On the Syntax and Semantics of Architectural Principles

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Abstract

This paper illustrates why architectural principles are important for IT management and how the principles can be used. By analyzing architectural principles at an enterprise, knowledge is gained on how to formulate principles so that they are an effective steering tool. This knowledge is transformed into a framework for formulating architectural principles. The analysis of the architectural principles has been performed from two different angles; have we got the principles right (syntax) and have we got the right principles (semantics). The industrial case is complemented with examples from literature.

1. Introduction

The need for management of IT resources in contemporary organizations is driven by the frequent changes in the general business environment. These changes can occur as mergers, acquisitions, strategic alliances, global partnerships, or dramatic economic changes and pressures etc. [1]. But there has also been a change in how IT is applied. Previously, business operations of most large companies were supported by a number of isolated software systems performing diverse specific tasks, from real-time process control to administrative functions. In order to better achieve business goals, these systems have in recent years been extended, and more importantly, integrated into a company-wide system in its own right, the enterprise system. The IT systems have typically not evolved through an enterprise-wide planned approach, rather each business unit has developed and acquired the IT systems they need individually [2][3]. Many IT decision are non-premeditated decisions due to lack of time, lack of information and lack of tools for consistent decision-making with a focus on the long term implications on the enterprise architecture.

Unfortunately, the combination of non-premeditated decision-making and rapid changes to the business environment over the past decades has made the enterprise systems quite wild-grown. As a result, the enterprise system oftentimes store redundant data, implement similar functionality, and the applications are deployed on a wide variety of platforms and utilize many different technologies [2][3][4][5]. Operation and maintenance of the enterprise system is therefore more expensive than it need to be, leaving less resources for creating extra value to the business organization. The regulatory environment of today has also put far more emphasis on the timeliness, completeness and accuracy of corporate information [6]. Together with the fact that technology has a major role in almost every product and services it is clear that IT is the heart of all significant business processes and is crucial to innovation and enterprise success [6]. Therefore it is extra important that the business gets as much as possible out of IT.

1.1. Outline

In the next chapter architectural principles is presented as the tool to change the wild-grown architecture of today (chapter 2). After that a framework from where architectural principles can be extracted, the architectural theory diagram, are presented (chapter 3). The subsequent chapters focuses on a review of real-world principles (chapter 5-7), where the enterprise' principles are found in (chapter 4). The paper is concluded by guidelines for writing principles (chapter 8) and conclusions on the performed review (chapter 9).

2. Architectural principles

Many large organizations spend more resources than necessary on IT and do not get the benefits they could from IT. Many enterprises have, for example, duplicate applications resulting in extra costs for operation and maintenance. System integration requires more resources due to the common "spaghetti architecture". Low data quality is quite common and Olson states that it can cost as much as 15-25 % of the company's profit [7]. When the CEO demands more

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value for the money spent on IT, it will be necessary to weed out the messy and inefficient architecture of today and start building something better from it. However, changing the wild-grown enterprise system is not a big bang project. It is not possible to wipe out all old systems and replace them with new ones. That would cost too much money and disturb the business too much.

Enterprise architecture is an approach for managing the company's software system portfolio. At the base of the approach are architectural models incorporating applications, infrastructure, functions, data, business processes, organizational units, and actors. Another important artifact of enterprise architecture is the goal architecture that describes the to-be architecture. The goal architecture takes its starting point in today's architecture. Since the enterprise system exists in order to support the business, the business needs drive the development of the goal enterprise architecture, see figure 1.

In order to reach the goal architecture architectural principles needs to be employed in all IT investment projects [6][8][9][10], see figure 1. In order to be successful in taking the enterprise architecture of today to the goal architecture the architectural principles must be key architecture drivers and future oriented [9]. Without a complete and enforced enterprise architecture, where architectural principles are used as a basis for making investment management decisions and high-level technical decisions, there is a risk that bought or built IT systems are duplicative, incompatible, and unnecessarily costly to maintain and integrate [8][10].

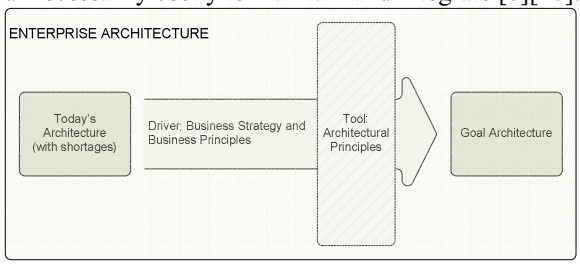

Figure 1. Transition from today's architecture to the goal architecture

Architectural principles define the underlying general rules and guidelines for the use and deployment of all IT resources and assets across the enterprise [6][9], see figure 2. Today every business decision has an information and technology implication [6][9]. Each architectural principle must therefore be clearly related back to the business strategy and business principles. Defining the architectural principles takes it starting point in the strategic endeavors of the business [6]. If business strategy tells us how an organization is going to compete in its chosen market, principles represents a shared understanding on what needs to happen if the organization is to successfully execute the strategies [6]. This will provide valuable insights into the transition activities needed to implement an architecture in order to support business goals and priorities [9]. In that case architectural principles can justify architecture activities by showing the rationale for the investment.

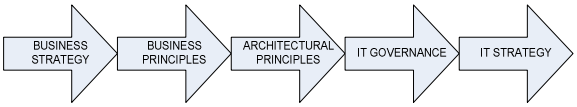

Figure 2. From business strategy to IT strategy, based on [6]

In table 1 four examples of principles from three different sources are presented.

Table 1 Architectural principles

• **Interoperability.** Software and hardware should conform to defined standards that promote interoperability for data, application, and technology [9].
• **Common vocabulary and data definition.** Data is defined consistently throughout the enterprise and the definitions are understandable and available to all users [9].
• **Investments.** Coordinate technology investments with the federal business and architecture [8].
• Information processing activities shall comply with applicable laws, orders, and regulations [10].

3. The Architectural Theory diagram

It is important that the principles represent the top issues for the enterprise. The Architectural Theory Diagram, ATD, defines 18 top issues for the CIO, see figure 3 [11]. The ATD give guidance on how these issues affect the business. By defining the elements of the ATD, e.g. information security, down to measurable units such as number of firewalls, existence of authorization procedures etc it is possible to assess the level of information security. The measures are also a good basis for follow ups of the architectural principles; has the level of information security been improved. The tree is decomposed into the different parts that the company consists of, seen from the CIO's perspective; the IT organization, the IT systems and the business organization. The construction of the ATD and full description of the parts are further elaborated on in [11].

- **The IT organization.** The IT organization may contain IT/IS staff directly under the CIO, distributed over the enterprise or outsourced. Irrespective of how the IT organization is organized, the CIO is responsible for the quality of the services produced by the IT organization, e.g. availability of an IT system is not only depending

of the IT system, but also on how fast the IT organization restores them. The components consist of all the processes that COBIT has defined for the IT organization [12]. For the ATD they have been divided into nine groups.

- **The IT system.** For all IT systems within the enterprise quality attributes are used for measuring the value for the business organization. The definitions are based on [13][14][15][16][17][18][19][20].
- **The business organization.** Since the focus of the ATD is how the IT resources generate value to the rest of the organization, it is suitable to decompose the business organization in categories of benefits from IT resources. The categories are based on [21][22][23][24].

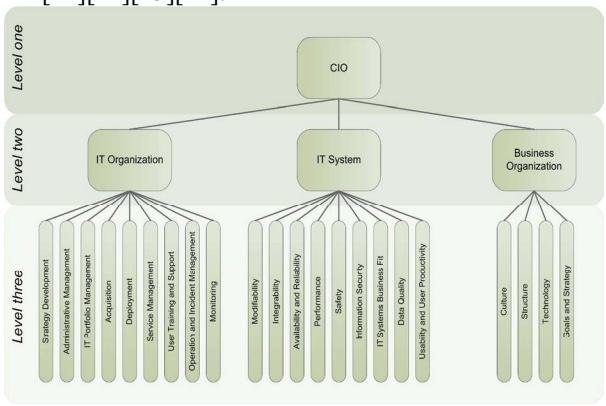

Figure 3. The Architecture Theory Diagram, level 1-3

If the principles are identified in a systematic way it is highly likely that all important principles will be defined. The ATD is therefore useful as a basis for architectural principles, since it both states what is important and also how it can be measured. Motivation for the principles and possible relations to the business strategy is offered by the business organization branch.

4. Architectural principles at Vattenfall

Vattenfall is one of the largest energy companies in Europe. They have a fairly decentralized organization, with business units that can acquire IT systems independently as long as the budget does not exceed a certain amount. Vattenfall employs thousands of systems, but approximately 400 of these are core IT systems. Since 2001 they have employed architectural principles (called guiding principles at Vattenfall). The principles are written to reflect the strategic choices Vattenfall has made to achieve high value and cost efficiency in IT investments. According to a Group Instruction document the principles should be used as a basis for defining more detailed IS/IT requirements, defining evaluation criteria and for assessing the conformance of existing systems and future development projects. The evaluation criteria are used for selecting hardware, software, future application function packages, and suppliers. For Vattenfall the principles are used as the base for a technology framework that defines what technologies and products to be used for IT. The principles are not imperative; they are only supposed to provide operative directions and guidance.

4.1 The principles

Vattenfall has 35 architectural principles grouped in the following way: Governance/GOV (9), Outsourcing/OUT (1), Risk Management and IS/IT-security/RIS (3), Systems Management/SYMA (1), Environment/ENV (1), Standardization/STD (5), Applications/APP (8), and Infrastructure/INF (6). The principles have an ID (e.g. GOV001), a category (e.g. Governance), a principle statement, and a motivation, implication and comments. The implications are on two formats, rules and results while the motivations are basically benefits. Comments are used only in some categories and reflect the current situation. In table 2 the 35 architectural principles of Vattenfall is cited. Note that in this paper it is only the principle statement that is cited.

Table 2 The architectural principles of Vattenfall

- GOV001. Non-differentiating processes should be standardized across the group, national standards and different types of markets needs to be considered.
- GOV002. Focus on value chain optimization across country borders.
- GOV003. All corporate and common initiatives should always seek to get optimum balance between effort and synergy potential (process/application/installation).
- GOV004. When selecting solutions a suite concept shall be used for non differentiating processes, while best of breed solutions supports areas where strategic advantages can be achieved.
- GOV005. A partly centralized funding model is needed to realize synergies through consolidated efforts. A centralized funding model bases funding on two factors: 1) project classification – corporate, common, unique, 2) projects under development and initial implementation.
- GOV006. Initiatives shall be implemented using a stepwise approach focusing on optimal alignment of business requirements to IT capabilities.
- GOV007. IS/IT Strategy development shall be an integral part of business strategy development.
- GOV008. IS/IT support the business processes and not the business organization. A business process re-engineering review must accompany all major automation efforts.
- GOV009. Control of development and implementation of IS/IT projects must comply with a corporate common project management model.
- OUT001. When consolidating IT related efforts outsourcing should always be considered as an option. Competence and solutions that create a competitive edge should be kept internal

in the Vattenfall group. IS/IT security will also be taken into consideration.

- RIS001. In connection with corporate acquisition, the necessary changes in information systems and the IT-infrastructure, including security and costs, shall be a part of analysis conducted prior to the acquisition.
- RIS002. IS/IT security options must be based on overall security for the entire Group and the measures must be well balanced to conform to the assessed threats and risks.
- RIS003. Projects for development or deployment of IT-solutions must take current security rules in consideration and perform security review before the implementation is decided. The responsibility for ensuring that security rules are complied rests with the line management.
- SYMA001. Configuration Management (CM) shall be applied.
- ENV001. We comply with existing laws, regulations, permits, and Vattenfall's environmental policy and take preventive action in order to reduce our environmental impact. This is accomplished by adopting sound methods for the collection and recycling of retired equipment and by using energy efficient products.
- STD001. When performing IT related activities, potential for consolidation/centralisation should always be considered.
- STD002. The number of partners and suppliers of consultant services must be limited and at the same time consider local expertise.
- STD003. Vattenfall's hardware and systems shall be acquired from few vendors.
- STD004 (applications). Common and corporate applications shall be flexible and scalable to match different needs within the business.
- STD004 (data). Corporate common data shall be identified and defines on a corporate level.
- STD005. When choosing system support for a business; function, cost, security, and time–to-market should be considered. The following criteria shall be used:
  - If a Vattenfall standard system for the specific function exists, that system shall be used.
  - If no Vattenfall standard system for the specific function exists, but systems for the function are already used somewhere else in the Group, those systems should be used in the first place.
  - If neither, standard systems shall be chosen in the first place and in-house development in the last place.
- APP001. Low hardware performance demands shall be put on the end-users environment.
- APP002. Server based applications shall be preferred.
- APP003. Applications shall be structured in such a way that the country or brand specific parts are well isolated. Non-specific parts should be reusable.
- APP004. Applications shall, when necessary, have multi language capabilities in screens, documentation, help-functions, etc.
- APP005. Usability of the systems should always be considered (End user as well as system support)
- APP006. Application development shall focus on reuse with integrated development environment.
- APP007. Applications (bought and build) shall utilize Application Programming Interface (API) that allows other applications to access its functions.
- APP008. Applications shall have a multi-tier architecture. Presentation, application logic, data logic and data storage shall be separated from each other.
- INF001. Industry, de jure or de facto standards will be used, when they exist and meet the business defined needs.
- INF002. All design, development and deployment of IS/IT components and processes will conform to the Enterprise IS/IT architecture.
- INF003. System structure and IS/IT availability shall enable mergers, acquisition, and establishment on new sites.
- INF004. Vattenfall shall provide a corporate common enterprise wide data network (VattNet) and link already existing networks according to technical and security policies for Vattenfall.
- INF005. Vattenfall shall have a common standardized platform based on international standards for the exchange of data, messages and documents between users internal and external to Vattenfall (employees, customers, partners, and vendors).
- INF006. Vattenfall shall have a platform for corporate Internet, extranet, and intranet applications, which provide information exchange possibilities for customers, partners, and employees and the business units subsidiaries.

5. Review of Vattenfall's principles

If the principles should be the effective tool they can be they must have the right focus and be written in the right way. Otherwise they might be misunderstood, misused or even not read. A review was performed to examine if the principles have the basic condition to be an effective tool. Linguistics deal with how written (and oral) language is constructed and percepted. Linguistic analysis of written language is divided between syntax, which is the *form* of the principles and semantics, which is the *meaning* and *content* of the principles [25].

Architectural principles are enterprise-wide requirements, with the difference that they are used in many projects over a long period of time. The discipline of requirements engineering states characteristics of good requirements, e.g. IEEE Std 830-1998, Software Requirement Specification, (see table 3) [26].

Table 3 Characteristics of good architectural principles divided on syntax and semantic

SYNTAX	SEMANTIC
Consistency	
	Stability
Verifiability	Verifiability
Unambiguousity	
Modifiability	Modifiability
	Correctness
	Completeness

Two characteristics have been excluded. The principles are few, equally important and fixated over time, which make it unnecessary to prioritize them and make them traceable. However, the characteristics only focus on how the requirement is written and not on the content. To review the correctness and completeness of the principles they have been mapped to the ATD and also benchmarked with other principles.

6. Syntax

Syntactic analysis is used to answer the question "Have we got the principle description right?". Writing the principle on the right format will make the document easier to understand and use and thereby hopefully gets a greater impact.

6.1 Consistency

The principles shall not conflict with each other. If they do it will be up to the reader to decide on the trade off, something that the writer of the document seldom wants.

As can be seen in table 2 there are no contradictions among Vattenfall's principles.

6.2 Verifiability

There are two reasons to perform follow-ups on the principles; first, in order to know if the goal architecture is reached and second to show that management is serious on that the principles must be followed. The principles must therefore be verifiable, i.e. measurable, both long-term (future architecture) and short-term (in projects).

Most Vattenfall statements can be measured and are therefore verifiable. However, today the principles do not explicit state what should be measured and therefore need to be reformulated. There are a few principles that are hard to verify, for example GOV002, GOV003, GOV005, GOV007, RIS001, RIS002, STD001, and APP005. These are not easily rewritten and some of them might not even be part of the architectural principles. Instead Vattenfall needs to clarify the underlying motif.

6.3 Unambiguousity

In requirements it is common that ambiguous words like "fast", "easy-to-use" etc are used. It is impossible to test whether an application fulfill such requirements or not. Another important rule is that it should not be multiple focuses in order to avoid confusion about what is important [26].

GOV006 concerns both the implementation approach and IT business alignment, i.e. it has multiple focuses. Other examples of principles with multiple focuses are GOV008, RIS003, APP003, and STD005.

6.4 Modifiability

Modifiability is important in requirements engineering since requirements oftentimes are numerous and changes over time. This is not the case with principles. Modifiability is still interesting to look at since a modifiable document has an easy-to-use organization [26] and that will increase the principles potential as a mean to communicate the CIO's vision and as an effective tool for reaching the goal architecture.

Vattenfall's guiding principles are found within multiple documents. Governance principles are found in one document, application principles in another etc. It is therefore difficult to get a good overview of all principles and it is also possible for a reader to overlook a group of principles. To store the principles in many documents also make the document overhead (document history etc) larger. Today the 35 principles need 38 pages. A more condensed way to write the principles would reduce the number of pages dramatically, see e.g. [8][9]. This will increase the overall understanding of the principles as a group and more people would read the document if it is shorter. If all principles were stored in a single document duplicates will be found easier and it will also be clearer that all principles strive in the same direction. One document is also easier to communicate.

The number of principles is another important factor to consider, since it is easier to communicate and remember a smaller number. The communication, use and follow up of the principles are also easier if they are equally important, which is more probable if the number of principles is low. The open group architectural framework, TOGAF, recommends enterprises to define ten to twenty principles and exemplifies with twenty principles [9].

With fewer principles written in a stringent way the document can be just a few pages long. The Federal Enterprise Architecture Framework, for example, uses four pages for ten principles and the Open Group Architecture Framework uses seven pages for 20 principles [8][9].

6.5 General comments

Even though Vattenfall's principles are grouped, the feeling of diversity is strong. Many principles address the same issues even though they are found in different documents (see chapter 6.4). The principle statements are on different levels, some are referring to what should be accomplished, others to why and

further others to how. Some examples on statements that include implications are ENV001 and GOV008. The statement of SYMA001 has a too long description on what Configuration Management is (has been excluded from table 1). This is a hinder when communicating or deploying the principle. Furthermore, many principles should be considered when buying applications for project managements etc, but just a few states when a principle should be employed. When responsibility and intended usage is not defined it is not completely clear how Vattenfall shall use the principle.

7. Semantics

Semantic analysis is used to answer the question "Have we got the right principles". To be able to answer that question one must know what the right principles are. As stated in chapter 3, a prioritized ATD is helpful. For the analysis the content of the principles are compared with a prioritization of the ATD performed by two Chief Information Officers at Vattenfall (see 7.4). The principles are also benchmarked with principles from other organizations (see 7.5).

7.1 Stability

The principles are supposed to be stable over time. Otherwise they will not be able to point out the direction for the future changes and contribute to a stable and consistent architecture.

Vattenfall's principles have potential to be stable, since they are on an overall level. APP002, APP007, APP008 states architectural approaches. These change over time. However one need to take position on these issues but that should be done as implications to a principle and not as a principle in its own right.

The principles have undergone one revision during the four years they have existed. A few new principles were added and some old were withdrawn. However, the largest change was a new grouping.

7.2 Verifiability

The semantic analysis of verifiability covers that the right thing is measured.

Assuming that the measurements are deduced from the statement and not the motivation in order to see if the principle is fulfilled, the intention of the principle is probably not measured in most cases. One example is INF001. This principle is easy to measure, but the measure will say nothing on whether the enterprise architecture has been improved. Standards are for example used for increasing the modifiability of the system, and thereby increase the useful life of applications and infrastructure, and increase the range of options for suppliers and alliances etc. Measuring if standards are used is a way to a priori measure whether the system will be more modifiable.

7.3 Modifiability

The semantic analysis of modifiability focuses on that the document should only contain non-redundant principles. If many principles are redundant it will be difficult to make changes in the document since changes must be done on multiple places. This will also effect the readability and understandability of the document and is therefore of interest here.

Many of Vattenfall's principles are completely or partly redundant. Examples of possible consolidations are:

- Reuse is addressed in three principles; INF002, APP003, and APP006.
- RIS001, RIS002, RIS003 and STD005 states that security must be considered when changes to the information systems or IT-infrastructure are made.
- GOV003, GOV004 and STD005 share the same purpose; standardizing and consolidate the system portfolio in order to find synergies, reduce cost for operation and implementation.
- INF004, INF005, and INF006 are all about interoperability, i.e. making sure that everyone that are supposed to share information are able to. They can be rewritten into: **Interoperability.** Employees, customers, partners, vendors, business units, and subsidiaries must be able to exchange data, messages and documents.

The reader can easily be confused when multiple principles share the same motivation, implication or principle statement without being consistent. One example is INF003, INF004, and STD004. The Principle Statement of INF003 is "System structure and IS/IT availability shall enable mergers, acquisition, and establishment on new sites." For both INF004 and STD004 this is the motivation. However the implication of INF003 is not the same as the principle statement of STD004 or INF004. Further, there is no traceability between the two principles and the implication for INF003 is not the same as the principle statement of STD004.

7.4 Correctness and completeness

When validating if the principles are correct and complete the following questions must be asked: Are the stated principles relevant to the organization? Are all necessary principles defined? How do we know that the list of principles is complete?

7.4.1 Comparing the principles with Vattenfall's prioritization of the ATD

The principles must be relevant to the organization. A prioritization of the ATD made by two CIOs at Vattenfall shows the interest of Vattenfall [27]. The architectural principles of Vattenfall have been mapped on the architectural theory diagram (ATD), see figure 4, and can therefore be compared with the prioritization of Vattenfall. Chapter 7.4.3 Mapping procedures explain how the mapping was performed.

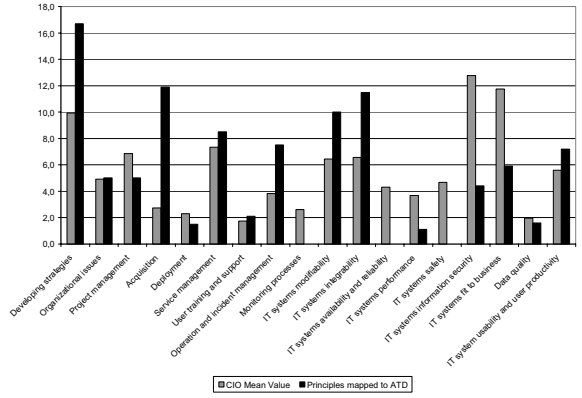

Figure 4. The prioritization of the architectural theory diagram and the principles mapped to the ATD

The mapping of Vattenfall's guiding principles onto the ATD shows that Developing strategies (16.7%), Acquisition (11.9%), Modifiability (10.1%), and Integrability (11.5%) are most referred to in the principles. As can be seen in figure 4, Developing strategies is the third most important aspect, according to the two respondents mean value. Acquisition got low priority from both respondents, while Modifiability and Integrability are of middle importance. Information security, that got the highest priority, gets 4.4% in the mapping and IT Systems' fit to business that was prioritized second do a little bit better but get 5.9%. Vattenfall must discuss whether this mean that Information security and IT Systems' fit to business does not get enough attention in the principles or that Acquisition, Modifiability and Integrability gets to much attention.

Looking at the bottom of the prioritization; User training and support, Data Quality, and Deployment has 2,1%, 1,6%, and 1,5% respectively, which places them in the lower range. Neither Availability and reliability or Safety is mentioned in the guiding principles while they are prioritized as middle important by the CIOs. Vattenfall must discuss whether this mean that Vattenfall overlook principles concerning Availability and reliability, and Safety.

7.4.2 Benchmark with principles from other organizations

Benchmarking aims at learning from others. If other organizations share the same principles as your organization, the right principles have probably been found. If not, you better ask yourself why. You must then consider whether you have the right set of principle or not. For the benchmarking The Open Group Architecture Framework (TOGAF), The Federal Enterprise Architecture Framework (FEAF), and the Treasury Enterprise Architecture Framework (TEAF) were chosen [8][9][10]. These frameworks have stated architectural principles that can be used as requirements for IT investments. Other well-known frameworks such as DoD Architecture Framework, Zachman Framework, and Spewak have not defined architetural principles and was therefore excluded from the study [28][29][30].

TOGAF's principles consist of a name, a statement, rationale and implications. The rationale and implication are quite detailed. The principles are written in a stringent way. TOGAF divide its 20 principles in business, data, and application principles [9]. FEAF's principles consist of a name, a statement, rationale and implications. FEAF states eight principles [8]. TEAF's principles only consist of a statement. It does not give any motivation to why the principles are important to fulfill. TEAF states ten principles where Interoperability has the strongest focus of the IT system concerns [10]. TEAFs principles are mapped to only six of the ATDs concern, resulting in high scores for these concerns. TOGAF, on the other hand, have many references to the ATD for every principle, resulting in low average scores. For the comparison with Vattenfall's principles the three frameworks have been summarized, see figure 5. By presenting them together the differences in the number of references are minimized and the comparison is also more straight-forward.

In figure 5 it can be seen that the focus of Vattenfall and the frameworks principles align very well. The largest differences are found for Project management, Data quality, and IT system usability and user productivity. For project management the

reasons are that Vattenfall has three principles focusing on assessing risks and also mention project management in a couple of principles. The principles in the frameworks are more concise in the statement and therefore are project management seldom mentioned. TOGAF, with the double amount of principle, contribute to the stronger focus on data quality in the frameworks. TOGAF has six principles for "Data Quality", of which one was mapped solely to Information security. Vattenfall and TOGAF, with 35 and 20 principles respectively, have approximately the same focus on IT system usability and user productivity. FEAF and TEAF, with eight and ten principle each, have no reference to IT system usability and user productivity. With a larger number of principles more content can be added.

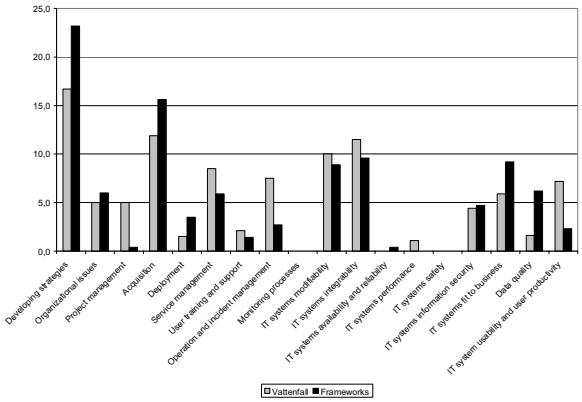

Figure 5. Principles from Enterprise Architecture Frameworks and Vattenfall mapped to the ATD

7.4.3 Mapping procedure

The mapping of the principles to the architectural theory diagram has been performed in an indicative manner, where the main objective has been to determine the foci of the principles. An interpretation of the issues addressed by each principle was carried out qualitatively. Both the principle statement and motivation and implication, if stated, were considered. It has been assumed that all references to the ATD from the principles are of equal importance. Furthermore, it is assumed that a principle which supports two or more concerns in the architectural theory diagram supports them to an equal extent. This is a simplification justified by the indicative nature of the review. For example, SYMA001, only support IT Organization concern 1 and therefore one whole point (1/1) was awarded to it. APP006 support three concerns, a third of a point (1/3) was awarded each of these three concerns. The total support by all products/cells for a specific concern was then summarized and converted into percentages.

7.5 General comments

There is one final remark on the content of the principles that has not been covered in the review; some of the principles are too general to actual be in the principles. Two examples are INF002 and GOV005.

8. Guidelines for writing principles

Architectural principles, used in the intended way, are an effective tool to move the enterprise architecture towards the goal architecture. However, that poses a few constraints on the syntax and semantic of the principles. In chapter 2 and in the review many guidelines and rules are given. They are summarized into the guidelines below. Architectural principles must be:

- Key architecture drivers that are future oriented, so that the enterprise can move towards the goal architecture.
- Relevant to the business and the organization in large, but a principle is not a general business or financial statement. A good and clear motivation is important.
- Stable, but possible to change. A principle must be durable; it can not be outdated quickly by advancing technology, therefore a principle does not select a specific standard or technology.
- Complete and correct, so that they covers every situation perceived.
- Understandable, definitive and precise, so that violations are minimized. The principle must therefore be worded directly and in simply terms understandable by both business and IT managers. The principles must be:
  - Few in numbers, approximately 10-20, so that people can remember them
  - One document, so that it is easy to survey all principles and impossible to overlook a set of principles
  - Of equal importance, so that all will be employed
  - One statement for each principle, to make it understandable
  - Not redundant, to make it understandable
  - Consistent, so that no misunderstandings occur on what should be applied
  - Recommends actions to be taken, so that they are clear on what should be done
  - Measurable, so that the adherence to the principles can be followed

In table 4, a recommended syntax for architectural principles is given. It is important that the syntax is stringent.

Table 4 Recommended syntax for architectural principles

PART OF THE PRINCIPLE	DEFINITION	EXAMPLE
Statement	What to improve	IT system's fit to business
Motivation	Why this is important for the enterprise	Increase the effectiveness in the business organization
Implication	What must be done and when, and who is responsible	Investigate the influence on the business processes when a new system is acquired. The project manager is responsible
Measures	How the fulfilment of the principles is measured. Both for the Enterprise Architecture long-term and short-term, e.g. after an investment.	Time to perform a business process.
Comment (if necessary)		

9. Conclusions

The architectural principles must represent the ten to twenty most important ways, both technological and organizational, to reach the goal architecture. The ATD, that is a comprehensive model of the CIO's concerns, is useful here. The ATD is well suited to use for prioritizations of concerns and from that identify the most important principles. The ATD also offers motivations for the principles by linking the principles to the benefits in the business organization. In order to support consistent decision making, be effectively communicated, be spread throughout the organization and be a means to drive architectural changes the principles must be consistent, verifiable, unambiguous, modifiable, correct, complete, and stable.

Vattenfall's principles are well aligned to the prioritizations of the concerns done by Vattenfall's CIO's and to the principles stated in the three benchmarked frameworks. However, Vattenfall could use a more stringent way to write the principles. Vattenfall should consider grouping all principles within one document, in order to minimize document overhead and increase the usability and it would be possible to formulate Vattenfall's principles in less than twenty without loosing content. That would also make it clearer what Vattenfall want to accomplish. That will make the interpretation of the principle clearer and the principle easier to communicate. In table 5 below a summary of the concluded analysis is presented.

Table 5 Summary of the concluded analysis

SYNTAX		SEMANTIC	
Consistent	Good. No inconsistencies were found.		
		Stable	Good. Two potentially non-stable principles were found
Verifiable	Improvable. Most principles were measurable, but some principles are hard to verify.	**Verifiable**	Improvable. It is hard to verify that the enterprise architecture has been improved.
Unambiguous	Improvable. Some principles with multiple focuses have been identified.		
Modifiable	Improvable. Multiple documents are used and too many principles	**Modifiable**	Improvable. Many redundant principles have been identified.
		Correct & Complete	Good. Some minor differences were found.

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