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# A FRAMEWORK FOR AUDITING WEB-BASED INFORMATION SYSTEMS

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## Abstract

*The last decade has seen an unprecedented rate of development of Web-Based Information System (WBIS). Enormous investment is currently being made in WBIS systems. There is a concern about whether the true capability of WBIS is being realized. As a consequence, growing attention is being paid to assessing the inherent contribution of WBIS. In this paper, we propose a WBIS audit methodology. The latter has two main features: 1) it structures the audit process as a hierarchical evaluation tree, using an Analytic Hierarchy Process model, 2) it allows the evaluation of a WBIS according to a specific set of criteria based on quality, security and readability requirements. Unlike past approaches, our methodology allows independent auditors, companies and users to minimize the time and effort needed to evaluate WBIS. It has been applied to a real-life example which is described in the paper, allowing us to validate our WBIS audit approach.*

*Keywords: web-based information systems, information system evaluation, audit methodology, IT effectiveness, audit tree, analytic hierarchy process.*

# 1 INTRODUCTION

The advent of leading edge auditing techniques which allow auditors to identify risks and evaluate the adequacy of controls over critical information systems in their organizations, has far reaching consequences for many areas of companies' activities. Although such auditing techniques are still in the early stages of development, the impetus towards their improvement is such that it has changed the character of research carried out mainly by the industrial research community. A large proportion of the current research effort is limited to the researchers that are normally associated with professional associations and organizations related to information systems auditing (Champlain, 1998). We argue that evaluation of WBIS is relevant for many IS people, both in industry and academia. As a consequence, work relating to the development of audit methodologies and tools is now carried out by information systems scientists (Akoka et al., 2000; Atzeni et al., 2002; Nicho 2008). The theoretical developments necessary to understand auditing methodologies are leading to major advances and are expected to have implications in information systems auditing techniques and tools. Auditing methodologies become increasingly important as organizations rely heavily on their information systems. The last decade has seen an unprecedented rate of development of web-based information systems which has created the opportunity for sophisticated WBIS, such as portals, on-line gaming, infotainment, aggregators, e-commerce applications, CRM (Customer Relationship Management) and EAI (Enterprise Application Integration) applications. During this period, the concept of Management Information Systems (MIS) has evolved from earlier uses of legacy systems. It is now defined to include advanced web-based systems. Enormous investment is currently being made in web-based information systems (Webb et al., 2006). There is a growing concern about whether the true capability of web-based information systems is being realized. The demand for WBIS audit has increased since the promulgation of the Sarbanes Oxley Act (Brown et al., 2005). The research described in this paper centers on the issue of Web Based Information Systems (WBIS) auditing. We present a methodology for the assessment of WBIS using criteria segmented according to three vantage points: quality, security, and readability requirements. This methodology, although aimed at independent auditors, allows companies and users, facing a shortage of audit expertise, to evaluate their WBIS with a minimum cost. This methodology can be applied to auditing different types of static WBIS and/or dynamic WBIS.

The structure of the paper is as follows: first, we briefly review in Section 2 current thinking on web-based information systems in the light of auditing. In Section 3, current auditing methodologies and techniques are reviewed. A special attention is devoted to COBIT (Control OBjectives for Information and Related Technology), the most recent and comprehensive internal control framework. In Section 4, we describe our web site auditing methodology. The description includes the key issues of information system auditing as well as the particular process which can be applied to web site evaluation. This methodology has been applied to a real-life example. The results are presented and discussed. Finally, in Section 5, we present some concluding remarks and identify some related problems for further research.

# 2 WEB BASED INFORMATION SYSTEMS

During the last decade, the impact of the web has transformed the role of information technologies from supporting legacy systems to collecting and delivering valuable data, allowing companies to determine customer buying habits and provide them better services. It is generally admitted that the Internet commerce technologies have reduced the cost of collecting buyer preference information (Dewan et al., 2000). WBIS are specific Information Systems (IS) taking advantages from the web technology, tightly integrated with legacy IS (Wang, 2001). An extensive analysis of WBIS can be

found in (Guo, 2008). WBIS are composed of five major components: the web site, online business processing, knowledge management, database, and software agents. It goes beyond the opportunities and services offered by web sites by supporting business processes.

There are several fundamental differences between traditional legacy systems and web-based information systems. The *technical dimension* of the latter attempts to expand the basic power of systems. New architectures, increased storage and access to information are processed more quickly and more efficiently. The *functional dimension* allows users to add specific functions that can be achieved in a more "intelligent" way. The *product dimension* is related to the ability of software editors to implement new products as well as new developments in commercial products. The final dimension concerns the aspects of *human use* of such web-based information systems and the effects they have on the user. The types of WBIS are vast and ever expanding. They include static and dynamics WBIS.

WBIS are considered to be suited to large-scale commercial exploitation. They offer a wide range of information content. They appeal and have value to a much wider public and not only to specialists or specific area users, as it is the case for legacy and traditional information systems. As a consequence, specific approaches are needed to evaluate them. Although the need for auditing web-based systems is as crucial as for auditing legacy systems, the way and means to perform such auditing process should take into account the specific dimensions discussed above. We propose specific ways of organizing the audit process, by capitalizing on approaches used in the past to evaluate legacy systems.

# 3 AUDITING INFORMATION SYSTEMS – A STATE OF THE ART

Information system auditor's main objective is to formulate an opinion about the effectiveness and the contribution of information systems to enterprise objective (Collier et al., 1995). His or her judgment can be influenced by factors such as his knowledge of the organization information systems, and the degree of risk of misstatement through errors. More generally, the purpose of an information technology (IT) audit is to evaluate IT controls (Mahnic et al., 2001). An IT auditor assesses and advises on the following aspects of information technology: effectiveness, efficiency, exclusiveness, etc. (Hermanson, 2006). A number of evaluation methods have been proposed to evaluate information systems as well as WBIS. Those that receive a special attention include balanced scorecard (Deschoolmeester et al., 2000), simulation (Anderson, 2000), and dynamic systems development method (Barrow et al., 2001). These methods are all of a multidisciplinary nature. They are based on evaluation theories, such as the economic theory (Svavarsson, 2002), the interpretive approach (Abu-Samaha, 2000), the critical approach (Jones et al., 2002), the structuration theory (Jansen et al., 2004), the ground theory (Jones et al., 2001), the contingency approach (Turk, 2000), the option theory (Svavarsson, 2002), and the social theory (Berghout et al., 1996). The variety of approaches, such as COBIT, ITIL, ValIT, etc., (ITGI, 2005) illustrates the lack of consensus (Chang et al., 2005; Simonsson et al., 2007). Although there is no common understanding regarding the appropriate evaluation theory, however, there are three main concepts that structure the audit process (ITGI 2005): information systems processes and domains, audit criteria, and audit framework.

## 3.1 Information Systems Processes and Domains

To ensure that information systems are functioning in an efficient and effective manner to help the organization achieve its strategic objectives, an audit process must be performed. This task involves analyzing information systems processes. Individual activities within an information system can be grouped into processes. The COBIT framework (ITGI 2005) identifies 34 information technology processes. The latter are grouped into four domains (Fig. 1).

| **Planning and Organization** | **Delivery and Support** |
|---|---|
| Define a strategic IT plan | Define service levels |
| Define the information architecture | Manage third-party services |
| Determine the technological direction | Manage performance and capacity |
| Define the IT organization and relationships | Ensure continuous service |
| Manage the IT investment | Ensure systems security |
| Communicate management aims and direction | Identify and attribute costs |
| Manage human resources | Educate and train users |
| Ensure compliance with external requirements | Assist and advise IT Customers |
| Assess risks | Manage the configuration |
| Manage projects | Manage problems and incidents |
| Manage quality | Manage data |
| **Acquisition and Implementation** | Manage facilities |
| Identify solutions | Manage operations |
| Acquire and maintain application software | **Monitoring** |
| Acquire and maintain technology architecture | Monitor the processes |
| Develop and maintain IT procedures | Assess internal control adequacy |
| Install and accredit systems | Obtain independent assurance |
| Manage changes | Provide for independent audit |

*Fig 1. COBIT IT domains and processes*

Legacy systems as well as web-based information systems include both technical and managerial components. Audit missions can be performed along dimensions related to IS domains:

| **Managerial and organizational dimension** | **Technological dimension** |
|---|---|
| information system strategic planning | computer security |
| functional information systems (marketing, human resource, logistics, and accounting information system, etc…) | data processing operations |
| data processing means and organizational procedures | current applications |
| management control of the information system function | new information system projects |
| law and accounting conformity rules | information system costs |
| | purchase and subcontracting |
| | telecommunication and network systems |

*Fig.2. Information system domains*

Any audit approach can be performed either on one of the 34 COBIT processes or one of the twelve IS domains described above.

### 3.2 Audit criteria

To satisfy business objectives, information systems need to conform to certain criteria allowing adequate control measures. The set of criteria considered by the different methodologies are not strictly equivalent but often overlap. COBIT combines a set of criteria related to business requirements for information. It is based on principles embedded in known reference models, such as quality requirements (quality, cost, and delivery), fiduciary requirements (effectiveness and efficiency of operations, reliability of information, compliance with laws and regulations) and security requirements (confidentiality, integrity, availability). More generally, audit criteria are generally segmented according to three vantage points (Nicho, 2008; Olsina et al., 2001):

- *Quality requirements* of outputs encompassing for example efficiency and performance.
- *Security requirements* described by the criteria of consistency, security, conformity and reliability.
- *Readability requirements* comprising feasibility, auditability and ability to evolve.

*Efficiency* is concerned with the amount of resources required to achieve business goals. It also concerns the provision of timely and adequate information in the most cost effective manner. *Performance* reporting measures the contribution of information systems to the organization objectives. *Consistency* ensures that information systems are composed of homogeneous and coherent subsystems. *Security* and protection concern the techniques used for protecting information systems from persons who are not allowed to access a part of or the whole information system. They are specified in terms of authorization constraints. *Conformity* relates to legal aspects. *Reliability* deals with information and computer resources being reliable with a minimal failure rate. *Feasibility* can be evaluated in terms of organizational, economic, technical and operational investigations. *Auditability* relates to the ability of auditing a part of or the whole information system. Finally, *the ability to evolve* deals with information systems being able to change and to adapt to new situations.

### 3.3 Audit frameworks

The IT audit frameworks enforce the concept of assurance and enables the alignment of IT goals with business goals (Grembergen et al., 2005 ; Yip et al., 2006). In order to satisfy business information requirements and organizations' objectives, the IS domains and/or the IS processes need to conform to all (or part of) the criteria defined above. The concepts of IS domains and IT processes as well as audit criteria play a central role in an audit process allowing companies to reinforce the objectives of internal control. Several frameworks of internal control (or audit frameworks) have been proposed: COSO, COCO, Cadbury, COBIT and eSAC (Brown et al., 2005). The COSO framework (COSO, 1992) was designed to provide assurance regarding the achievement of objectives in financial reporting and in the compliance with laws and regulations. The COCO framework (COCO, 1995) is very similar to COSO but presents additional concepts not included in COSO such as controls allowing auditors to identify risks of failure in maintaining organizations' ability to exploit opportunities. The Cadbury framework (Cadbury, 1994) aims to provide assurance of the safeguarding of assets against unauthorized use of disposition and the maintenance of proper accounting records. Unlike the three frameworks described above, the eSAC report is the first framework that is intended to provide "sound guidance on control and audit of information systems and technology" (Stott, 2008). Following the SAC report, COBIT has been developed as a framework to evaluate practice in IT (ITGI, 2005). COBIT is considered the most effective and helpful tool for IT audit (Singleton, 2006). It is based on control objectives as proposed by the Information Systems Audit and Control Foundation (ISACF). It is positioned to be more comprehensive for management than existing focused control models for IT. COBIT framework considers seven criteria (effectiveness, efficiency, confidentiality, integrity, availability, compliance, and reliability), and five IT resources (people, application systems, technology, facilities and data). It identifies to which of the seven criteria each of the 34 processes (described in paragraph 3.2) apply. Finally, it identifies which of the five IT resources

are applicable to each information system process. COBIT provides audit guidelines to facilitate the evaluation of the control objectives. Although COBIT is considered to be the most comprehensive IT auditing framework and is internationally developed and applied, it suffers from several drawbacks:

The COBIT audit process is undertaken from the viewpoint of IT processes. Identifying the processes involved in an audit mission can be very difficult and often impossible. Let us consider for example the audit of a strategic application. Determining the COBIT domains, processes and tasks can be a paramount task. Since COBIT is not built on the concept of information systems domains, auditing an application requires identifying the processes being involved. This is a context-based task and is dependent on management and auditors expertise. This difficulty can be encountered when auditing domains such as application systems, computer networks, marketing information systems, new IT projects, and more generally WBIS.

The COBIT audit process requires time and resources to be performed. There is no guideline allowing auditors to minimize the time and the efforts to be devoted. This is due to its lack of theoretical foundations. COBIT is based on best practices and does not have any underlying theoretical model. In addition, COBIT does not provide any CASE tool allowing auditors to increase their productivity.

In the context of the Internet era, new web-based information systems are being designed, developed, and implemented very quickly. As a consequence, it is becoming increasingly difficult to perform effective audits of web-based information systems using traditional auditing methodologies such as COBIT.

The audit process of web sites is only beginning to make its presence felt beyond the industrial research community. It is therefore not surprising that only a limited number of contributions exist. I/PRO (I/PRO) compares panel versus audit approaches for measuring web site traffic. Danna et al. (2000) consider access patterns in their approach of web site auditing. Lewin uses a limited number of criteria in its audit framework. (Deshpande et al., 2002) perform web site auditing as a first step towards its reengineering. Some quality criteria relevant to web site auditing are discussed in (InDIMENSIONS). Finally, Atzeni et al. (2002) present a methodology for the assessment of web site quality using a hierarchical model. As it can be seen, there are very few papers that explicitly deal with web site overall auditing, beyond the quality aspects. We define below a specific approach to WBIS auditing.

The aim of this research is to contribute to the existing knowledge base in IS evaluation by providing an auditing methodology based on information system domains (as described in paragraph 3.1) and criteria combined to form a weighted hierarchical tree:

- Minimizing the time and efforts needed to perform the audit process. This can be realized only if the methodology has an underlying theoretical model (in our approach it is a hierarchical multi-criteria analytical model),
- Adapted to new applications such as web-based information systems,
- Implemented with a computer assisted audit tool, increasing the effectiveness and the efficiency of the auditing process.

# 4 AUDITING WBIS – A DOMAIN-BASED APPROACH

The fundamental feature of our framework, called INFAUDITOR, is that audit domains and audit criteria can be combined to form a hierarchical tree defined as a finite set of nodes such that:

- the non-terminal nodes represent the audit domains and sub-domains (i.e. legacy applications, web based applications, development methodology, system characteristics and documentation, system security, marketing information system, etc),

- the terminal nodes represent elementary domains to which the tests of control must be applied.
- INFAUDITOR considers two types of tree:
  - a general tree covering all the information system domains and tests of control,
  - several non-independent sub-trees corresponding to the audit of particular information system domains such as a WBIS.

When auditing a particular domain such a WBIS, weights are attributed to the nodes of the general tree, leading to a customized sub-tree. For each test of control, a grade (or a qualitative appreciation) is given to the terminal nodes of the sub-tree. The weights and the grades enable the auditor to determine scores for different domains, leading to an aggregate audit score. Based on these evaluations, the auditor can choose the opinion that best classifies the client's information system. The structure of the audit hierarchical tree is represented as follows (Fig. 3) where D stands for domain, SD for sub-domain, T for control test, G for grade and W for weight. For example, the control test $T_{1,2}$ results in a grade $G_{1,2}$, the domain $D_1$ can then be evaluated to $W_{1,1}*G_{1,1} + W_{1,2}*G_{1,2}$. Then $D_1$ evaluation will be weighted by $W_1$ in the global evaluation grade.

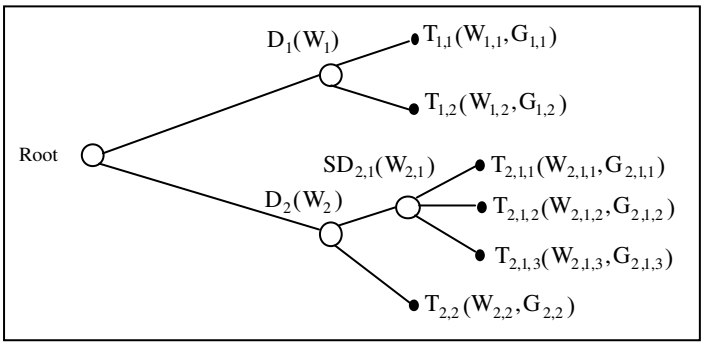


*Fig 3. INFAUDITOR : The Hierarchical Tree*

All the grades are given using a quantitative scale. At any level of the tree, the sum of the weights of a node's children is equal to 1. The weights of the nodes indicate not only their participation in the final evaluation, but also the tests the auditor should perform.

The general audit tree is very wide, since information system auditing involves many domains. An originality of INFAUDITOR is that it covers all the aspects of information system auditing while other methods usually focus either on the managerial aspects (marketing, human resource, logistics information system, etc) or on the technical aspects (computer network, system security, applications, new projects, etc). INFAUDITOR thus incorporates the knowledge of the different expertise domains of information systems.

The general audit tree is implemented by rules. For each node of the tree (representing the domain or the sub-domain to be audited), a rule represents the link between this node and its parent. Storing the tree by rules makes it easy to maintain and favors a prototyping approach. The enrichment of the tree requires only adding new rules, without having to rewrite the whole structure.

This customization ability by means of rules is a major contribution of INFAUDITOR. The literature on audit often insists on the importance to adapt the described audit methodologies to particular cases, but usually does not indicate how to adapt them (Hansen et al., 1986). The rules of customization are scarce in the literature (Jacob et al., 1991) and for the purpose of developing INFAUDITOR, practitioners were interviewed to get the expertise. This customization process has been applied to WBIS resulting in the audit sub-tree given below (Fig. 4). We argue that the three criteria (quality, security, readability) mentioned above are suited for WBIS evaluation. These criteria have been decomposed in several sub-criteria taking into account the specific characteristics of WBIS. The first column represents the aggregate criteria (quality, security, readability). The second column represents

their respective sub-criteria. For example, conformity, user-friendliness, etc. are the sub-criteria of quality. This decomposition process is repeated for each sub-criterion leading to the sixth column.

This methodology and the subsequent audit tree have been applied to a real-life example related to a European lotto company. This company has developed an IT based strategy in order to renew its game offer and to propose additional lotteries. Its web site is a new channel for lottery players. Forty-eight thousands connections are recorded each month. The rationale for the audit is to verify the adequacy of this WBIS with the company's strategy.

The audit process was mainly based on qualitative interviews and quantitative measures. Qualitative interviews were conducted with the managers of the lottery company. Quantitative measures were obtained through a survey launched on the web site. A comparison between the web site content and the initial specifications was performed. The main results are summarized below (Fig. 5). For space limitations, we quoted only the most significant conclusions at the second aggregate level. As it can be seen, our methodology allows the lotto company to determine the strengths and weaknesses of its web site. This audit approach can be used at different levels of detail (domain, sub-domain, elementary domains) as audit tool for both auditors and end-users.

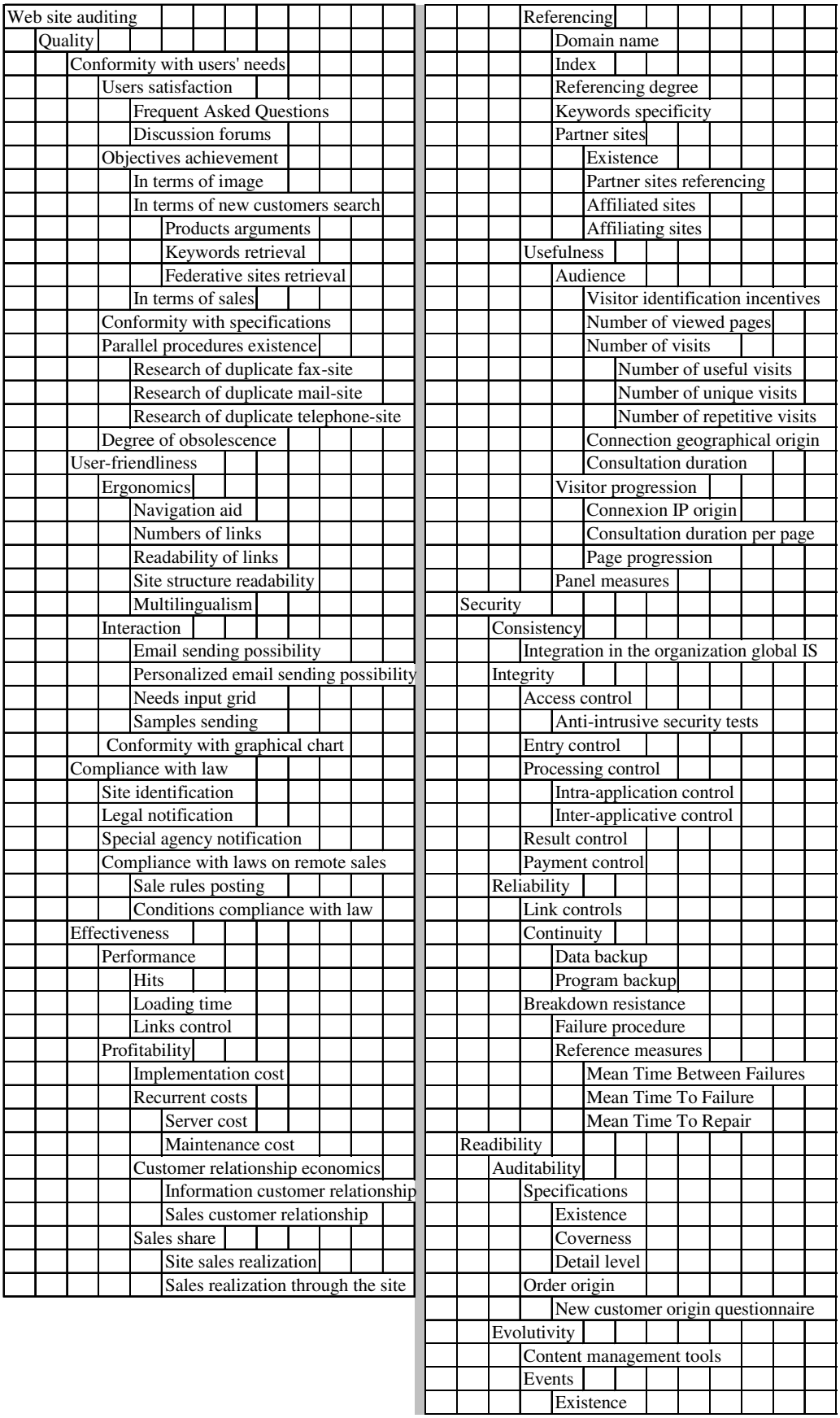


*Fig. 4. WBIS audit subtree*

| | | |
|---|---|---|
| Quality | | |
| | Conformity with users' needs | |
| | | The web site complies with the main specifications and requirements. More than 80% of the users are satisfied. Update procedures are carried out on a regular basis. A specific ad hoc committee is responsible for this task. However, the meetings of this committee are not formalized |
| | User-friendliness | |
| | | positively. Navigation capabilities make the web site utilization very intuitive. |
| | Compliance with law | |
| | | Law and regulations are strictly observed by the webmaster. There is a real compliance with laws and regulations. |
| | Effectiveness | |
| | | Web services offered to the users show a high performance behavior. There is almost no waiting line. A mirror site enables a continuous backup. The server is very powerful with adequate communication lines. Profitability analysis shows economies of scales with a very good rate of return on investment. Human resource costs are very limited. However this cost analysis is biased by the fact that the costs are not isolated from the company's general expenses. Moreover, the audience could be better if the web site offers incentives such as email contacts, free games. Finally, more practical information about the games is needed. |
| Security | | |
| | Consistency | |
| | | Development site is different from the running site. Norms and standards are reinforced using adequate documentation. However, there is lack of coordination given the fact that there exist several communication channels (fax, email, surface mail). Customer relationship is incomplete, especially in case of errors. |
| | Integrity | |
| | | Several automatic entry and processing controls are provided. Moreover, check-list procedures are used. However, control is limited to the web site new pages. No global control is provided. |
| | Reliability | |
| | | Few failures are mentioned. A failure procedure is available, as well as a written documentation. The MTTR is evaluated to less than 3 hours, which is considered to be acceptable. |
| Readability | | |
| | Auditability | |
| | | The web site was launched after a prototyping effort, without any update procedure and vision. |
| | Evolutivity | |
| | | The maintenance is performed only by one person. As a consequence, documentation is very scarce. |

*Fig. 5. A real-life example*

# 5 CONCLUSION AND FURTHER RESEARCH

The web based information systems phenomenon provides an important occasion to reassess the claim that traditional auditing frameworks are not suited for web site evaluation. In this paper, we surveyed and discussed audit approaches used in the evaluation process of legacy systems. Underlying our discussion is the belief that there is a need for a specific approach to web-based information system auditing, and, in particular, for web site evaluation. We defined a domain-based approach allowing auditors to perform in an effective and efficient way a web site audit process. Our framework helps auditors, companies and users in structuring the audit process using relevant criteria. It proved to be a cost-saving approach in web site audit practice. Using an analytic hierarchy process, the audit process is structured as a hierarchical evaluation tree. Thus the audit controls are performed only on terminal nodes, minimizing time and effort needed to evaluate the whole domain. Let us remind that COBIT does not have any hierarchical structure. Therefore all the audit tests should be performed. Let us mention that COBIT is a practitioner based approach. It is not theoretically grounded. Our approach takes advantage of the analytic hierarchy process. Finally our approach has been extensively used to audit several domains providing an alternative to COBIT. This framework has been applied in a real-life setting in order to audit a European lotto web site.

A fundamental limitation of the whole approach of WBIS auditing as presented in this paper is a lack of consideration of the interdependencies between criteria. These interdependencies can be handled by using links between criteria. Another limitation is a lack of guidance tool allowing auditors to decide how best to proceed during an audit process, how to gain access to explanations on what has been happening during past audit missions, and how to access to ever-increasing historical information that can be used, for example when deciding the values to be assigned to the different criteria. Finally, a well-known limitation is the one related to the underlying analytic hierarchy process for multi-criteria decision making.

This discussion suggests that a number of particular research directions should be pursued. Firstly, more experiments with our approach are needed, as is the testing of specific web sites such as e-commerce applications, and more generally any web based information system application. Secondly, an attempt must be made to develop an extended framework which fully captures multi-criteria network analysis model. A particular challenge is to compare our framework with alternative methodologies, such as COBIT. It might be of paramount to consider heuristic inspections in order to identify the most obvious usability flows. At the same time, the calibration of our hierarchical model for different activity sectors, depending on the enterprise size, is needed. Finally, an adaptation of our approach in the learning process will be useful, allowing auditors to focus on the explanation capabilities of the system.

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