OPEN ISSUES ON INFORMATION SYSTEM ARCHITECTURE RESEARCH DOMAIN: THE VISION

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Abstract: Currently organizations, pushed by several business and technological changes, are more concern about Information systems (IS) than ever. Though organizations usually still face each IS as a separately technological issue with slight relations with business domain. This paper discusses the importance of the Information System Architecture (ISA) as the tool for ensuring a global view on IS and for explicitly assessing alignment between technology and business processes and strategies. In this paper, considering the numerous topics, technologies and buzzwords surrounding ISA domain, we identify the major ISA open issues, namely: ISA Modelling, ISA Methodology, ISA Evaluation, IS Architectural Styles and Patterns, and IS/Business Alignment. We also present our advances in addressing some of these issues, by proposing an approach for ISA evaluation and IS/Business Alignment measure. This approach is supported on an ISA modelling framework and provides several indicators and measures for ISA evaluation. This approach is applied to an IS health care project evaluation.

1 INTRODUCTION

During the last decade several important technological progresses have been accomplished in the computer science, as component-of-the-shelf (COTS) software have raised and established (namely ERP, CRM, B2B and Intranet systems), the mobile and communication technologies have emerged, and the integration technologies has been raised and reinvented (where *webServices* stands for integration current hot buzzword) (W3C, 2001).

Organizations, on the other hand, were faced with new business challenges in a changing business environment – as the market globalization, the costumer process reorientation, the need for product innovation, the product life cycle reduction, and the raising importance of efficient information and enterprise knowledge handling. These new business needs have being forcing organizations to redesign their strategies, reengineering their business processes and positioned efficient information handling in every organization agenda. (Davenport and Beers, 1995).

In spite of significant efforts and investments at business and software levels, currently organizations do not get the expected returns by just using the "best" or the latest IT in the market (Boar 1999).

This paper discusses the preponderant role of the Information System Architecture (ISA) in ensuring Enterprise Information Systems (EIS) fully aligned with organization strategy and business needs.

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The ISA topic is a quite new issue since only in last decade the need for handling concepts that overwhelm the description of how a system is internally built emerged (Zachman 1987). Currently, the ISA research field is quite confuse – considering its immaturity and its different influences – being quite difficult to agree in a common definition for ISA, to set ISA major concepts, or define ISA relations to Enterprise Architecture and Software Architecture, among many others issues, as explained in section 2.

This paper pretends to review and present ISA major research issues namely ISA modelling, ISA methodologies, ISA evaluation, IS architectural styles and patterns, and IS/business alignment assessment (see section 3).

In section 4, we present our research in the ISA field and we propose an approach for ISA quality evaluation, namely IS/business alignment, informational entities accuracy, technological choices, etc. This approach is further explored in our first field experience in the Portuguese public health care system (see section 5).

2 INFORMATION SYSTEM ARCHITECTURE CONCEPTS

The research described in this paper is enclosed in the organizational engineering research domain (also known as enterprise engineering) (Liles et. al 2003). Organizational engineering's main focus is on the organization, namely its internal and external business environment and the information system that supports business needs. The authors share the CEO (Center for Organizational Engineering) vision on organizational engineering research domain described in Figure 1.

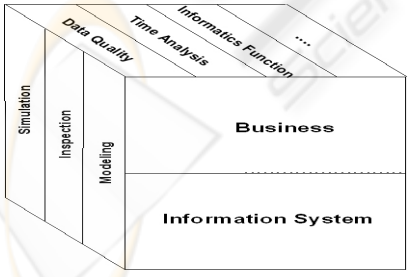

Figure 1. CEO vision on Organizational Engineering (Vasconcelos et. al. 2001)

As described in Figure 1, Enterprise Architecture (EA) considers all the issues relevant for getting a coherent and comprehensible picture of enterprise (as people, business, strategy definition, systems, governance principles, etc.). EA is a group of models defined for getting a coherent and comprehensible picture of the enterprise (Tissot et. al. 1998). EA is considered a vaster concept than ISA, which includes business strategies and processes, besides Information System (IS) models that support them. Usually, at enterprise architecture level, IS are consider "simple" resources used in business (as people, equipment and material, etc.) – e.g., (Eriksson, 2000) and (Marshall, 2000).

Information System Architecture (ISA) addresses the representation of the IS components structure, its relationships, principles and directives (Garlan et. al. 1995), with the main propose of supporting business (Maes et. al. 2000).

Spewak in (Spewak, 1992), argues that the ISA description is a key step in ensuring that IT provides access to data when, where and how is required at business level. ISA is also important in ensuring IS flexible, durable and business oriented (Zijden et. al. 2000), in providing the means for business, IS and IT components alignment, and ensuring greater efficiency using IT (Open 2001).

Quoting IEEE (IEEE 1998), the ISA level should be high. Thus, ISA is distinguished from software engineering topics – as representation and analysis methods (e.g., E-R diagrams, DFD) – presenting an abstraction of internal system details and supporting organization business processes (Zijden et. al. 2000).

ISA usually distinguish three aspects, defining three "sub architectures" (Spewak, 1992):

- **Informational Architecture**, or Data Architecture. This level represents main data types that support business.
- **Application Architecture**. Application architecture defines applications needed for data management and business support.
- **Technological Architecture**. This architecture represents the main technologies used in application implementation and the infrastructures that provide an environment for IS deployment.

Informational Architecture's major propose is the identification and definition of the major data types that support business development (Spewak, 1992), (DeBoever, 1997). Inmon (Inmon, 1997) characterizes data (the support of the information architecture) through different dimensions: primitive vs. derived, private vs. publics and historical vs. operational vs. provisional data. He argues that the ISA should be influence by the data characteristics.

The second architecture level, defined by DeBoever (DeBoever, 1997), is the application (or system) architecture. This architecture defines the main applications needed for data management and business support. This architecture should not be a definition of the software used to implement systems. The functional definition of the

applications that should ensure access to data in acceptable time, format and cost is this architecture main focus (Spewak, 1992). Application architecture defines the major functional components of the architecture.

The Technological architecture defines the major technologies that provide an environment for application building and deployment. At this level, the major technological concepts relevant for the IS are identified – as network, communication, distributed computation, etc. (Spewak, 1992).

3 A VISION ON INFORMATION SYSTEM ARCHITECTURE OPEN ISSUES

As stated before, ISA is a quite new research area. In the past (until de 90's) modelling the relations between different information systems and business was not an issue, since each system existed in its standalone world. Thus, ISA was not a concern, since software engineering approaches managed to address most of individually information system issues.

With network and communication evolutions, complex systems interfaces were implemented in order to ensure data synchronization. The maintenance costs raised, the problems derived from redundant data became a major issue (and cost) for organizations.

In the 90's, the information systems growed-up, and became part of each enterprise's department business. The database management systems transformed file replication in database replication (Inmon, 1997). The traditional software engineering approaches failed to answer these new needs and several ISA research topics emerged.

In this section we present an overview on currently ISA major open research topics. The ISA research topics list described next was not developed through a statistical literature review, since these topics are open issues and some of them are not yet addressed in literature. The topics presented were driven not only from literature review but mostly from our field experience on the area, namely considering several real organizations ISA problems.

Our goal is to establish a common research ground for this area in order to develop our investigation and cooperate with other researchers in the field.

3.1 ISA Modelling

The representation and graphical manipulation of a model on some thing or concept is a critical tool for discussion and abstraction. ISA modelling is concern on the conceptual definition of ISA major notions and its representation in a graphical way.

EAB (Enterprise IT Architecture Blueprints) is a reference research in this topic. Boar verified that IT architectures do not have a repeatable, coherent, non-ambiguous and easily perceptible representation. He proposed a set of blueprints for IT Architecture drawing in a systematic, coherent and rigorous way (Boar 1999). However, introducing 61 new notions and icons, not supported in any norm, or standard language, organizations, in order to use EAB, are forced to have an high knowledge and experience on EAB (turning out its acceptance and adoption difficult).

In the 90's, software architecture had similar concerns, namely there was not a consensus in software architecture concepts. IEEE formed a task force that defined IEEE 1471 norm: "Recommended Practice for Architectural Description of Software-Intensive Systems", that provides a conceptual framework for software architecture (IEEE 1998). Based on IEEE 1471, Open Group proposed a framework for ISA design and evaluation: TOGAF – The Open Group Architectural Framework. This framework, among other things, proposes a technical reference model that defines a taxonomy for coherent, consistent and hierarchical description of the services provided by the application platform. TOGAF framework focus is mainly technological, not addressing ISA at informational and application levels. Moreover, TOGAF framework does not introduce any modelling blueprints, but a set of IT notions and principles.

The clarification of the major concepts that are relevant for ISA modelling is a fundamental step in order to have a formal and simultaneously comprehensible and useful (conceptual and technological) tool for ISA representation, namely at informational, application and technological levels.

However, currently, there is not any language, mechanism or tool that addresses all ISA concepts. The identification of such concepts and base notions for ISA representation, are a vital step in ISA semantic manipulation and for all the research in the area.

The relation between the different concepts in ISA sub-architectures (informational, application and technological) and business is also an open issue. In IS/business alignment assessment is crucial to navigate between these abstractions levels – for example, if a business process is changed for some

reason (e.g., business process reengineering) it is important to navigate to the systems and infer which informational entities, applications and technological components may need changes.

3.2 ISA Methodology

A major research topic in ISA is focused on the definition of methodologies for Information System Planning.

Spewak proposes a methodology – Enterprise Architecture Planning (EAP) – able to define application architecture from informational and business requirements (Spewak, 1992). Using Spewak methodology and Zachman framework several institutions have been proposing adaptations that best answer to its needs – interesting case studies are Information System Architectures in the American Federal Government (FEAF 1999), DoD Technical Reference Model (DoD, 2002), Treasury Enterprise Architecture Framework (FEAPMO, 2002), among others. Though Spewak methodology is the most known information system planning approach, it has several problems that make it quite difficult to use in real problems. Namely, Spewak approach defines applications based only in relations between data and business activities, not considering current technologies or existing solutions, which turn out his approach quite inapplicable in most situations.

Other approaches for IS planning have been proposed by several consultant firms as IBM (Hein, 1985), SAP (Miller, 1998), Microsoft (Lory 2003). However most of these approaches are technological dependant on the technology that the firm is selling.

Approaches as CIMOSA (AMICE 1993) and RM-ODP (International 1995) try to address the enterprise architecture and the system architecture simultaneously.

3.3 ISA Evaluation

The quality measure of the ISA is another research topic in this area. The quality measure is concern on inferring the ISA accurateness to a business model, existing technologies, and corporate strategy.

ISA evaluation is an important research topic since currently there are only adhoc and non methodological ways to evaluate if an ISA fits enterprise business and enterprise strategy. The ISA evaluation is also an important topic for assess if new information systems are align with current ISA at informational, application and technological levels.

Traditionally ISA evaluation is accomplished using common financial ratios (Wagner, 2003). However these approaches proved to be very difficult to use, since IS benefits quantification is a not a simple task. Giaglis presents an approach for quantifying IS benefits (Giaglis, 1999). A central point in IS evaluation is IS/Business alignment assessment, present in section 3.5.

3.4 IS Architectural Styles and Patterns

The identification of design patterns and best practices in ISA is an important topic in order to aid the information system architect in the creation of an ISA.

In software engineering research field software engineers when defining a software system use software architecture best practices (Gamma, 1995). The definition of architectural styles and patterns transform software architecture from an art into standard engineering practices.

In traditional architecture (as building architecture) the use of patterns is the natural way to define new architectures (Jacobson 2002).

Currently in ISA there are no patterns or architecture styles for all sub-architectures (informational, application, and technological). However there are some best practices that are becoming patterns. For example, at technological level the three tier architecture is a quite used pattern (where data, business logic and presentation are separated in different components) (OOPSLA, 2001).

Though ISA is still much of art instead of an engineering effort and therefore this research area is still in its infancy.

3.5 IS/Business Alignment

In the Critical Issues of Information Systems Management (CIISM, 2001) report, the alignment of Information Systems (IS) with Business represents 54.2% of the Information Systems Managers' concerns and in the same study, the IS Alignment takes second place as the factor that most contributes to the IS' success in the organization.

Taking this into consideration, we define Alignment among Business, Systems and Information as a way to quantify the coherency level in relation to the business necessity, the systems offer and information management (Pereira, 2003). However, in order to evaluate the coherency level among these components two important points must be attended: (i) the architecture must be correctly defined and contemplate all the relevant situations for the organization (see section 2) and; (ii) to this

architecture the rules that guarantee the alignment must be applied (see section 4).

Attending to the previous paragraph, the interdependency between Enterprise Architecture and Alignment is unquestionable, since the first one is the mean to the second one and to achieve the wish of having an "aligned organization", definitively, the architecture definition and ensuring its alignment might not be a necessary or sufficient condition, but is surely the best way to guarantee it.

Other important point, it is ISA evaluation presented in section 3.3. Understanding how IS/Business is aligned/misaligned contributes to the architecture assessment as a component of that evaluation.

In next section we describe our approach to some of these research topics.

4 OUR APPROACH

In this section we describe how we are addressing some of the open issues described in section 3, specifically ISA Modelling (3.1), ISA evaluation (3.3), and IS/Business align assessment (3.5).

4.1 ISA Modelling

In order to model the enterprise the Organizational Engineering Center (or CEO, for short, in Portuguese) proposed the CEO framework (Vasconcelos et. al. 2001) for modelling enterprises using a restricted set of business objects. The CEO framework was defined as an UML profile (UML 1997).

Although the CEO framework could not be used to define a complete ISA, it presented some interesting extensions to represent dependencies between businesses and systems. The business objects defined in the framework are *goals* for strategy modelling; *processes* for business process modelling, *resources* for business resource modelling, and *blocks* for IS modelling. The CEO framework also ensures consistency, easy of use and provides mechanisms to maintain integrity with the ultimate goal of reducing the "impedance mismatch" between business and IT architectures.

Recently, CEO framework founding concepts at Information System level where investigated and an UML profile for ISA modelling at informational, application and technological levels was proposed (Vasconcelos et. al., 2003). Figure 2 presents the current core concepts of the CEO framework (at ISA level).

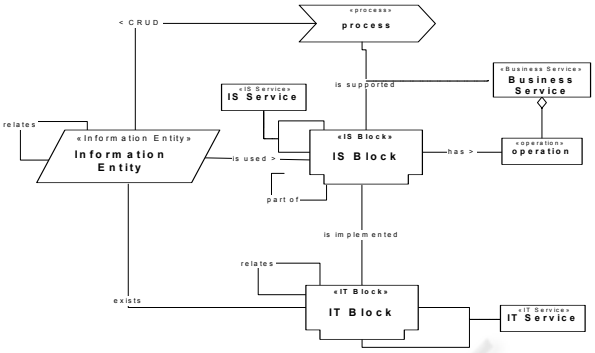

Figure 2. CEO UML Meta-model Extensions for ISA (Vasconcelos et. al., 2003)

The core concepts in the CEO framework profile are:

- Business Process – a collection of activities that produces value to a customer;
- Information Entity – any person, place, physical thing or concept that is relevant in the business context and about which is possible and relevant (for the organization) to keep information;
- IS Block – a collection of mechanisms and operations organized in order to manipulate data;
- IT Block –infrastructure, application platform and technological/software component that realizes (or implements) an (or several) IS Block(s).

These blocks can be further specialized; for instance at technological level CEO defines IT Infrastructure Block (representing the physical and infra-structural concepts), IT Platform Block (representing the collection of services needed for implementing and IT deploying applications), and IT Application Block (representing the technological implementation of an IS Block). Please see (Vasconcelos et. al., 2003) for further detail.

4.2 IS/Business Alignment Assessment

The IS/Business Alignment Assessment is based on three dimensions deriving from the Enterprise Architecture's components: Business Architecture, Information Architecture and Application Architecture.

In this approach, understanding the relationships that exist among the architectural components and the possibility of measuring the alignment as the result of three possible misalignments, is the key that enables us to evaluate the IS/Business Alignment as the misalignment:

- between Business Process (BP) (part of Business Architecture) and Information (part of Information Architecture);

- between BP (part of Business Architecture) and Applications (part of Application Architecture);
- between Applications (part of Application Architecture) and Information (part of Information Architecture).

In Figure 3, we present the rules that allow us to quantify the alignment. As mentioned, the Alignment is based on three dimensions, and these individually quantified allow us to quantify the alignment as one (Pereira, 2003).

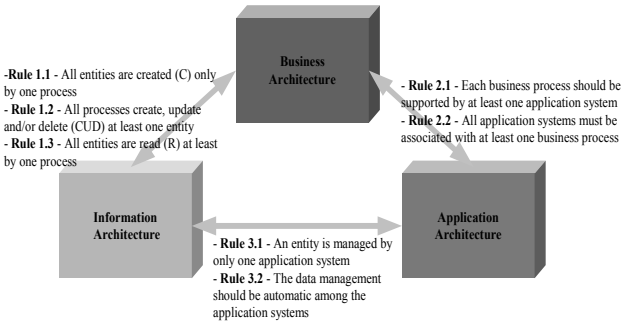

Figure 3: IS/Business Alignment's Rules

Following are presented the formulas that allow us to quantify the alignment; these formulas are based on the rules presented in the Figure 3. As mentioned, the Alignment is based on three dimensions that individually quantified allow us to quantify the alignment as one.

For the Alignment between Business Architecture and Information Architecture the formula defined is, $AlinAN\_AI = \left(\frac{nEcP}{ntE} + \frac{nPE}{ntP} + \frac{nErP}{ntE}\right)/3$ where:

- nEcP represents the number of entities created by only one business process (Rule 1.1)
- nPE represents the number of processes that create, update and/or delete (CUD) at least one entity (Rule 1.2)
- nErP represents the number of entities that are read (R) by at least one process (Rule 1.3)
- ntE, number of total entities
- ntP, number of total processes

For the Alignment between Business Architecture and Application Architecture the formula is, $AlinAN\_AA = \left(\left(1 - \frac{nASwBP}{ntS}\right) + \left(1 - \frac{nBPwAS}{ntP}\right)\right)/2$, where:

- nASwBP represents the number of application systems without any business process associated (Rule 2.2 negation)
- nBPwAS represents the number of business process without any support by an application system (Rule 2.1 negation)
- ntS, number of total application systems
- ntP, number of total processes

Relative to the Alignment between Application Architecture and Information Architecture we have, $AlinAA\_AI = \left(\left(1 - \frac{nEMA}{ntE}\right) + \left(1 - \frac{nGM}{nGM + nGA}\right)\right)/2$, where:

- nEMA represents the number of entities managed by more than one application system (Rule 3.1 negation)
- nGM represents the number of cases managed manually (Rule 3.2 negation)
- nGA represents the number of cases managed automatically among application systems
- ntE, number of total entities

With the formulas presented it is possible to quantify separately each one of the dimensions presented in the alignment, being the level of alignment obtained by the average of the obtained values for each one of those dimensions.

4.3 Assessing ISA quality indicators

Aiming the identification of ISA quality attributes and the identification of a methodology for inference on the ISA suitability for a business model and other restrictions, several prototype studies are being accomplished.

We are using the UML profile for ISA, described in section 4.1, in order to model the AS-IS ISA, representing the current architecture.

We also defined several indicators and metrics at business and system level for evaluation of IS/IT projects. In order to infer the **ISA Suitability for the organization** some indicators were defined**:**

- Functional Overlapping indicator, defined as:

  $\sum Fold \;/ \sum Fnew$, where:

  Fnew – function implemented by the propose project

  Fold – function implemented by the propose project that already exist in other systems in the organization

- Integration indicator defined as:

  $Integration\ Cost / \Pr oject\ Costs$

- Technology change indicator defined as:

  $\sum NewIT / \sum IT$, where:

  NewIT – new technology introduced by the project that is not used in other existing IS of the organization

  IT – technology proposed by the project

- Informational Entity Overlapping indicator, defined as:

  $\sum IEexist_{CUD} / \sum IEnew_{CUD}$, where

  $IEexist_{CUD}$ – informational entity Created, Updated or Deleted by the systems proposed but already exist in other organization systems

  IEnew –informational entity Created, Updated or Deleted by the systems proposed.

- Informational entity model compatibility indicator, defined as:

  $\sum IE_{\neq \mathrm{Re}\,f.Model} / \sum IE_{new}$, where

  $IE_{\neq \mathrm{Re}\,f.Model}$ – Informational entity, which attributes differed from Information entity reference model.

  IEnew – informational entity Created, Updated or Deleted by the systems proposed.

We have defined several other ISA evaluation indicators considering financial, project, business processes, systems interfaces, among other specific topics – for further detail please refer to (Vasconcelos et. al., 2004).

The approach described in (Vasconcelos et. al., 2004) revealed to be useful when evaluating new IS projects that should be part of a previously defined ISA. However the approach was not very accurate when measuring IS/business alignment. We address this issue in next section.

4.4 An integrated ISA evaluation approach

In order to measure the ISA quality, we realized that in the approach described in previous section the business/system alignment measure was poorly accomplished (for example the approach does not shows if an entity is created by multiple business processes). Thus, in this paper, we will present an approach to integrate the concepts beyond the IS/Business formulas described in section 4.2 in the approach described in 4.3, in order to have a global ISA evaluation approach.

Thus, in addition to the quality indicators described in section 4.3, we propose to integrate the concepts presents on the alignment formulas as a detail view of the Functional Overlapping and Informational Entity Overlapping indicators.

By this we are trying to improve the ISA evaluation as set of several dimensions and one of those dimensions is the alignment among business, systems and information.

Applying the alignment formulas to the ISA evaluation can help us to understand it not only as a horizontal and global assessment but also as a composition of some restricted and vertical views.

In the following section, we show the first experience's results using the alignment formulas onto a Portuguese project.

5 FIRST EXPERIENCE

This section presents our first attempt to apply the integrated ISA evaluation approach described in section 4.4 in evaluating a project in the Portuguese Health Care System.

The project proponent is a large Portuguese hospital with about 5000 employees (1000 medical doctors). In the past, the hospital information systems' (IS) grown as independent information islands (according to hospital health care units). The project proposal described here focus on a particular business process: the drug management process, see Figure 4.

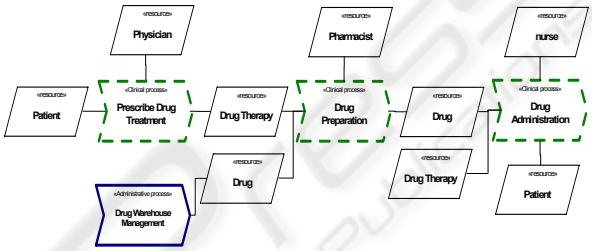

Figure 4. Drug Management Business Process

This business process consumes and produces several informational entities as drug, patient, drug prescription, health care professional, administrative/management personnel and drug supplier. The drug and drug prescription informational entities add additional attributes and alter the format of existing ones. Figure 5 presents the *Drug* informational entity.

Entity Name	***Drug*** *Informational Entity n.º 11.1*
Identifier	name
Type	Thing
Description	Substance used for medical purposes sold on pharmacies, produce in laboratories or in the pharmacy.
Relations	is prescribe by an physician (12.1) is used in a patient (1) is prepared by a pharmacist (12.3) nurse (12.2) may ensure patient is having correctly the drug

Figure 5. Drug Informational Entity

Currently this business process is badly supported throw the Hospital Drug System (HDS) that only supports the pharmaceutical activities and poorly supports physicians and nurses' activities. This project is expected to deliver an IS that supports the full business process and thus reducing prescription mistakes (mostly cause by paper based physician prescription), minimizing nurses wasted time in "copying" drug prescription from paper to the system and reducing process time by 30% to 60%. The proposed integrated drug management system (IDMS) application architecture is described in Figure 6.

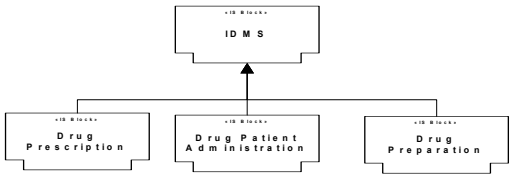

Figure 6. Proposed integrated drug management system (IDMS) application hierarchical view

Considering the evaluation indicators, integrated with the IS/Business formulas, we developed the project evaluation. In this section, only some of the ISA quality indicators are described.

In terms of ISA, the IDMS presents some functional overlapping with the HDS, once it will implement some operations that already exist in the HDS such as drug creation, search, update and delete as well as drug prescription functions. Thus, the functional overlapping indicator ($\sum Fold / \sum Fnew$) presents a value near 0.4 (meaning that about 40% of functions already exist in current systems).

Project Integration costs are very high (40% of project cost), 70% of which are related with the integration between HDS and IDMS.

At technological level, IDMS is based on different technologies than the reference model ones (namely the IT platform and server hardware), presenting a technology change indicator of 0.5 (meaning that about half of project technologies are new technologies for the organization).

The IDMS presents an informational entity overlapping indicator ($\sum IEexist_{CUD} / \sum IEnew_{CUD}$) of 1, meaning that all the informational entities create, updated or deleted in the proposed system already exist in other organization systems, which justifies the project high integration costs.

Considering the global ISA, the IDMS presents a interface disregarding indicator near 1, meaning that almost all interfaces provided by the IDMS do not respect at technological level the standard defined in the hospital ISA plan.

We also realized that 31% of entities are created by more than one process (Rule 1.1, Figure 3) and this happens because the same entity is partial used by several processes. Some processes (9%) never created/updated/deleted at least one entity, being against Rule 1.2, but this result is justified because these are the processes that elaborate the statistics reports. In the alignment between business processes and information, Rule 1.3 was fully satisfied, all entities are read at least by one process. As final comment about this type of alignment we have a level 80% of alignment and if we consider the Functional Overlapping and Informational Entity Overlapping indicators, the alignment result sustain the indicators previously presented as a way of identify where the problem is.

We do not present here the analysis for the other two types of alignment, for page limitation reasons.

Considering the previous indicators the project proposal (as presented before) was rejected. However, considering the possible incomes of having the drug management business process fully supported, some suggestions were required in order to re-evaluate the project proposal. Currently we are waiting for the "new" proposal.

6 CONCLUSIONS

This paper describes our vision on major information system architecture open issues. We started by presenting ISA concepts and ISA relations with other edging research areas (as software architecture and enterprise architecture). Considering the technological and conceptual mess on ISA area this paper establishes a common referential for ISA hot research topics, namely: ISA Modelling, ISA Methodology, ISA Evaluation, IS Architectural Styles and Patterns, and IS/Business Alignment.

Besides setting a vision on ISA domain, we describe our current approach to ISA evaluation. This approach is based on our previous work and, in this paper, we combine it with IS/business alignment measures. The proposed approach was used for evaluating an IS health care project.

This first experience confirmed that the approach provides the tools (namely measures) for evaluating and ISA considering existing IS and business processes. However, in this first evaluation, we notice some difficulties in putting together all the different measures in order to have a final evaluation grade. Thus, we are now working on combining all the measures in a fully integrated approach.

Currently we are planning to build an ISA best practices database and integrate this knowledge in an ISA Computer Aided Evaluation methodology and tool.

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