2009 Fourth International Conference on Software Engineering Advances

# *Exploring and Overcoming Major Challenges in IT Infrastructures Faced by IT Executives*

*Luís Alexandre Ferreira da Silva*
QUASAR/VALSE Team, CITI
Departamento de Informática
Faculdade de Ciências e Tecnologia
Universidade Nova de Lisboa
Caparica, Portugal
luis.alexandre@fct.unl.pt

*Fernando Brito e Abreu*
QUASAR/VALSE Team, CITI
Departamento de Informática
Faculdade de Ciências e Tecnologia
Universidade Nova de Lisboa
Caparica, Portugal
fba@di.fct.unl.pt

***Abstract*** *— This paper aims at identifying top challenges faced by IT executives in IT infrastructures to help the formulation of meaningful research questions. The introduction of this paper describes the importance of IT infrastructures to organizations. The top challenges according to a recent survey are also introduced in the state-of-the-art section. Then, to improve our understanding and face challenges, we propose an approach based upon a research method and we describe several research techniques that we plan to use (e.g. laddering technique) and the use of empirical research in IT infrastructures. Finally, we present the expected contributions, work already performed and some preliminary results.*

***Keywords*** *– Information Technology, Modelling, Management techniques, Knowledge acquisition, Software engineering.*

## I. INTRODUCTION

The concept of Information Technology (IT) infrastructure, is an encompassing one that stands for the use of IT components (computers, networks, hardware, middleware and software) upon which systems and services are built and run, to manage and process information [1]. IT infrastructures present major opportunities and challenges to organizations in today's turbulent and globally competitive environment. More than ever, in the world's current economic scenario, IT executives and people responsible for IT infrastructures must know which the biggest challenges are and they should have the ability to overcome challenges and turn them into competitive advantages. To do that they must have processes, tools and techniques in place and understand where they stand today, where they should go and how to get there. Currently, there are several challenges faced by IT executives [2, 3]. We decided to use a scientific approach to acquire knowledge from IT executives, regarding the challenges they face in managing large and complex IT infrastructures. From there we intend to formulate a set of research questions and then propose an approach to overcome those challenges,

Regarding paper organization, we describe the state-of-the-art on this subject on the next section and then, on section III we proceed with a description of the research objectives and approach that we plan to follow to improve our understanding on the inherent problems and difficulties faced by IT executives in IT infrastructures. We then describe the current state of our research, followed by (on section V) our work plan. We finally present, in section VI, some preliminary conclusions.

## II. STATE-OF-THE-ART

Several frameworks, such as ITIL [4] or COBIT [5], have emerged to provide guidance and help organizations to create, operate and support IT Infrastructures and processes, while ensuring that the investment in IT delivers the expected benefits. These frameworks define a set of standard procedures and processes that organizations should adopt to improve efficiency and effectiveness in those activities [4]. These frameworks address the domains of IT management and governance [6]. Even with all these frameworks and best practices defined, there are several problems [3, 7] faced by IT executives in the management of IT infrastructures.

The focus of this work is to identify the top challenges faced by IT executives, regarding their IT infrastructures and propose mitigation solutions for those challenges. Prior research has recognized the importance of a flexible IT infrastructure as a source of competitive advantage [8]. Often IT infrastructures are perceived as the main impediment to the new business challenges [9], so most IT executives spent a significant part of IT budgets on IT infrastructures [10]. A high priority for them is then the reduction of costs, while improving service levels and showing quantifiable value from IT investments [11]. A recent Gartner survey [3] found out that the current biggest challenges for IT executives are:

- Aligning activities with the business;
- Making more with smaller budgets;
- Power, cooling and space;
- Managing the rate of technology change;
- Modernizing legacy applications;
- Finding/retaining IT talent;
- Determining how to source IT services.

978-0-7695-3777-1/09 $26.00 © 2009 IEEE
DOI 10.1109/ICSEA.2009.91

According to this survey, aligning activities with the business represents the main challenge, followed by making more with a smaller budget. According to IT executives the factors that most influence these challenges are:

- The growing availability of low-cost, easy-to-use devices;
- An increasingly ubiquitous, pervasive and affordable communication infrastructure;
- An explosion of content;
- Number of devices in datacenter and their impact in power and cooling;
- Aging workforce;
- Cloud computing;
- The rising cost of energy;
- Increased awareness of green IT;
- Social networking.

IT executives are also under pressure to be more agile, manage constant change from internal and external sources, align IT services with business requirements and implement business practices so that they can make business-level decisions on IT service pricing, packaging, sourcing, delivery optimization, investment opportunities and other business matters. There is a direct relation between IT infrastructures and business performance. Research found that robust IT infrastructures are a key driver of productivity and growth [8]. The employees in organizations with better IT infrastructures are more productive and IT executives with better information systems, control significantly better their business [12]. These conclusions create pressures on IT that can be hypothetically classified as "good" and "bad" pressures. Pressures to add business value by increasing productivity, pressures to increase end-user productivity or pressures to improve collaborations with customers, are examples of "good" pressures. On the other side, we have the "bad" pressures to reduce costs, improve security, keep business up and running, among others, that do not necessarily push the business ahead. According to analysts, these "bad" pressures consume 70% of most IT budgets today [13].

According to [3] the list of pressures, ordered by decreasing level of importance, is the following:

- 24/7 availability;
- Business continuity and disaster recovery;
- Cost reduction and/or cost management;
- Demonstrating business value;
- Increasing changes and pressure to move faster;
- Data center space, power and cooling;
- Modifying the IT operations architecture for virtualization;
- Defining business oriented IT services and SLAs;
- Modifying the IT operations architecture for SOA.

Since we are working on the definition of the PhD work plan of the first author around the topic of IT infrastructures management, we have to identify which are the open problems in this area that deserve to be explored. Published work in this area is commercial in nature, thus most probably driven by market forces and hype. To derive a more objective and independent view on the challenges and open problems that this knowledge domain faces, we purpose a research method that will be detailed in the following section.

## III. Research Objectives and Approach

This section describes the research method and objectives, research techniques, as well as the importance of performing empirical research in IT infrastructures.

### A. Research Method

The research method adopted consists of four phases: (1) identify, (2) diagnose, (3) solution finding and (4) results package as presented in Figure 1.

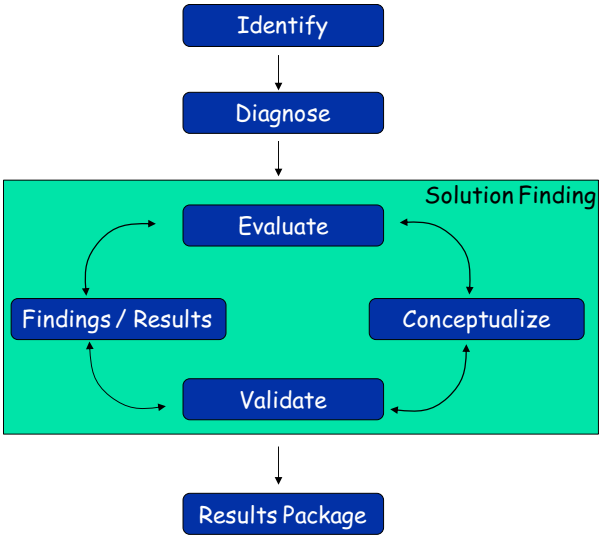


Figure 1. Phases of adopted research method

Each of the research method phases will be detailed in the next subsections.

#### 1) Identify

This phase is responsible for the identification of challenges faced by people responsible for managing IT infrastructures. It is important to maintain a list of challenges organized by impact, in order to prioritize them. This phase has the following activities:

- Identify challenges faced by IT infrastructure executives;
- Identify organizations which are available to collaborate;
- Identify key IT executives;
- Select the techniques to acquire information;
- Plan a detailed agenda of what is to be covered during information elicitation sessions;
- Develop supporting checklists.

Notice that there are several tools and techniques that can be used for the purpose of this stage. Subsection B will detail the ones that we are planning to use. After all these activities

have been accomplished, we can move forward to the next phase.

*2) Diagnose*

The main goal of this phase is obtain as much information as possible for each of the challenges faced in organizations regarding IT infrastructures. This means drilling down the challenges into each of the singular events/problems included in the challenge. We decided to use the laddering technique [14] that will be further detailed. This phase comprises the following activities:

- Interview preparation;
- Performing and recording the interview;
- Organizing the information collected;
- Result analysis;
- Conclusions.

With all the information collected and analyzed, we should carefully select the challenge(s) and formulate the research questions for which we expect to find mitigating solutions during the PhD research work. The selection of the challenge(s) should clearly identify the reasons of the selection, as well as the advantages and disadvantages compared with others.

*3) Solution Finding*

With the research questions defined, we will focus our work on understanding and finding solutions for each of the selected challenges. The process of finding solutions is an interactive process with four phases: (1) Evaluate, (2) Conceptualize, (3) Validate and (4) Findings. The solution finding may encompass the use of empirical research.

*a) Evaluate*

In order to perform this evaluation we may use multiple techniques such as an empirical research approach with the objective of detailing and finding gaps or difficulties that are in the source of the challenge. The main idea is to clearly identify and characterize each aspect.

*b) Conceptualize*

This process is responsible for designing and selecting scenarios and solutions to solve the selected challenge. The main idea is to identify all the possible solutions and select which one represents the best approach. To simplify the selection process for each possible solution, advantages and disadvantages should be identified.

*c) Validate*

This phase is responsible to validate the solution. This can be performed trough (i) tests in organizations and check if results are the expected ones, (ii) using hypothesis tests to compare two samples of cases (the first sample using the solution and second sample not using the solution), (iii) simulation and (iv) check solutions with experts.

*d) Findings / Results*

The findings/results are dedicated to the observation and analysis of the results obtained with the validation process. The deliverables of this phase includes not only the results obtained with the solution, but also recommendations regarding optimizations.

*4) Results Package*

Once a solution is found, it is essential to package the results so that they can be used in the context of an organization. This involves documenting the whole solution, and including a discussion on the results achieved. The discussion should focus on aspects such as the interpretation of the results, the limitations of the solution and lessons learned.

## B. Research Techniques

There are important techniques [15] that can be used to obtain information. These techniques can be organized in three groups as presented in Figure 2:

- Natural techniques – This technique involves the expert performing tasks they he would normally do as part of his job. Examples of these techniques are interviews, questionnaires, group meetings and observation techniques [15];
- Contrived techniques – This involve the expert performing tasks he would **not** normally do as part of their job. Examples of these techniques includes card sorting, three card trick, rep grid technique, constrained tasks, 20-questions, commentating and teach back [15];
- Modeling and mediation representation techniques – in this type of technique the expert performs a task he would normally do, but with constraints. This is useful for focusing the expert on essential knowledge and priorities. Example of these techniques include laddering, process mapping, concept mapping and state diagram mapping [15].


Figure 2. Research Techniques (adapted from [15])

Due to the nature of the information to be acquired and the type of informant, we decided to use a modeling technique called laddering in the "identify" and "diagnosis" phases. Depending on the challenges and the nature of the research questions, we may also have to use a combination of techniques and probably conduct an empirical research during the solution finding phase of the research method presented earlier. Both laddering technique and empirical research will be further detailed.

*1) Laddering Technique*

The laddering technique used in the diagnosis phase is a structured approach to perform one to one interviews with the goal of obtaining more information regarding a particular challenge or even new challenges.

Laddering helps to elicit the higher or lower level abstractions of the concepts that people use to organize their world. The method is performed by using probes. Probing means to "peel back the layers" of the informant's experience. Laddering and probing is used to: "understand the way in which the informant sees the world" [16].

The goal is to start the interview by focusing on certain aspects related to IT infrastructures and let the informant talk even about other aspects not related with IT infrastructures. The interviewer uses a limited set of standard questions to elicit informant requirements. This is based in the assumption that the informant requirements are organized in a multidimensional or multifaceted set of hierarchies. Laddering provides a structure for the elicitation of information using a 'facet', which is a convenience way to describe individual hierarchy and decomposition requirements. It comprises a multi-level architecture topping down from the highest level to the lowest level as shown in the illustrative example presented in Figure 3.

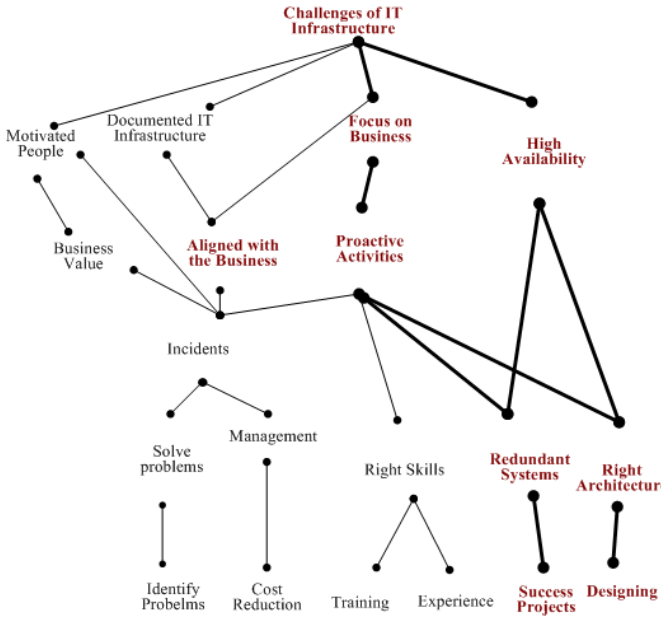


Figure 3. An example of laddering technique (adapted from [15])

The procedure of the laddering technique, originally presented by Rugg and McGeorge [17] is summarized as follows:

- **Step 1** - selecting/faceting a seed item. An interviewer or domain expert first selects a seed item, which is a point within the domain in question, from any level within the hierarchy;
- **Step 2** - preparing/phrasing the probes. The interviewer uses probing questions to move around the structure embedding the seed item. Some of the frequently used probes or phrasings include 'is-a', 'has-goal' and 'part-of';
- **Step 3** - directing/leveling the semantics. Another paths are recommended to change the direction once laddering is not possible such as 'bottoming out' or 'topping out';
- **Step 4** - decomposing/classing the explanations. Explanations are then decomposed recursively until terms such as classes, attributes and entities bottom out (descend to the lowest point possible);
- **Step 5** - recording/coding the sessions. Several coding methods are available for laddering, including paper record, graphic representation (such as *LadderTek* developed by the second author and pseudo-production rule [18]. Appropriate labeling that displays the names of classes and attributes is advisable;
- **Step 6** - analyzing/post-processing the results. This enables the elicitors to gain insights into the results of laddering. Quantitative analysis can be employed to post process the results obtained.

## C. Empirical Research in IT Infrastructures

The empirical research in IT infrastructure calls for the need of experimentation and observation rather than theory. This process is used during the solution finding phase of the research method presented earlier.

As the field of IT seeks to develop valid, proven theories about its infrastructures, the empirical research is a very important subject. Empirical research in IT infrastructures implies building models such as application domain or problem solving processes and checking if our understanding is correct trough testing or experimenting in the real world. The analysis of results involves the ability to change or refine our models over time.

As Singleton and Straits [19] stated, "*appeals to authority, tradition, revelation, intuition, or other non-empirical ways of knowing which may be acceptable in other endeavors such as philosophy cannot be used as scientific evidence*". For us to better understand challenges in IT infrastructures, it is essential to develop and test IT infrastructures theories using actual observations.

In order to overcome the identified challenges and advance in IT infrastructures theorization, it is important to use a rigorous and scientific process, where theories are based in evidence and substantiation.

This process of experimentation and learning requires the development, tailoring and evolution of methods that support

evolutionary learning in order to overcome challenges, as well as the establishment of processes that support IT infrastructures that:

- are relevant to the needs of the organization;
- can be predicted and estimated effectively;
- satisfies all the stakeholders;
- does not contain contradictory requirements.

This empirical research process in IT infrastructures should also include validity. As defined by Robson [20], validity is "the degree to which what is observed or measured is the same as what was purported to be observed or measured". The purpose of validity as originally defined, is to give researchers, their peers, and society as a whole a high degree of confidence that positivist methods being selected are useful in the quest for scientific truth [21]. Common validity considerations used in social and management science [22] that should be applied to IT infrastructures research are: construct validity, convergent validity, discriminant validity, internal validity, and external validity. These are discussed below.

- **Construct validity** – Construct validity is when an instrument measures the intended construct, instead of measuring something different. Particularly in the study of IT infrastructures, construct validity is problematic because the ambiguity of terminology makes it hard to compare experimental variables across organizations;
- **Convergent validity** – this validity is concerned with the coherence of results. For example if two IT executives are asked to rank a set of ten challenges in IT infrastructures, like the ones suggested by Gartner in [3] would they agree on their rankings? If executives cannot converge on an understanding of challenges, then the construct is not valid. For a study to have convergent validity there must be convergence on the meaning of the construct of interest, which is extremely difficult in the field of IT infrastructures. Another possible source for the lack of convergent validity is that IT executives rely on their own experiential heuristics, gained through a lifetime of experience, but each has a different set of experiences;
- **Discriminant validity** – this validity refers to the degree to which one theoretical construct differs from another. If for example IT executives are asked to rate IT infrastructures, are they indeed rating IT infrastructures prowess or are they rating another construct such as the IT infrastructure topology? If it is not possible to discriminate between IT infrastructures prowess and these other constructs, then the study lacks discriminant validity. Campbell and Fiske in [21] proposed a Multi-Trait Multi-Method matrix to assess convergent and discriminant validity of data gathered on multiple traits (theoretical constructs), using maximally dissimilar methods such as self report and unobtrusive observation;
- **Internal validity** – Internal validity includes the consideration of alternative explanations other than the theory being tested. Cook and Campbell in [23] list a vast number of threats to internal validity. The internal validity is assessed using three criteria: (1) Independent and dependent variables are meaningfully related, (2) variation in the independent variable is contemporaneous with, or precedes variation in the dependent variable, (3) there is a reasonable causal explanation for the observed relationship and there are no plausible alternative explanations for it;
- **External Validity** – This is a problem of generalizability or in other words, what the experimental results mean outside the particular context of the experiment. External validity refers to the approximate validity with which we can for instance conclude that the presumed concerns can be generalized to and across different types of organizations and IT executives. The research sample and setting must be representative of the population of interest in order to have external validity. In addition, external validity may be a problem if one seeks to generalize from what people say in a survey to what people actually do, since there is a notorious lack of relation between attitude and behavior [20]. This was one of the main reasons that lead us to select the laddering technique described before. There are things that can be done to help external validity, including sampling randomly, replicating results in a diverse setting, using multiple methods, and using field research.

## IV. Current Work and Preliminary Results

We are currently in the "identify" phase of the research method, with techniques to acquire information defined, some of key executives also identified and preparing a detailed agenda of what is to be covered in sessions. We are preparing the use of the Laddering technique for knowledge acquisition in what concerns the top challenges and understand which are the underlying problems behind each challenge. This approach is expected to help formulating meaningful research questions and prepare the rest of the work plan to address and mitigate some of the challenges. We have been researching on IT infrastructures, namely by proposing a model-based approach to evaluate IT infrastructures in terms of size, complexity, adoption of best practices, and automatic classification of topology among other aspects [24] and performed also the identification of key stakeholders in IT infrastructures, their job description and their "stake", which represent a valuable input for this phase particularly in the identification of key executives.

## V. Work Plan and Implications

The work plan for this research is based on the method presented on section III and encompasses the realization of four major phases. The outcome of the first phase is the identification of challenges based upon the use of several tools and techniques. The second phase ("Diagnose") aims at obtaining as much information as possible regarding the challenges identified in the first phase and based on that select the ones to address. We expect to have this finished in

the first semester of the second year of our work plan. With problems clearly identified, the focus of the next phase ("Solution Finding") will be to propose mitigating approaches to identified problems. To do so, we will follow an interactive process with four phases (i) evaluate, (ii) conceptualize, (iii) validate and (iv) findings. We plan to share the research work in scientific communities and we expect to have this phase finished in the first semester of the third year, to start the last phase, which is ("Results Package"). With the results validated in scientific communities we plan to pack the results so that they can be used in the context of organizations. This involves documentation, discussion on the results achieved, limitations, lessons learned among other aspects.

## VI. CONCLUSIONS

The growing importance of IT infrastructures in organizations and particularly their impact in the business are the main motivations for this research work. This research work aims at identifying challenges faced by IT executives regarding IT infrastructures and propose an approach to mitigate some of these challenges. We defined a research method with four major phases and we plan to use several research techniques such as laddering technique to acquire information from IT executives regarding their IT infrastructures, in order to identify the main problems this community is facing. We will then try to tackle some of those open issues, first by performing some empirical research upon data collected from the operation of real-world IT infrastructures to understand the underlying phenomena, and them by proposing some mitigating solutions.

## REFERENCES


[1] Sirkemaa, S.: 'IT infrastructure management and standards', *Proc. of Coding and Computing, 2002. Proceedings of the International Conference on Information Technology*, Las Vegas, April 2002, 2002.

[2] Hoving, R.: 'Information Technology Leadership Challenges-Past, Present, and Future', *Inf. Sys. Manag.*, 2007, 24(2), pp. 147-153; Benamati, J.S., and Lederer, A.L.: 'Decision support systems unfrastructure: The root problems of the management of changing IT', *Decis. Support Syst.*, 2008, 45(4), pp. 833-844.

[3] Chuba, M., and Scott, D.: '*Top Challenges Facing IT I&O Executives'*, No. G00160214, September, 5, 2008.

[4] OGC: *IT Infrastructure Library (ITIL) - Service Strategy (Version 3)*, The Stationery Office), London, 2007.

[5] Symons, C., Orlov, L.M., Brown, K., and Bright, S.: '*COBIT Versus Other Frameworks: A Road Map To Comprehensive IT Governance'*, No. 38442, January 5, 2006.

[6] Salle, M.: '*IT Service Management and IT Governance: Review, Comparative Analysis and their Impact on Utility Computing'*, June, 2004.

[7] Scott, D., Holub, E., and Pultz, J.E.: '*Organizing for IT Infrastructure and Operations: Trends and Best Practices'*, 23 January, 2006.

[8] Byrd, T.A., and Turner, D.E.: 'An exploratory examination of the relationship between flexible IT infrastructure and competitive …', *Information & Management*, 2001, 39, pp. 41-52.

[9] Ganek, A., and Kloeckner, K.: 'An overview of IBM Service Management', *IBM SYSTEMS JOURNAL*, 2007, 46(3), pp. 375-385.

[10] Weill, P.: '*Compilation of MIT CISR Research on IT Portfolios, IT Savvy and Firm Performance (2000-2006)'*, 2007; Weill, P., Subramani, M., and Broadbent, M.: 'IT Infrastructure for Strategic Agility', *MIT Sloan School of Management*, 2002(329), pp. 30.

[11] Ernest, M., and Nisavic, J.M.: 'Adding value to the IT organization with the Component Business Model', *IBM Systems Journal*, 2007, 46(3), pp. 387-403.

[12] Iansiti, M., Sarnoff, D., and Favaloro, G.: '*Enterprise IT Capabilities and Business Performance'*, March 16, 2006.

[13] Bartels, A.: '*The State Of Enterprise IT Budgets: 2008'*, March 27, 2008.

[14] Olson, J., and Reynolds, T.: *Understanding Consumer Decision Making: The Means-end Approach to Marketing and Advertising Strategy*, Erlbaum Mahwan, NJ, 2001.

[15] Goble, C.: '*Ontology Engineering & Ontology Acquisition'*, The University of Manchester, 2002.

[16] Reynolds, T., and Gutman, J.: 'Laddering theory, method, analysis, and interpretation', *Understanding Consumer Decision Making*, 2001.

[17] G. Rugg, P.M.: 'Laddering', *Expert Systems*, 1995, 12(4), pp. 339-346.

[18] Chen, C.-H., Khoo, L.P., and Yan, W.: 'PDCS--a product definition and customisation system for product concept development', *Expert Systems With Applications*, 2005, 28(3), pp. 591-602.

[19] Singleton, R., Straits, B., Straits, M., and McAllister, R.: *Approaches to social research*, lavoisier.fr, 1993.

[20] Robson, C.: *Real world research: A resource for social scientists and practitioner-researchers*, books.google.com, 2002.

[21] Nunnally, J.: *Psyclometric Theory*, New York: McGraw-Hill, 1978.

[22] Straub, D.: 'Validating instruments in MIS research', *MIS quarterly*, 1989.

[23] Cook, T., Campbell, D., and Peracchio, L.: *Quasi-experimentation*, Houghton Mifflin Boston, 1979.

[24] Silva, L.F.: *Assessment of IT Infrastructures: A Model Driven Approach*, MSc dissertation, Universidade Nova de Lisboa, October 2008.