or cut-paste procedures, resulting in data inconsistency among different plans due to information duplicity or lack of data. Finally, through spreadsheets, the constraint analysis process is inefficient, with a reflection in the low reliability of short-term production plans, since constraints which are essential for the continuity of operations are frequently not identified and removed in due time.

A possible strategy for the dissemination of Last Planner concepts in the building industry is through computational tools, which must increase the efficiency of those responsible for the preparation and control of production plans. Thus, data can be stored and analyzed by different professionals and building companies.

In this paper, the Work-Task computational system is presented. Its main objective is to facilitate the dissemination of the Last Planner methodology. Therefore, a strategy to make it freely available to the market and research institutions was sought. Also, an attempt was made to develop it trough an interface resembling electronic spreadsheets, aiming at mitigating the aforementioned problems. The implementation of Last Planner concepts can be facilitated since the use of Work-Task does not represent a substantial change in work habits of production planning professionals.

BACKGROUND RESEARCH

The analysis of the literature on system development revealed that most software are, in general, aimed at complex projects, managed by large and medium-size building firms. A few of the reviewed papers showed the importance of using graphic tools in order to facilitate system use.

Chau & Zhang (2005) developed a system prototype aimed at site management and whose peculiarity is the connection between the construction plan and the 3D model of the edification. The authors stress the importance of the proposed system for the management of complex projects, ever more present nowadays.

Sadeghpour et al. (2004) present a CAD-based model for site planning. According to these authors, the system allows site layout analyses providing greater support to the decision-making process of those responsible for construction management.

Soibelman & Garret (2005) report the need of an advanced data management system in civil construction. According to them, this is a means of guaranteeing that information exchange and integration be efficient among the different agents involved in construction process. In their framework, CAD4D and the use of new sensor technologies, radio frequency identification tags and wearable computers are presented as necessary elements for construction management.

Ma et al. (2005) present a 4D computational system aimed at integrating AutoCAD with MS-Project. Through the system one can follow a schedule and obtain a simultaneous 3D visualization of the site.

Another aspect of research on IT applied to civil construction companies is the need to integrate all intervening agents. In general, integrated systems have the Internet as the element that can improve the company-environment information flow.

Rischmoller & Alarcón (2005) presented a framework for the study of IT applied to civil building. According to it, civil construction is dealing with multiple agents, of different sizes and different IT cultures.

Lam & Thomas Ng (2006) developed a prototype system for quality management based on the Internet as the means to organize the checking, reporting and auditing of a building firm. The aim is to have an easier and more agile quality management.

According to Nitithamyong & Skibniewski (2004), the fragmentation of civil construction is seen as one of the main causes for the sector low productivity. The authors discuss the factors that increase the likelihood of success in web-based construction projects management systems. However, one of the barriers for the implementation of such systems is the resistance of a few users, particularly if they already have a well-established work pattern.

Lee et al. (2006) presented a system that aimed at supporting the tactical and operational aspects of management. The authors emphasize the use of their systems in complex projects.

According to Arayici & Aouad (2005), the avoidance of integrated computational systems by building industry professionals is explained by their difficulty in using such systems. The authors highlight that a successful approach must value simplicity and the integration of in-use systems.

However, another research line is directed towards computational systems that use pre-existing management techniques. Soini et al. (2004) report the development of a computational system for the application of Line-of-Balance. Huang & Sun (2005) developed a system for non-unit based repetitive scheduling. Their system attempts at dealing with situations involving repetitive activities, but whose resource needs, costs and time may differ among repeating units.

Regarding lean construction, there are research lines pursuing systems based on management techniques. Choo et al. (1999) present a system based on Last Planner methodology. It facilitates the identification of constraints associated to production tasks, thus allowing the designation of constraint-free work packages to teams, increasing production plan reliability.

Alarcón & Calderón (2003) developed a system that supports the dissemination of Last Planner concepts. Although the authors work with a spreadsheet-based platform, there is no explicit definition of the user interfaces in the paper.

Kankainen & Seppänen (2003) studied the connection of a commercial software called DYNAProject^{TM} with lean construction principles. The system uses the line-of-balance technique and the authors recognized that unfamiliarity with the technique is a major barrier to its implementation.

The literature reviewed converges on the efficiency benefits of the use of computer systems in project management. However, such systems are directed to medium and large firms, which operate with a large number of contractors and with complex costly projects, sometimes costing millions of dollars. Similar research for small firms and projects has not been detected.

RESEARCH METHOD

This research tried to find an answer to the following question: how to develop a computer system that can help the dissemination of Last Planner concepts among small civil construction firms? Last Planner methodology was chosen for it is associated to many successful results reported in the literature (Ballard e Howell, 1998; Ballard, 2000).

The following was determined initially: the system should not cause substantial changes in the user's work routine. Therefore, an 18-month project began, with the aim of identifying the main requisites of the to-be-developed computer system.

The research method was divided in five main stages:

- Background research: many works were studied in order to identify the strategies adopted for the development of project management and production management systems. A compilation of the main and most recent papers is present in this paper.
- Analysis of the application of Last Planner methodology in construction projects: the analysis was based on the experience of one of the authors with the implementation of the Last Planner methodology in 30 construction projects (Bernardes, 2001).
- Analysis of existing systems: three commercial software and two developed in Universities were analyzed. The analysis criteria were fixed in order to allow a comparison with the Work-Task system.
- Development of the Work-Task system: the system was developed in Visual Basic, a language mastered by the development team. One aim was to automate tasks that were manually performed by Last Planner methodology users, in order to increase efficiency and avoid the abandonment of the tool due to difficulties in its use.
- Laboratory validation: after development, there was the laboratory validation of the system. This was performed in a small construction firm in Porto Alegre, RS, Brazil. During the validation process, the firm continued applying the Last Planner methodology through electronic spreadsheets. During the project, an attempt was made to implement the Last Planner methodology through the Work-Task system. However, in order to avoid radical changes in the firm's work routines spreadsheets were used in the construction site. Therefore, one of the professionals responsible for the construction planning used the Work-Task system in four meetings, during four weeks, in the laboratory facilities of the Federal University of Rio Grande do Sul/Brazil. In the first meeting, the professional received a brief training on the system. Next, he used the system to develop production plans. The work team followed the process recording the professional's questions about the system. Suggestions from the professional caused systems improvements.

LAST PLANNER METHODOLOGY AND WORK-TASK SYSTEM

The Last Planner methodology has among its main objectives the increase in the reliability of production plans. Thus, it is based on an approach that tries to identify the tasks that can be performed, through a detailed work of constraint detection and removal.

The methodology can be implemented through the development of medium- and short-term production plans (Ballard, 2000). Medium-term planning aims at linking master plan goals to those assigned in short-term production plans. Planning at this level is called Lookahead Planning (Ballard, 1997). Through this, workflows are analyzed, with the aim of obtaining a sequence that reduces the number of activities that do not aggregate value to the productive process (Ballard, 1997). The activities proposed in this type of plan describe the construction process to be used (Tommelein et al., 1994), including specification of constructive methods and identification of resources that are necessary to execution (Tommelein & Ballard, 1997).

With an interface that is similar to that present in spreadsheets usually employed by building companies, the Work-Task system attempts to facilitate the implementation process of the Last Planner methodology. Figure 1 shows a standard window of the system for a pilot project. As it can be seen, the window provides low-complexity menus and it is very similar to a spreadsheet.

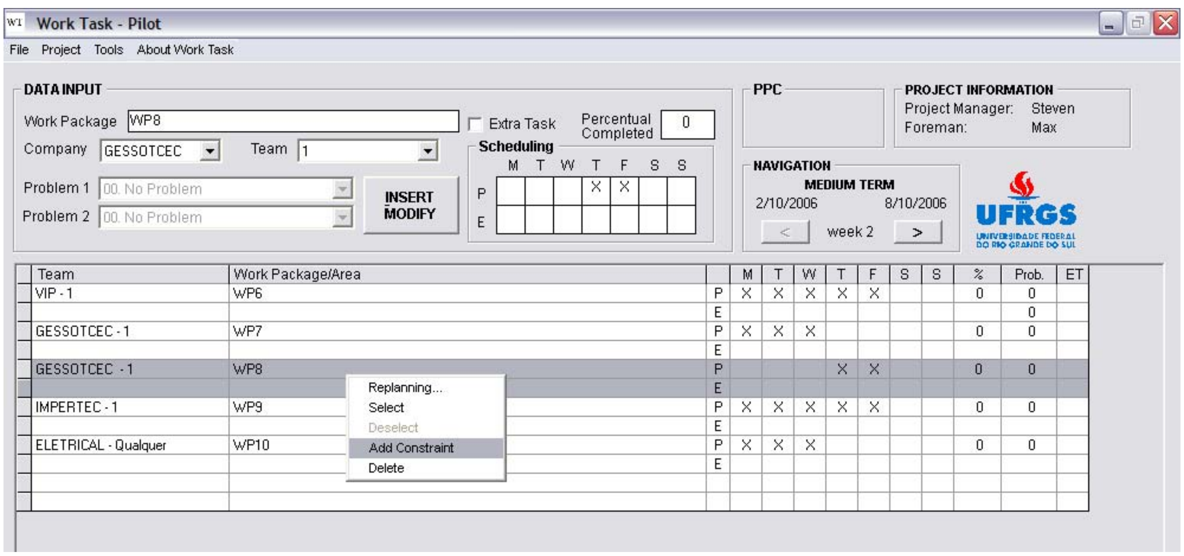

Figure 1 – Development of the medium-term plan

An effective constraint management is a way to avoid interruptions to the workflow. The constraint management is conducted through a module of the Work-Task system called C.A.S. (Constraint Analysis System). With the C.A.S it is possible to link different types of constraints to a given work package, minimizing thus the chances of errors when a late removal of a constraint occurs (Figure 2).

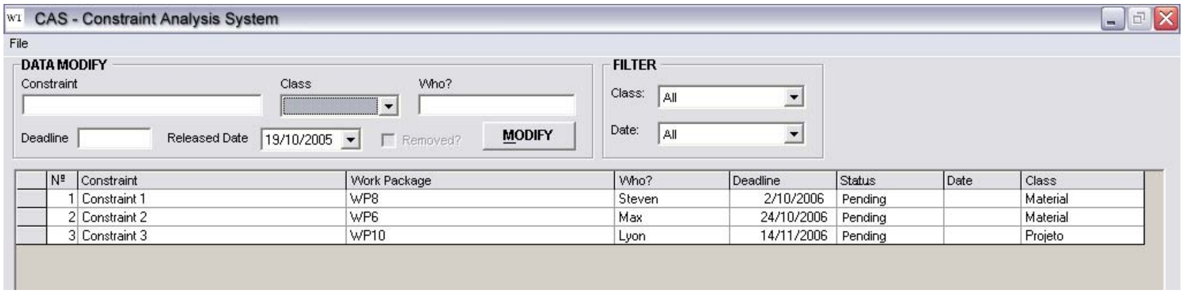

Figure 3 – Constraint Analysis System

Ballard & Howell (1998) propose a short-term planning that should be developed based on actions directed to protect production against the effects of uncertainty. According to their work, it is possible to protect production by employing tangible plans. This is achieved as these plans are submitted to an analysis of requirement compliance and an analysis of problems that cause interruption to the workflow (Ballard & Howell, 1998). In the Work-Task system, the short-term planning is developed in a spreadsheet that is identical to that of the medium-term, which makes its application much simpler (Figure 3).

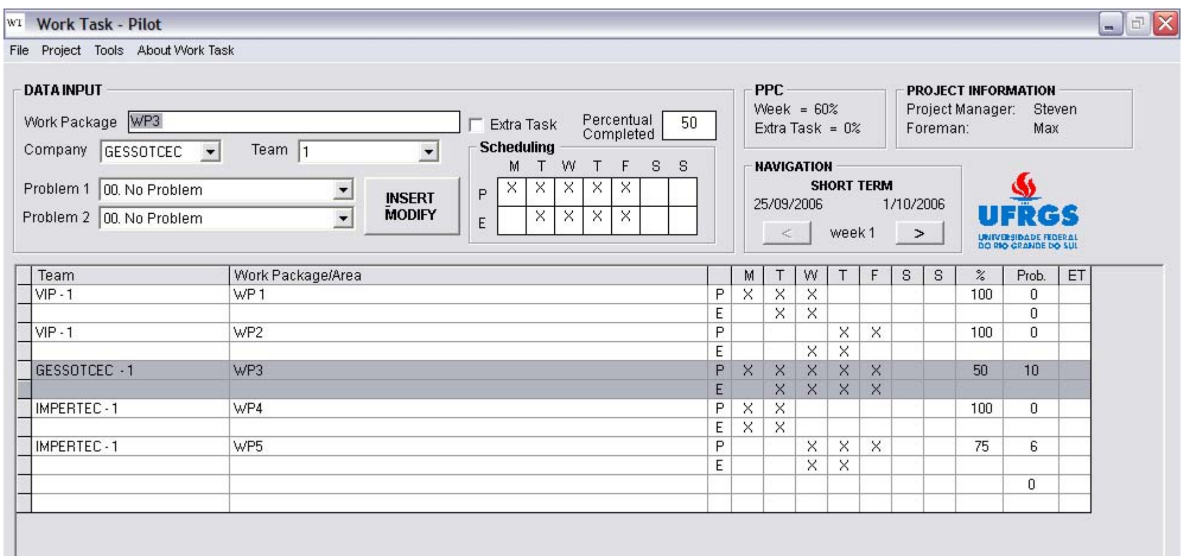

Figure 3 – Development of the short-term plan

According to Henrich et al. (2005), the Last Planner methodology is better suited for complex projects with a large number of discrete tasks, in which it is usually important to keep critical tasks under control. However, low-complexity projects also produce positive results when this methodology is applied (Bernardes, 2001).

COMPARATIVE ANALYSIS BETWEEN THE WORK-TASK SYSTEM AND SIMILAR SYSTEMS

For this research, an attempt was made to conduct a comparative analysis between the Work-Task and similar systems directed towards project and production management. Throughout the project, it was possible to find two systems developed by two Universities. Despite all efforts, the authors of these systems refused to make a demo version available for analysis. The analysis was then based on data extracted from articles published by these authors.

As for commercial systems, two companies – notably recognized in the Brazilian civil construction market – offered demonstrative versions for analysis. A third system was obtained by loan from research projects conduct in the Federal University of Rio Grande do Sul/Brazil.

After the analysis of the published papers and of the available computer systems the following was concluded:

- Commercial systems present integrated solutions for different company areas. They can be acquired integrally or in modules and present a CPM-based interface for the project management. The investigated systems required intensive training, since they have various data input and data analysis windows. Production planning uses a few elements from the Last Planner methodology, such as the identification of the resources that are required to maintain the workflow. However, the use of those systems can be complicated by the excessive number of steps and procedures required for data input. Also, the systems did not allow integration with other computer systems in the company.
- The systems presented in scientific papers presented integrated solutions only for the production management area, not for other functional areas. Although they have the Last Planner methodology in their conception, one notices that they propose new work routines, implying extra employee training hours. One of the systems is not even available on the site mentioned in the paper.
- The Work-Task system does not have modules directed to the integration with other company areas. However, since it is free software, it can have its code altered so as to facilitate integration. The system uses only one standard window, thus facilitating its implementation and increasing its continuous usage in the company.

WORK-TASK VALIDATION

The validation of the Work-Task system occurred in a four-week period. The option made was to validate it in a building company in Porto Alegre/Brazil. The company had implemented the Last Planner methodology in a 24-week construction project (the industrial pavilion for a logistics operator). The implementation was followed by one of the authors of this paper, who performed diagnoses of the company production planning process. Normally, the company allocated an engineer to be the technically responsible person of the project. The professional was also responsible for project planning, using Gantt diagrams prepared via MS-Excel or MS-Project. Therefore, the plans had a low level of details and there were no formal operational plans to help production management.

Before implementation, one of the authors taught a course aimed at disseminating the Last Planner methodology. Two of the company's engineers attended the course, which was followed by a seminar about the company implementation strategy for the methodology.

Regarding the strategy, it was decided that the production planning and control system would be developed in two basic levels: tactical and operational. Initially, at the tactical level, a CPM would be elaborated aimed at identifying the task sequence that was better suited to the project. At the operational level, the system would include the Last Planner methodology. However, since the Work-Task system was in its final development stage, MS-Excel was used in support to the methodology implementation.

During 24 weeks, a weekly meeting was held at the site in order to update the tactical planned developed with MS-Project. Moreover, medium-term and short-term plans were prepared with MS-Excel. Throughout each week, plans were checked and control reports generated – a control report was prepared in the week following the plan update.

The Work-Task system was validated in the company after 16 weeks. Its implementation occurred in parallel with the system implementation, i.e. the spreadsheet routine was not abandoned in the meantime.

Validation occurred in a laboratory that belonged to the Federal University of Rio Grande do Sul (UFRGS). An employee would visit the laboratory once a week to review the plan created for the Work-Task system during site meetings. On the first meeting, the employee received system training and he was then requested to transfer the site plans to the Work-Task system.

On the fourth meeting, the employee was enquired on the Work-task system ease-of-use, in comparison to the manner in which the Last Planner methodology had been used from the beginning of the project. The focus of the questioning was easiness of use in short- and medium-term production plans, constraint management, and control report generation. The employee stated that the system rendered the plan/report preparation and control processes more agile, and added that the systematic of constraint identification and control was easier, since the system would use a graphic format and would integrate constraints with the medium- and short term planned tasks.

After week 24, the end of the project, a seminar was held, aiming at detecting actions for a generalized implementation of the Last Planner methodology for other projects. The seminar involved the company owner, the project engineer and a third engineer from the company. During the seminar, the present were requested to identify problems and put forward suggestions that would allow an improvement in the Last Planner methodology implementation. The conclusion was that the Work-Task system should be used in other company projects because it facilitated methodology implementation, reducing planning and control times.

CONCLUSIONS

Through this research, it was verified that there is a scarcity of works related to the development of computer systems for small construction firms. In general, systems are developed with an eye on medium and large companies and for complex projects.

The strategy adopted in the development of the Work-Task system can be considered as the main contribution of the present work, because it does not cause a radical change in the modus operandi of the company during the Last Planner methodology implementation: in fact, the application of Work-Task facilitates the implementation. However, as in any new computer system, users must be trained and system usage must be part of the company strategic planning.

Background research and the analysis of past implementation studies (Bernardes, 2001) were fundamental for the definition of system requirements. Bernardes (2001) noticed that, on many instances, purchased systems were not used by construction companies because of the great effort required during implementation. This could be reverted if there were a gradual transition from the old to the new work manner. In this transition stage it is important to recognize and improve the elements that render user work more efficient. Thus, interface simplicity can be an advantageous aspect towards a successful implementation.

The Work-Task system was released free of charges at the site www.ndprodutos.ufrgs.br, in the download area. This was a strong attractive for small construction firms in Brazil, as confirmed by the emails received after the release. However, there seems to be a limit for which simplicity acts favorably during implementation. There is no definite answer as to how complexity interferes in system implementation, a subject that will be pursued in further researches.

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REFERENCES

Alarcón, L, Calderón, R. (2003). "A production planning support system for construction projects." *Proc., 11th Annu. Conf. on Lean Constr.,* Virginia Tech, Blackburg, Virginia, USA, July 2003.

Arayici, Y., Aouad, G. (2005). "Computer integrated construction: an approach to requirements engineering." Emerald, *Engrg., Constr. and Architectural Mgmt*., 12 (2) 194-215.

Ballard, G., Howell, G. (1998). "Shielding Production: An essential step in production control." ASCE, *J. of Constr. Engrg. and Mgmt*., 124 (1) 18-24.

Ballard, G. (1997). "Lookahead planning: The missing link in production control." *Proc., 5th Annu. Conf. on Lean Constr.,* Gold Cost, Australia, July 1997.

Ballard, G. (2000). *The Last Planner System of production control.* Ph.D. Diss., Faculty of Engrg., University of Birmingham, 192 pp.

Bernardes, M. (2001). *Production planning and control model for small-sized construction companies.* Dr. Diss., School of Engrg., Civil Engrg. Department, Federal University of Rio Grande do Sul, 289 pp. (in portuguese).

Chau, K. et al. (2005). "4D dynamic construction management and visualization software: 2. Development." Elsevier, *Automation in Constr.*, (14) 512-524.

Choo et al. (1999). "WorkPlan: Constraint-based database for work package scheduling." ASCE, *J. of Constr. Engrg. and Mgmt*., 125 (3) 151-160.

Henrich et al. (2005). "Context of production control in construction." *Proc., 13th Annu. Conf. on Lean Constr.,* University of New South Wales, School of Civil and Environmental Engineering, Sidney, Australia, July 2005.

Huang, R., Sun, K. (2005). "System development for non-unit based repetitive project scheduling." Elsevier, *Automation in Constr.*, (14) 650-665.

Kankainen, J., Seppänen, O. (2003). "A Line-of-balance based schedule planning and control system." *Proc., 11th Annu. Conf. on Lean Constr.,* Virginia Tech, Blackburg, Virginia, USA, July 2003.

Lam, K., Thomas Ng, S. (2006). "A cooperative Internet-facilitated quality management environment for construction." Elsevier, *Automation in Constr.*, (15) 1-11.

Lee et al. (2006). "Dynamic planning and control methodology for strategic and operational construction project management." Elsevier, *Automation in Constr.*, (15) 84-97.

Ma et al. (2005). "Application of 4D for dynamic site layout and management of construction projects." Elsevier, *Automation in Constr.*, (14) 369-381.

Nitithamyong, P., Skibniewski, M. (2004). "Web-based construction project management systems: how to make them successful?" Elsevier, *Automation in Constr.*, (13) 491-506.

Rischmoller, L., Alarcón, L. (2005). "Using lean principles as a framework to study information technology in construction." *Proc., 13th Annu. Conf. on Lean Constr.,* University of New South Wales, School of Civil and Environmental Engineering, Sidney, Australia, July 2005.

Sadeghpour et al. (2004). "A CAD-based model for site planning." Elsevier, *Automation in Constr.*, (13) 701-715.

Soibelman, L., Garret, J. (2005). "Advanced construction data management to support proactive project control." *2nd. Seminar on Information Technology and Communication in Civil Constr.,* University of São Paulo, São Paulo, Brazil, Apr. 2005.

Soini et al. (2004). "Implementation of Line-of-balance based scheduling and project control system in a large construction company." *Proc., 12th Annu. Conf. on Lean Constr.,* LO-School, Copenhagen, Denmark, Aug. 2004.

Tommelein et al. (1994). "Assembly of simulation networks using designs, plans, and methods." ASCE, *J. of Constr. Engrg. and Mgmt.*, 120 (4) 796-815.

Tommelein, I. D., Ballard, G. (1997). "Lookahead planning: Screening and pulling." *Proc., 2nd. Int. Seminar on Lean Constr.,* October 1997, A. S. I. Conte, Logical Systems, São Paulo, Brazil.