JYX JYVÄSKYLÄN YLIOPISTO UNIVERSITY OF JYVÄSKYLÄ

This is a self-archived version of an original article. This version may differ from the original in pagination and typographic details.

Author(s): Hirvonen, Ari; Pulkkinen, Mirja

Title: Evaluation of Enterprise IT Architecture Solutions – How can an ICT consultant tell what is best for you?

Year: 2003

Version: Published version

Copyright: © Authors, 2003

Rights: In Copyright

Rights url: http://rightsstatements.org/page/InC/1.0/?language=en

Please cite the original version:

Hirvonen, A., & Pulkkinen, M. (2003). Evaluation of Enterprise IT Architecture Solutions – How can an ICT consultant tell what is best for you?. In Management Centre International Limited. Proceedings of the 10th European Conference on Information Technology Evaluation (pp. pp 327-337).

Evaluation of enterprise IT architecture solutions – How can an ICT consultant tell what is best for you?

Ari Hirvonen
TietoEnator Oyj, Jyväskylä, Finland
Ari.P.Hirvonen@tietoenator.com

Mirja Pulkkinen
University of Jyväskylä, Finland
Mirja.Pulkkinen@titu.jyu.fi

Abstract: ICT has become a key business enabler and a competitive factor for enterprises. Enterprise architecture, developed by ICT consultants and ICT end-user organizations, is emerging as the management tool for intertwined business and IT planning. For managerial decisions, there is a need to evaluate the business value of architecture development results, but only a few models for this have so far been presented. Here we present the V-model for EA testing and validation that marks the evaluation points in EA management, and guides which evaluation tools could be used.

Keywords: Consulting, Information Management, Evaluation, Enterprise Architecture, Quality

1. Introduction

The central role of ICT and its strategic use was recognised early (Somogyi and Galliers 1987, Earl 1989, Ward and Griffith 1996), but only in the past decade this has become reality in business organisations to a larger extent. There might be different perceptions of what the mandates of IS, IT or business strategy are (Hackney et al. 2000), but the merging of these is inevitable due to recent developments.

Johansen (1988) sees several business environment factors as driving forces for the new uses of ICT: industry de-regulation, to which we could add market de-regulation and changes in organisational structures and roles, e.g. team (or process) organisation; frequent mergers and acquisitions; and the outsourcing and geographic spread of organisations (Johansen 1988, Ives and Jarvenpaa 2002).

On the other hand, many changes in business organisations were either directly caused, or speeded up by, technology changes. In the beginning of the 90's, computer networks begun to enable radically new ways to organise business operations, work and the intra- and inter-organisational supply chain.

Acronyms for a new business revolution coming after another have been introduced since then: BPR, TQM, JIT, ERP, CRM - many of these are directly associated with information systems, the technological advance acting as a booster or a catalyst for business change (Dickson 2003). The deep impact of ICT in the strategies and operations of enterprises has been indisputably pointed out (Henderson and Venkatraman 1999, Seltsikas 2000, Ward and Peppard 2002). Business organisations require comprehensive information management and the leveraging of organisational information (Quinn et al. 1996, Hackney et al. 2000).

Comprehensive management of the information systems and technology assets in an entire corporation has thus become a part of the top management's agenda, not only a task of the IT function. The evaluation of technology solutions and their accuracy for the business operations they support, as well as the screening for new, possibly smarter solutions are the tasks of the ICT asset management and business strategy planning team.

Recent studies have uncovered a lack of capability to evaluate the value gain from either ICT investments (Remenyi 2000, Hallikainen 2003), or the use of IT consultants (Market-Visio 2003). Our study contributes to this field with an evaluation model for enterprise information systems management that also takes into account the needs of consulting projects. The model

is based on theoretical and practical findings presented in the literature on enterprise architecture (EA) management and software engineering. It has been further developed and validated in practice in EA projects at TietoEnator, the fourth largest full-service ICT provider in Europe.

The study consists of the following sections:

Section 2 deals with the enterprise architecture concept and methodologies for EA management, as well as systems and software architecture evaluation approaches. Further, as a restriction to the model to be created, it discusses the role of an ICT consultant.

In section 3, enterprise architecture consulting projects are surveyed, and a general outline of them is given.

Section 4 presents the enterprise architecture evaluation V-model, derived from the concepts presented in Section 2, as well as the practical evidence from the real EA projects presented in Section 3.

Section 5 concludes the study and presents areas for further examination.

2. EA management, evaluation approaches and consulting

2.1 Enterprise architecture management

As a tool for a more controlled use of ICT and its accurate application and evaluation in organisations, Enterprise Architecture management is suggested (Zachman 1987, Sowa and Zachman 1992, Spewak 1992, Malhotra 1996). It provides the context for evaluation suggested by Remenyi (2000) and is a good candidate to manage all the items that lead to success (Seltsikas 2000):

- Alignment of IS with the corporate strategy and business models
- Business process redesign and renewing of organisational forms
- Competitive advantage
- Architecting and managing the underlying ICT for all above.

There are several frameworks and reference architectures that guide the enterprise wide information systems architecture management. Besides the Zachman matrix (Zachman 1987, Sowa and Zachman 1992), other efforts to explore the field have resulted into management process models, methods and frameworks of enterprise information systems planning and development (Spewak 1992, Armour et al. 1999, Hay 2003, The Open Group 2002, Perks and Beveridge 2003).

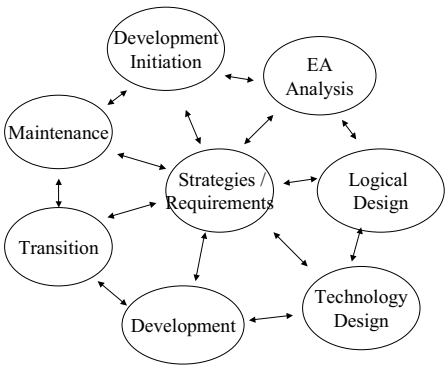

Figure 1: EA Management Cycle – an Example

Yet these frameworks and processes focus mostly on ICT end-user organisations' needs. They support a holistic approach, which is a necessity for an organisation managing its own EA. The EA management is usually depicted as a cycle with gradual development phases (Figure 1, adapted from the TOGAF Architecture Development Method, The Open Group 2002, Perks and Beveridge 2003). A consultant needs a different approach for discrete development projects within the general management framework.

In the EA management and development methodologies, evaluation is usually included as an issue. As an example, The Open Group's Architecture Development Method (The Open Group 2002, Perks and Beveridge 2003), suggests evaluation at each phase transition. However, the concrete steps how to do it remain vague, and guidance how to use existing evaluation tools is not provided. This would be an essential point, firstly thinking of the strategic significance of enterprise architecture, and secondly for evaluating the consulting results.

2.1.1 Software evaluation

In software engineering, there are methods, tools and defined generic process models that have been proven in practice (Sommerville 1998). The software community therefore tends to face the new challenges of managing a whole enterprise's information systems with this framework. Parallel to the establishing of the discipline of Software Architecture (Shaw and Garlan 1996), Enterprise Architecture has also been studied, mostly in the Enterprise Application Integration (EAI) context (Linthicum 2000.)

Software development methods are well equipped with evaluation tools for assessing different aspects of software architectures (Dobrica and Niemelä 2001). Besides SAAM (Software architecture analysis method) and related methods, for example the Architecture Trade-off Analysis Method ATAM (Kazman et al. 1999), there are also more economics oriented ones, like the Cost Benefit Analysis Method (CBM, Ionita et al. 2002).

In addition to evaluation methodologies, a general model for software validation and verification, the so-called V-model (Wallace and Fujii 1989) has been widely accepted for software quality assurance. The model follows the software life cycle and suggests a suitable evaluation technique to be applied at different stages of the life cycle (Figure 2).

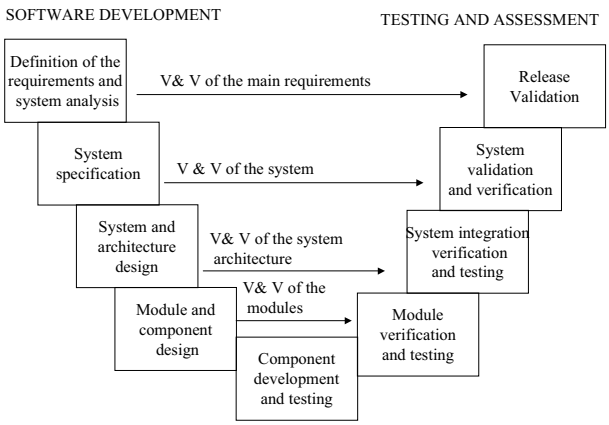

Figure 2: The V-model of software validation and verification

In software engineering, we are looking at the development of one computerized system at a time. We will adapt these evaluation concepts to the context of enterprise architecture planning and development, an environment where there are multiple systems a need for some systems' interoperability. The evaluation model basically answers the questions

- What to evaluate – what is the IT structure to be evaluated at a time

- When to do it, and when to plan the assessment and testing
- How, or with which method, it can be assessed.

The model should define the points in the EA planning process where evaluation is in place to validate achieved planning results, to guide further work and to provide a basis to make choices between alternative solutions. In order to outline a practical process model usable in an EA consultant's work, we first look at the role of the consultant (next subsection) and survey EA consulting cases (Section 3).

2.1.2 Consultant's role

An ICT service provider is facing an unprecedented task in the constantly changing business environment of their clients, who are trying to cope with the task of managing a portfolio of variegated legacy systems, the integration of these systems, and evaluating the need for the acquisition of new technology. The clients expect the consultant to tell how to be on the safe side: How to avoid missing any opportunity in business or organisational development, and to acquire the right technology for the new business models and systems, that soon may become entry thresholds for a branch (Dickson 2003).

EA development and consulting has emerged as a new area that joins several areas of business consulting and development with ICT (Figure 3) and is an attempt to meet the client's needs in today's world.

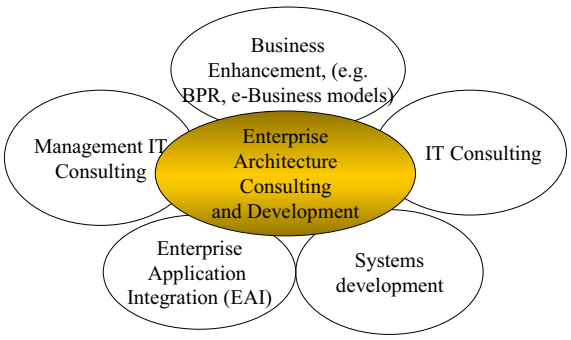

Figure 3: Joining the forces: enterprise architecture consulting and development

Consulting is different from the end-user organisation's EA planning. Over time, a client organisation must manage and develop the entire EA, whereas a consultant will get only limited development tasks with clients varying in size, competence and resources. As EA planning tasks are instances of the merged business and IT strategic planning and development, the consultant is expected to:

- Have both business and technology skills
- Take part in finding and creating new business opportunities with ICT
- Help in creating added value with ICT for the business (applies to both existing technology and new investments)
- Ensure the quality of ICT management and development; good quality of consultant work ensures the desired results for the customer

Two methodical approaches to solve the problem can be observed. In one, management and business consulting ideas are employed for management IT consulting (Block 2000, Spewak 1992). In the other, software engineering professionals extend the methodological and practical approaches of information systems to an enterprise architecture framework.

Yet, there seems to remain a gap between these two approaches as shown in Figure 4. Enterprise architecture consulting and EA development is suggested as a bridge to make both efforts a seamless continuum (Malhotra 1996, Buchanan and Soley 2002, Hirvonen et al 2003). Seamless transition from one approach to the other is needed to address both the business and financial interests, and the technology fit.

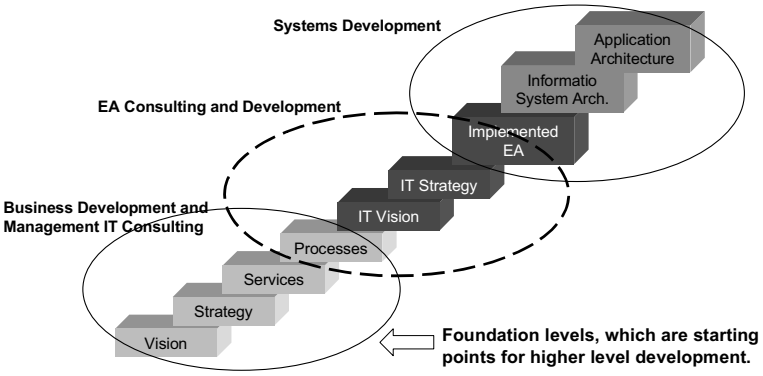

Figure 4: Activity Areas of an ICT consultancy and their logical dependencies.

3. EA Cases: frequency, characteristics, evaluation needs

To understand the nature and the process of EA consulting and development projects, we undertook a survey at TietoEnator, and established characteristics and a rough process model for these projects. The total number of different project type and different kind of personnel in them at TietoEnator within the time frame 2001-2002 is given in Table 1. Consultancy cases are fewer in number than systems development projects, but strategically more important, because they characteristically deal with the development of the foundations of whole enterprises. EA development (Figure 4) is divided here into two sub-areas: Comprehensive EA consulting and focused EA technology consulting.

Table 1: The number of different roles and projects at TietoEnator 2001 – 2002

Type of project	Approximate Number of projects	Number of personnel
Management consulting	70	60
Enterprise Architecture consulting	50	60
EA technology consulting	140	80
Systems development	1000	9 000
Total	1260	12 000

We asked the senior EA consultants representing three business areas that serve different industries, to provide descriptions of typical EA consulting cases in their business area. By typical we mean projects having a recurring process and the same abstraction level and objectives for different clients. The consultants were asked to describe the project, its scope, the development process and the produced results. As a result, nine projects were documented. To supplement the data, we conducted interviews with four senior consultants. The interview

results were reviewed by and discussed with the interviewees. The process and the results are reported in full detail in Hirvonen et al. (2003).

The surveyed consultancy projects (Table 2) varied in scope, size and abstraction level. The scope and abstraction level also evolved during iterations as understanding of the problem domain developed. Technology architecture planning was a typical part in nearly all cases. It seems that the technology competence created in recurring cases is most in demand from the consultants, although not always. Case 1 focused only on systems architecture planning. There were large projects and long cases in calendar time (case 4), but also very quick and short ones (cases 8 and 9). There were cases where the relative amount of client personnel in the project was clearly greater than the consultants' (cases 2, 3 and 6), but also cases where most of the project staff were consultants (cases 4 and 7).

In these nine cases, various sub-areas of EA (Figure 3) were emphasised. There were cases focusing on EAI planning or technology evaluation, but also more holistic enterprise level information, systems and / or technology architecture consulting cases, as well as mixtures of the areas. All cases had some common phases. Evaluation foundations are set in project initiation, project ending and requirements analysis phases. Project level quality targets are set, project goals decided and finally evaluated.

Common tasks in every case were:

- **Present situation analysis**, where the current state of the planned area is analysed
- **Requirements analysis**, to collect, analyse and prioritize business requirements
- **Roadmap planning**, which contains plans for transition periods, projects and project dependencies, and estimates costs and ROI for the target architecture
- **Project initiation and ending activities**, which are common with any project, but have some special requirements in consulting cases, for example in regard to personal co-operation and communication.

Table 2: Typical EA planning cases

Case	Business Archi-tecture Planning	Information Architecture Planning	Systems Architecture Planning	Technology Architecture Planning	No. of Clients in the Project	No. of Consul-tants in the Case	No. of Work-shops	Length in Months
1			X		4	3	6	6
2		X		X	8	3	N/A	4
3	(X)	X	X	X	11	3	N/A	5
4	(X)		X	X	7	9	30	11
5				X	2	2	16	4
6				X	12	3	12	5
7	(X)		X	X	1	3	N/A	7
8				X	2	2	6	2
9				X	1	1	3	1

Consultancy approaches also differ; most of the planning responsibility can lie on the consultant, or either he/she only supports the client's planning effort. Cases 1, 4, 5, 8 and 9 had nearly same number of consultants and customers and the responsibility was also divided accordingly. On the one hand, variation in project scope also requires varying validation and evaluation approaches and techniques, and on the other hand, common consulting related evaluation techniques are needed.

According to the interviews, regard was paid to both of these and they were a part of the Business Areas' standard procedures. Project level quality target setting and evaluation procedures were a well-managed area. Varying single development target quality assurance activities were also used, most commonly reviews. These practise proven methods are also used in our evaluation model.

4. Evaluation in EA context

Our survey of EA projects and literature on EA management, indicate that both an organisations' internal and co-operative EA development with consultants have differences, but both also have common starting points and objectives: the same problem domain and interest for business success of the target organisation. A validation and evaluation approach for continuous EA management, and support also for restricted EA development projects and consulting cases are needed.

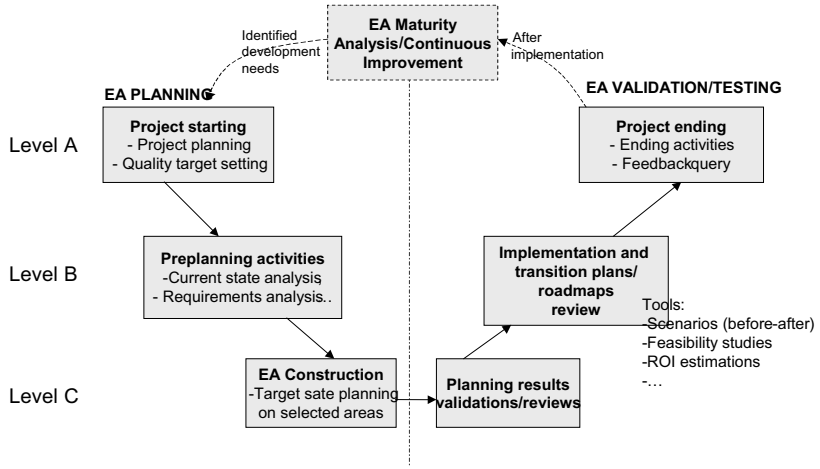

Figure 5: EA V-model for planning and validation

These approaches are integrated in our V-model for EA testing and validation (Figure 5). Parts of the model are being tested in actual use at TietoEnator and its customer organisations.

The basic concepts of this model are the same as in the original V-model for software testing (Section 3). The lowest level of the model presents the most precise detail level and the shortest time between results production and testing. In the upper parts of the model, the level of detail decreases and the time frame grows longer.

We have found that identified quality targets and testability or measurability should be followed all the way from the beginning to the end of the project and should also be included in the lower level viewpoints during the process. Focusing on testing, testability, test planning and quality issues early in the process is the key benefit of the original V-model. If the testing is planned too late in the process, quality targets can be impossible to reach. This also applies in EA development. Next we will look at the model in more detail.

4.1 Maturity analysis and continuous improvement

Our EA V-model starts at the level of EA maturity analysis and continuous improvement. Here the EA management and the management process are improved, new EA development targets are identified and development priorities are set. This is a continuous process, which can also be developed with aid of consultants. Useful maturity analysis models can be found in literature. At this level, three main issues must be ensured:

- Maturity of the EA management process,
- EA linkage to business,
- Development processes value creation potential to the business.

A healthy EA development process is a precondition to business aligned EA development target selection, which initiates a new EA development cycle.

4.2 Development initiation and ending

At the top level, the theme is EA development or consultancy project (Figure 5, LEVEL A). At this level, the key question is: does the project as a whole meet the expectations and business needs? The time interval between project starting and ending activities is the longest.

Starting activities may set some outlines and requirements, which will affect the whole development project. Our consultancy experience indicates that high variation in consultancy cases' scope and the abstraction level will often lead to a situation where some reasonable results are requested in the project's starting phase, but are out of reach. Typical signals of resistance (Block 2000) are "confidential information" (consultants do not receive all necessary information) or lack of client resources (not enough client's specialists or management involved). Quality target setting is the key procedure to cope with these challenges and has therefore been introduced as a standard procedure.

The quality target-setting phase can proceed in parallel with project planning, which is typically performed at managerial level when the contract is negotiated. The process can be iterative and every time when project scope, goals or other issues are changing the project notably, the process is repeated. Quality target setting has the following steps:

- Working process is described on a rough level. The project goals are defined, and plans made to achieve them.
- Targets are identified, classified and priorities are set. The client is advised to carefully think what is really needed, and to set a weight value on each target. Typically there remains a maximum of five weighted and prioritised targets described, which are concrete, measurable and reachable.
- The client and the consultant approve an agreement on what to measure and what are the required indicator levels.
- Preconditions are checked and described; responsibilities for them and concrete tasks are distributed and possibly timetable is set.

Both client and consultant should have a clear conception of the objectives and preconditions to reach them. Good targets are such that the consultant can effect their attainment. If a precondition is not fulfilled, the situation should be handled as a normal project management team issue immediately.

At the end of the project, a client satisfaction query is made with questions relating to the project quality targets set in the beginning. The client is asked whether the targets reached are clearly lower or clearly better than expected on a five-step scale. The results of the queries can be collected yearly and used for setting the staff's personal bonuses. This procedure is also useful to ICT end-user organisations internal IT development efforts.

4.3 Pre- and post planning activities

At the middle level, validation focuses on business goals and development plans (Figure 5, LEVEL B). In each EA planning project there can be multiple development areas, like systems and technology architecture planning, which need separate and combined result validation and evaluation (e.g. Table 2, cases 2, 3, 4 and 7). The key questions at this level include

- Do the requirements describe business goals
- Are the plans to fulfil the requirements realistic
- Is the organisation able to follow the plans to completion
- How the plans should be improved.

The time interval between pre- and post planning activities is the second longest in our model. Preplanning activities, like requirements analysis, will set outlines and requirements for the whole planning activity.

In EA development we are dealing with the future strategic success of the company. Because many of the EA planning results will have their expected impact in the future, the only way to evaluate the attainability of those goals is by creating different kinds of scenarios and then analyse what the possible consequences are. A valid method for this level validation is for example the Cost Benefit Analysis Method (CBAM, Ionita et al. 2002). Detailed guidance for setting up business scenarios is given in TOGAF (The Open Group 2002).

Approaches basing on clear-cut measuring can also be used. These are typically related to measurable system qualities or technical variables. For example, consolidation of the current ten servers to one will cut current costs by x thousand €. In smaller projects this level evaluation and validation can be integrated with LEVEL A activities.

4.4 Single planning results validation

The lowest level of the model focuses on the single planning results technical quality (Figure 5, LEVEL C). In each development area there can be multiple detailed planning results, like guidelines or technical descriptions in technology architecture planning.

The quality of the results and how they could be improved are the key questions at this level. The time interval between planning result construction and validation is the lowest in our model. Quality targets set at higher levels of the model should also guide evaluation at this level.

Reviews, as well as previously mentioned measuring and questioning based approaches could also be used at this level. The SAAM and related methods, especially ATAM (Kazman et al. 1999) propose well-established ways to evaluate solutions at this level. The methodology can be also adapted to EA cases. The strength of the review technique is its ability to benefit from experiences in previous cases.

5. Conclusions

For a full-service ICT service provider, today's all-encompassing strategic use of information systems in their client's organisations means a challenge in many ways. Consulting and development tasks starting with business consulting and ending up with systems design and development require different methodical approaches for evaluation. Within the scope of a whole enterprise, there are several areas to be worked on ranging from pure enterprise information technology infrastructure to intelligent use of IT for business strategy development. There is a growing demand for evaluation of IT with business evaluation metrics to see the real value of IT investments and to compare varying technology solutions.

Yet, the evaluation of isolated efforts like the acquisition of IT infrastructure equipment or single system development gives a narrow basis for evaluation. Architectural planning is the decision-making arena where the essential qualities of a future state can be estimated. This has been established both in enterprise wide planning and in software development. Architecture provides the big picture that captures dependencies between the parts, thus being more than just the sum of its parts. By exploring enterprise architecture, we get more solid ground for IT evaluation than by only assessing one component at a time.

Consultants and ICT end-user organisations both contribute to EA development, the first mostly in technology issues and the second in domain and business issues. Both are also contributing to evaluation and validation in their speciality areas to ensure business value creation. Because of this divided responsibility, consultants alone cannot tell their clients what is best for them, but rather consulting is always a joint effort and learning process between participants.

Evaluation and validation methods and tools are needed to cover all areas from the ICT end-user organisation's continuous EA management to discrete EA development projects, to ensure early corrective actions and sustained business value of the EA. This means not only evaluating single IT investments, but also the entirety of the ICT in an enterprise. To develop EA and to evaluate it, it has to be looked at in manageable chunks. The value an ICT consultant creates for a business is related to the questions what, when and how to evaluate. Recognising the

seminal work previously done for both EA management for user organisations, and for development and evaluation of software architectures and software validation and verification, we have presented an Enterprise Architecture Validation model (EA V-model) for EA testing, evaluation and validation. The model is intended to guide an IT end-user organisation's continuous EA management, but it also takes into account consulting and the needs of EA development projects.

The EA evaluation model marks the evaluation points in the EA management cycle, and guides which evaluation methods, either to assess the economic value of present systems or planned investments, or to measure information systems' qualities, could be used. It also indicates when to plan evaluation for different stages in the EA management cycle, thus ensuring efficient allocation of development efforts and resources. Focusing early enough in the EA process on evaluation, assessment, testability and test planning as well as on quality issues is the key benefit of the model.

Further research topics raised in this study are

- A clearer picture of EA area as the IT evaluation context
- More profound study on EA consulting and the ways to do it, process and its outcomes
- Further study on client vs. consultant roles
- Methodical development of EA V-model by experimenting with it as a whole

References

Armour, F J, Kaisler, S H and Liu, S Y: Building an Enterprise Architecture Step by Step. In: IT Pro, July/August 31-39, IEEE 1999.

Buchanan, R D and Soley M: Aligning Enterprise Architecture and IT Investments with Corporate Goals. White Paper, META Group, Inc. 2002.

Block, P: Flawless Consulting, A Guide to Getting Your Expertise used, second edition. Jossey-Bass/Preifer 2000.

Dickson, G W (North Carolina State University): Drivers of IT Success and Failure. Technology or Management? Lecture Notes of a Guest Lecture at the Department of Computer Science and Information Systems, University of Jyväskylä, March 2003.

Dobrica, L and Niemelä E: A Survey on Software Architecture Analysis Methods. IEEE Transactions on Software Engineering, Vol 28, No 7. 638-653. IEEE 2002.

Earl, M J: Management Strategies for Information Technology. Prentice Hall 1989.

Hackney, R, Burn, J and Dhillon, G: Challenging Assumptions for Strategic Information Systems Planning: Theoretical Perspectives. Communications of the Association for Information Systems. Volume 3, Article 9. AIS 2000.

Hallikainen, P: Evaluation of Information Systems Investments. Dissertation, Helsinki School of Economics 2003.

Hay, D C: Requirements Analysis. From Business Views to Architecture. Pearson Education Ltd. Prentice Hall 2003.

Henderson, J C and Venkatraman, N: Strategic alignment: Leveraging information technology for transforming organisations. In: IBM Systems Journal, Vol 38 No 2-3, 472-484. International Business Machines 1993/1999.

Hirvonen, A, Pulkkinen, M, Ahonen J, and Halttunen, V: A Case Study on the Difficulties of Moving from Enterprise Architecture Development to Software Engineering Projects. Submitted to International Conference on Software, Science Technology and Engineering. IEEE Computer Society 2003.

Ionita, M T, Hammer D K, Obbink H: Scenario-Based Software Architecture Evaluation Methods: An Overview. Proceedings of the International Conference on Software Engineering 2002.

Ives, B and Jarvenpaa S: Applications of Global Information Technology: Key Issues for Management. MIS Quarterly, Volume 15 Issue 1, p 33. MIS Quarterly and The Society for Information Management 1991.

Johansen, R.: Computer Support for Business Teams. The Free Press, MacMillan, Inc. 1988.

Kazman, R, Barbacci, M, Klein, M, Carriere, S J and Woods, S G: Experience with Performing Architecture Tradeoff Analysis. Proceedings of International Conference for Software Engineering ICSE'99. 54-63. May 1999.

Linthicum, D S: Enterprise Application Integration. Addison-Wesley 2000.

Malhotra, Y: Enterprise Architecture: An Overview. WWW document. URL: www.brint.com/papers/enterarch.htm Accessed: 17.4.2002. BRINT Research Institute 1996.

Market-Visio: IT Konsultointi Suomessa 2003-2004. http://www.marketvisio.fi/ Accessed 28.4.2003

Perks, C and Beveridge, T. Guide to Enterprise IT Architecture. Springer 2003.

Remenyi, D: The Elusive Nature of Delivering Benefits from IT Investment. In: Electronic Journal of Information Systems Evaluation (EJISE), Vol 3, Issue 1. Delft University of Technology 2000. URL: http://www.iteva.rug.nl/ejise/index.html Accessed: 27.6.2003.

Quinn, J B, Anderson, P and Finkelstein, S: Leveraging Intellect. In: Academy of Management Executive Vol. 10 No. 3. 7-27 1996.

Seltsikas, P: Managing Global Information Strategy: Xerox. In: ICIS 2000. Proceedings of the Twenty-First International Conference on Information Systems 791-806. Association for Information Systems, 2000.

Shaw, M and Garlan, D: Software Architecture. Perspectives on an Emerging Discipline. Prentice-Hall Inc. 1996.

Sommerville, I: Software engineering. 5th ed., Addison-Wesley 1998.

Somogyi, E K and Galliers, R D: Strategic Information Systems Management: Towards Strategic Information Systems. Gordon & Breach Science Publishers 1987.

Sowa, J F, Zachman, J A, Extending and formalizing the framework for information systems architecture. IBM Systems Journal, Vol. 31, No. 3, 590-616. IBM 1992.

Spewak, S H: Enterprise Architecture Planning. Developing a Blueprint for Data, Applications and Technology. John Wiley & Sons, 2000.

The Open Group: TOGAF 8, The Open Group Architecture Framework, "Enterprise Edition". The Open Group 2002. http://www.opengroup.org/architecture/ Accessed 28.1.2003.

Wallace, D R and Fujii, R U: Software Validation and Verification. IEEE Software, Vol. 6 Nr. 3, 10–17. IEEE 1989.

Ward, J and Peppard, J: Strategic Planning for Information systems, third edition. John Willey & Sons Ltd. 2002.

Zachman, J A: A framework for information systems architecture. IBM Systems Journal, Vol. 26, No. 3, 276-292. IBM 1987.