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INTEGRATING ENTERPRISE ARCHITECTURE AND NP ISO 4457

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Abstract

The growing importance of NP ISO 4457 and Enterprise Architecture (EA) is becoming increasingly recognized. However, since they are distinct governance approaches with different perspectives, organizations end up facing several challenges, which leads to efficiency problems, waste of resources and misalignment.

This thesis proposes to overcome such problems by integrating NP ISO 4457 with EA. This way, a Reference Architecture is developed, using Archimate, which helps organizations to conform to the Standard's requirements, by determining how processes and resources are organized and realized. This is a unique contribution, since the Reference Architecture can be applied generically to every organization.

Keywords: Enterprise Architecture, NP ISO 4457, ArchiMate, Innovation

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List of acronyms

DI – Documented Information
DSRM – Design Science Research Methodology
EA – Enterprise Architecture
RDI – Research, Development and Innovation
QM – Quality Management

1. Introduction

There are several risks associated with innovation – big investments, excessive focus on the innovation process to the detriment of existing products, non-acceptance of the new product by the market, among others. However, if organizations don't innovate, they will also face some risks that will probably result in reducing profitability, losing image, placing obsolete products on the market, in short, losing competitiveness (Certif, 2016).

As with any management decision, risks must be assessed against the potential benefits, allowing organizations to understand that knowledge and innovation are the core factors of economic development (ibid.).

With the growing demand on innovation and innovation being "a generating value mechanism, whose impact and usefulness results in benefit for both the organization and the society" (NP ISO 4457, 2007b: 4), it is of the outmost importance to have a standard that aims to define the requirements of an effective management system for Research, Development and Innovation (RDI), allowing organizations to reach their innovation objectives (NP ISO 4457, 2007).

Nevertheless, many times, organizations end up confronted with the challenge of deciding how to adopt the standard and what are the overlaps, contradictions and gaps (Bernard, 2012), as well as having different organizational departments or teams handling innovation, which leads to efficiency problems, waste of resources and misalignment.

Being Enterprise Architecture (EA) a coherent set of "principles, methods, and models that are used in the design and realization of an enterprise's organizational structure, business processes, information systems, and infrastructure" (Lankhorst et al, 2009: 3), it forms a natural combination with NP ISO 4457, since "a well-designed and documented EA helps an organization to conform to the" NP ISO 4457 requirements, by determining how "processes and resources are organized and realized" (Lankhorst et al, 2009: 18). Therefore, developing an EA that supports the RDI process' management is relevant to many organizations.

We propose that NP ISO 4457 can be modeled in EA terms, allowing the development of a Metamodel that can be used as a base to define a Reference Architecture. Such theoretical model can be applied to every organization in a generic way, avoiding the waste of unnecessary resources, increasing efficiency and improving alignment, among other benefits. Therefore, our research question will be "How NP ISO 4457 can be integrated with EA".

Our goal is to "acquire knowledge that enables the development and implementation of a solution to a fundamental problem faced by many organizations" (Gama, 2014: 5)**.** To achieve it, we decided to apply the Design Science Research Methodology, since it is the methodology that best enables the development and validation of a proposal to solve a problem with no initial validated theory and with insufficient existing knowledge (Hevner et al, 2004).

The following sections of this thesis follow the methodology's specific sequence of steps/activities: "**Literature Review**" covers the most relevant published work associated with the subject, providing us a theoretical background; "**Research Design**" exposes the methodology applied, the reasons to justify the thesis (motivation) and the research questions; "**Proposal**" presents an approach to solve our research questions; "**Design and development**" solves the research questions by mapping the relationship between NP ISO 4457 and EA concepts, developing a Metamodel and a Reference Architecture and creating a questionnaire to confirm the adherence of the NP 4457 Reference Architecture against an actual RDI management system; "**Demonstration**" implements the NP 4457 Reference Architecture in a real organization, to identify the fit between real RDI management system and our Reference Model. Demonstrating this way how the proposal can solve the initial problem; "**Evaluation**" assesses the quality of the results (the NP 4457 Reference Architecture), using "The Moody and Shanks Framework"; "**Conclusion**" summarizes and presents the conclusions, by comparing the results with the research questions and discussing the proposal applicability, as well as exposes limitations and proposes themes for further work.

2. Literature review

2.1. Enterprise architecture

In the late 1980's, references to EA began to emerge in various management and academic literatures, "with an early focus on technical or systems architectures and schemas for organizing information" (Bernard, 2012: 40). The first and best-known EA framework introduced was the Zachman Framework, whose objective was to define "logical constructs (architectures) to represent organizations" (Gama et al, 2013: 3). According to Zachman (1987), an organization doesn't have just one single architecture, but a set of layered architectural representations (Gama, 2013).

Since then, the concept of EA analysis and design "has evolved to include views of strategic goals, business services, information flows, systems and applications, networks, and the supporting infrastructure" (Bernard, 2012: 40).

Today, EA can be defined as the "design or description that makes clear the relationships between products, processes, organisation, information services and technological infrastructure; it is based on a vision and on certain assumptions, principles and preferences; consists of models and underlying principles; provides frameworks and guidelines for the design and realisation of products, processes, organisation, information services, and technological infrastructure" (Engelsman et al, 2011: 11). Moreover**,** EA "is a strategy and business-driven activity that supports management planning and decision-making by providing coordinated views of an entire enterprise" **(**Bernard, 2012: 31**).**

The most important characteristic of an EA is that it provides a holistic and integrated view of the enterprise (Lankhorst et al, 2009; Bernard, 2012). It captures the essentials of the business, while still allowing for maximal flexibility and adaptivity (Lankhorst et al, 2009).

EA is usually composed by five closely interrelated layered architectures which are: Business, Process, Application, Information, and Technology (Lankhorst et al, 2009; Gama, 2012;

Barnden et al, 2013). By aligning such architectures, a blueprint of the organization is obtained, providing improvements in governance, increasing guidance and support and allowing the achievement of current and future business objectives (Pereira and Sousa, 2004; UNECE/Eurostat/OECD, 2012; Gama et al, 2013).

2.2. TOGAF

The Open Group Architecture Framework (TOGAF), a framework developed and currently maintained by The Open Group, "is the *de facto* global standard for Enterprise Architecture" (The Open Group, 2016). It provides "the methods and tools for assisting in the acceptance, production, use, and maintenance of an EA" (Gama et al, 2013: 3), enabling the (re)design of an organisation in a uniform and standard way (Lankhorst et al, 2009).

The first version of TOGAF, in 1995, "was based on the US Department of Defense's Technical Architecture Framework for Information Management (TAFIM)" (Van Sante and Ermers, 2009: 7). Subsequently, new versions of TOGAF were developed and published by The Open Group Architecture Forum (Van Sante and Ermers, 2009).

In 2002, Version 8 enabled the expansion of "the scope of TOGAF from a purely technology architecture to an Enterprise Architecture, by including business and information systems architecture in the new version" (Van Sante and Ermers, 2009: 7).

Version 9, TOGAF's latest version, enabled the inclusion of new features as higher level of description detail and modular structure, providing greater usability, more focus on holistic enterprise change and more consistency of output (The Open Group, 2011).

2.3. ArchiMate

ArchiMate, an Open Group standard, is an open and independent EA modelling language that supports the description, analysis and visualisation of the "different architecture domains and their underlying relations and dependencies" in a precise and formal way (Jonkers et al, 2009: 7). It also facilitates the communication among stakeholders (Jonkers et al, 2004).

According to the ArchiMate modelling framework (Appendix 1), an EA is structured along two dimensions: layers and aspects (Engelsman et al, 2011). The layer dimension decomposes the enterprise into three layers: business, application and technology (Engelsman et al, 2011). These layers are connected by the principles of service orientation, "where each layer exposes functionality in the form of a service to the layer above" (Lankhorst et al, 2009; Gama, 2013: 4). "The aspect dimension distinguishes between information, behavioural and structural aspects of the enterprise" (Engelsman et al, 2011: 10). However, Engelsman et al. (2011) proposed extending Archimate with a fourth aspect – motivation, providing the context, intention, motivation "or reason behind the architecture of a system, or behind architecture decisions" (Meertens, 2013: 136). This extension, as well as the Implementation and Migration extension, is "now part of the official ArchiMate standard specification" (ibid.).

2.4. NP ISO 4457

The NP ISO 4457:2007 standard outlines criteria for an effective Research, Development and Innovation (RDI) management system.

Aiming as the fundamental goal of "adding value to the organisation or to the users of their products" (NP ISO 4457, 2007b: 8), a company should design and document a RDI management system, based on their objectives, targets and RDI policy. This management system will allow the company "to create knowledge and transform it into economic and social wealth" (NP ISO 4457, 2007b: 5), as well as to control, evaluate and increase the effectiveness of their innovation performance.

To guarantee that "its processes are adequately resourced and managed, and that opportunities for improvement are determined and acted on" (ISO 9001, 2015: vi), "the RDI management system follows a PDCA approach – Plan-Do-Check-Act, directed to continuous improvement" (NP ISO 4457, 2007b: 4). This approach also allows organizations that already have RDI practices and, simultaneously, management systems implemented according to known

standards (ISO 9001, ISO 14001, among others) to have an easier integration process (Certif, 2016).

Although NP ISO 4457 is a process-based framework, most of its clauses are about describing requirements that guarantee an effective RDI management system. The Standard is divided into four distinct sections (Sociedade Portuguesa de Inovação, 2013). It starts by stating the responsibilities of management for the RDI management system. It then gives requirements for the RDI planning, followed by implementation and operation, and evaluation of results and improvement.

As soon as the RDI system "is installed, a company can request an audit" by an independent certification body and, if it conforms to all the criteria, the company will be NP ISO 4457 registered (NP ISO 4457, 2007; Lankhorst et al, 2009:17).

Note that at this standard, and according to the OECD/Eurostat Oslo Manual (2005), innovation is understood in its broader sense, "including new products (goods or services), processes and new marketing or organizational methods" (NP ISO 4457, 2007b: 5).

3. Research Design

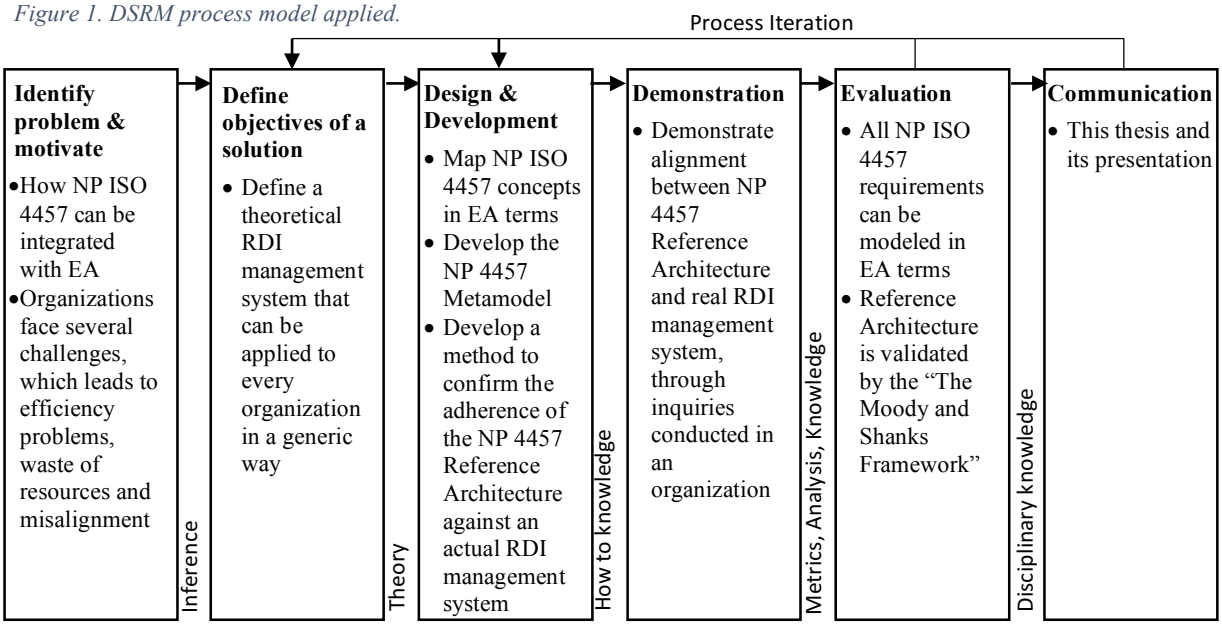
3.1. Methodology

The methodology applied is Design Science Research (DSRM), as it is the methodology that best enables the development and validation of a proposal to solve a problem with no initial validated theory and insufficient existing knowledge, in an innovative way (Hevner et al, 2004). Design Science Research is an iterative and incremental problem-solving process (Baskerville et al, 2015) that produces a "designed object with an embedded solution to an understood research problem" (Peffers et al, 2008: 6). Such object or artifact may include constructs, models, methods and instantiations (Peffers et al, 2008).

According to Peffers et al. (2008), DSRM application should follow a sequence of six activities: problem identification and motivation, definition of the objectives of a solution, design and

development, demonstration, evaluation and communication (Appendix 2). As the sections of this thesis follow the methodology's steps/activities, we mapped them on the DSRM process model, as illustrated in Figure 1.

Figure 1. DSRM process model applied.



3.2. Research Problem

3.2.1. Research Motivation

EA is considered "an indispensable instrument in controlling the complexity of the enterprise and its processes and systems" (Lankhorst et al, 2009: 11), while NP ISO 4457 provides organizations an important instrument that supports their ability to develop innovative projects (Certif, 2016). Moreover, EA's goal is to achieve organizational effectiveness through a "well-orchestrated interaction of organizational components" (Lankhorst et al, 2009: 6), providing improvements in governance, increasing guidance and support and allowing the achievement of current and future business objectives (Pereira and Sousa, 2004; UNECE/Eurostat/OECD, 2012; Gama et al, 2013), while NP ISO 4457's goal is to "define the requirements of an effective management system for" RDI, allowing organizations to achieve their innovation objectives (NP ISO 4457, 2007b: 4). In addition, EA and NP ISO 4457 are applied with a broad scope, since EA covers several domains (not just IT domains) (Lankhorst et al, 2009) and NP

ISO 4457 considers innovation activities both from goods and services companies, both in traditional (low-tech) and more sophisticated (high-tech) sectors (Certif, 2016).

Although NP ISO 4457 and EA apparently describe different fields, they form a natural combination, since "a well-designed and documented EA helps an organization to conform to the" NP ISO 4457 requirements, by determining how "processes and resources are organized and realized" (Lankhorst et al, 2009: 18). Conversely, the need for a RDI management system "may direct focus to an EA initiative, by putting the emphasis on those processes and resources that are critical" from an innovation point of view (ibid.). Therefore, developing an EA that supports the RDI process' management is relevant to many organizations.

Furthermore, since the implementation of a RDI management system can be seen as an architecture change, it is of the outmost importance to avoid the duplication of efforts and resources, which may result in loosing synergies and increasing costs (Gama, 2014).

Besides, no studies were found relating both frameworks and namely the exercise of defining an NP 4457 Metamodel based on EA principles and using the EA language of ArchiMate.

3.2.2. Research Questions

Our main research question will be "How NP ISO 4457 can be integrated with EA". However, in order to answer it, the problem needs to be subdivided into the following research questions:

Q1. What are the mapped concepts between the Standard and EA;

Q2. How can these be represented by a Reference Architecture;

Q3. If an organization has an RDI management system based on NP ISO 4457, the NP 4457 Reference Architecture is a reference model for the RDI management system.

4. Proposal

In this section we start by mapping NP ISO 4457 concepts in EA terms (Q1). Once we have these concepts we can modulate them (Q2), resulting on the NP 4457 Reference Architecture. It is then possible to evaluate on a real organization the fit between their NP ISO 4457 and our

Reference Architecture (Q3), assessing how distant is the real RDI management system from the Standard requirements, i.e. the real implementation and the theoretical one. This way we can identify gaps that can represent non-conformities or improvement opportunities.

4.1. Relationship between NP ISO 4457 and EA concepts

Having a uniform representation is crucial to map NP ISO 4457 concepts in EA terms as we need to have the same language to describe similar concepts.

For EA, ArchiMate was the modelling language chosen as it is "a visual design language with" suitable concepts for describing, analyzing and visualizing relationships amongst "architecture domains and their underlying relations and dependencies" (The Open Group, 2012: 2).

As for NP ISO 4457, a Portuguese written standard, the description language is a natural one.

As there is no formal RDI graphical language similar to ArchiMate to represent RDI concepts, we decided to consider that NP ISO 4457 could be represented as part of the EA, which lead us to develop the Metamodel as an EA, using ArchiMate.

To map NP ISO 4457 concepts in EA terms, we started by identifying the EA Layers and the respective Core EA artifacts. Then we associated these artifacts with relevant ISO 9000 Fundamental Concepts (ISO 9000 is normatively referenced in NP ISO 4456, which is the standard that describes the terminology and definitions of RDI activities). Finally, we associated these concepts with the NP ISO 4456 Terms and Definitions (and other NP ISO 4457 relevant terms), creating a relation between NP ISO 4457 artifacts (i.e. NP ISO 4456 Terms and Definitions) and EA generic artifacts.

4.2. NP 4457 Metamodel and Reference Architecture

The NP ISO 4457 clauses can be related with motivational aspects of the EA and the EA architecture layers. In this thesis, we only focused on two of them (process and business), since the remaining three layers (information, application and infrastructure) are not addressed in the Standard and are quite organization dependent.

To clarify these relationships, an EA Metamodel was developed as a graphical representation, ensuring consistency and supporting the recognition of relationships among concepts in different views (The Open Group, 2011; Barnden et al, 2013).

Once the Metamodel was developed, we started modeling all the 24 clauses of the NP ISO 4457, following TOGAF's approach. We first identified the main concepts in accordance with our proposal Metamodel and then we populated the associated EA viewpoint, mapping the clause requirements into the Metamodel EA elements and relations. So, a Reference Architecture was developed based on the components of a RDI management system of a hypothetical organization aligned with the requirements of NP ISO 4457.

It was then possible to rearrange the overall NP ISO 4457 framework according to Archimate's standard viewpoints and domains, providing us an architectural view on the impact of implementing a RDI management system in an organization. Consequently, proving that such implementation can be considered an architecture change.

4.3. Gap between an actual RDI management system and the NP 4457 Reference Architecture

Finally, we analysed the gap between the baseline EA associated to the actual RDI management system and the "objective EA" (the NP 4457 Reference Architecture).

In this thesis, we analysed an organization with a RDI management system already implemented, allowing us to directly compare both EA. This way we were able to conclude about the NP 4457 Reference Architecture's adherence to reality.

To sum up, once the concept mapping is developed, the steps are as follows:

- Definition of a Metamodel;
- Modeling of all NP ISO 4457 clauses, following TOGAF's approach, and creating one viewpoint for each clause;

- Development of a Reference Architecture based on the viewpoints per clause, allowing the creation of theoretical RDI management system of a hypothetical organization;
- Application of the Reference Architecture to a certified organization, comparison of results and actualization of the Reference Architecture accordingly;
- Evaluation of the NP 4457 Reference Architecture, after the previous adjustments, using the "The Moody and Shanks Framework" (Faroleiro, 2016).

5. Design and development

5.1. Relationship between NP ISO 4457 and EA concepts

The results of the concept mapping are shown in Appendix 3. However, though each NP ISO 4456 and NP ISO 4457 artifact should optimally be listed once, some occur more times according to different perspectives of the artifact (e.g. "Evaluation" can be considered an Assessment or a Business Process depending on the context).

5.2. NP 4457 Metamodel and Reference Architecture

Since EA representations usually start from a Motivation perspective, we started by defining the Motivation Metamodel, "which is used to model the motivations, or reasons, that underlie the design or change of some EA" (Gama et al, 2013: 7).

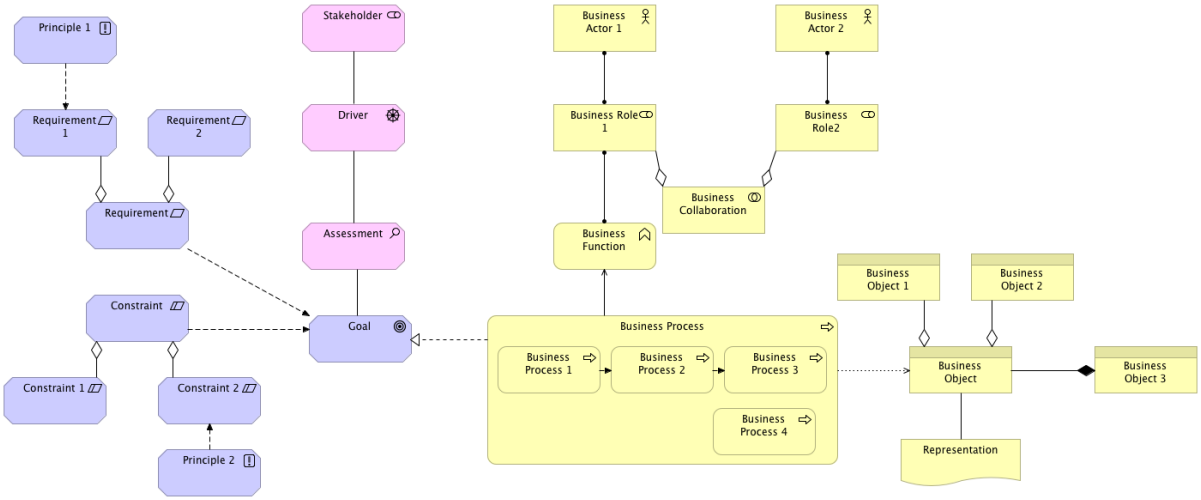
As shown in the purple and pink side of the Metamodel (Figure 2), the NP 4457 Motivation Metamodel states that stakeholders define drivers which promote management questions (assessments) that should be answered by goals achievement. These goals can be influenced by requirements and constraints, which can be an aggregation of other requirements or constraints respectively, which in its turn can be influenced by principles.

After the Motivation perspective usually comes the Business Execution approach. Therefore, only then did we define the Business Execution Metamodel.

As shown in the yellow side of the Metamodel (Figure 2), the NP 4457 Business Execution Metamodel states that Business Actors are assigned to Business Roles that interact with other Business Roles via Business Collaborations. From a firm perspective, the Business Role involved in this Business Collaboration belongs to a Business Function that executes/uses a Business Process, which can be a composition of Business (sub)Processes. These Business Processes access Business Objects that can be compositions and/or aggregations of other Business Objects and can be associated with specific Representations (Faroleiro, 2016).

By merging the Motivation and the Business Execution Metamodel, we obtained the NP 4457 Metamodel as represented in Figure 2. This Metamodel answers all Zachman Framework's questions, since the Motivation Metamodel answers the "Why" (as motivations are identified), while the Business Execution Metamodel answers the questions "What" (as information is identified, specifically business objects and representations), "Where" (by showing the way constituent parts are interrelated or arranged, in other words, where these parts are located within the organization), "When" (by the existence of sequences, represented by the flow and triggering relations), "Who" (through business actors and roles) and "How" (through business functions and processes) (Gama et al, 2013).

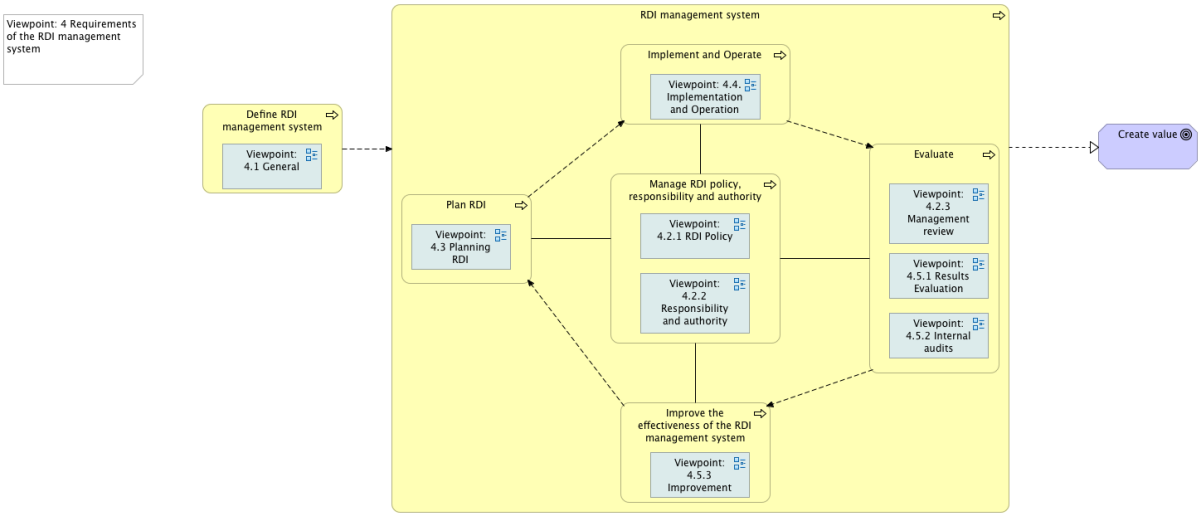
Figure 2. NP 4457 Metamodel.



Then, we began modelling all 24 clauses using the Metamodel, obtaining the NP 4457 Reference Architecture. We started by representing the Requirements viewpoint (clause 4),

enabling us to have a broader perspective about the existing relations among the different clauses, as represented in Figure 3. Then, we populated the remaining viewpoints.

Figure 3. Viewpoint 4: Requirements of the RDI management system.



Some viewpoints can aggregate more detailed viewpoints, following the same structure as the Standard's clauses. As an example, we present the Implementation and Operation and the Competence, Awareness and Training viewpoints (Figure 4 and 5 respectively).

Figure 4. Viewpoint 4.4: Implementation and Operation

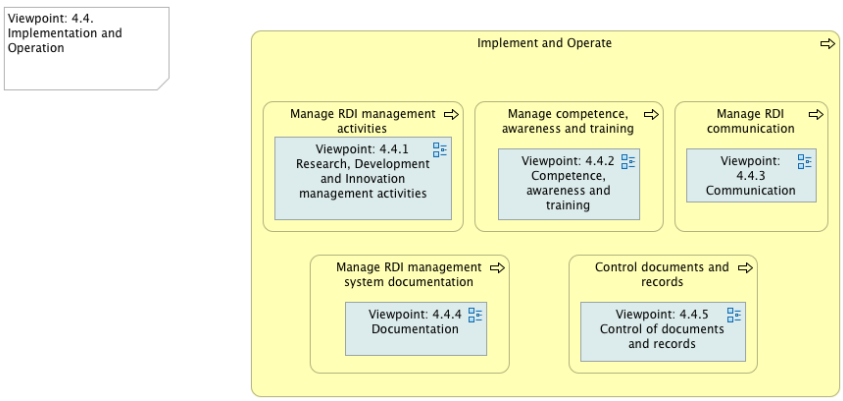
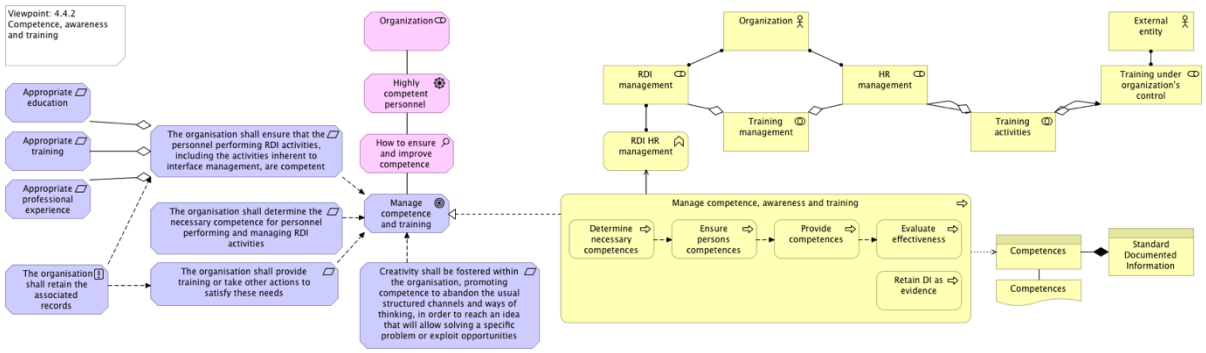


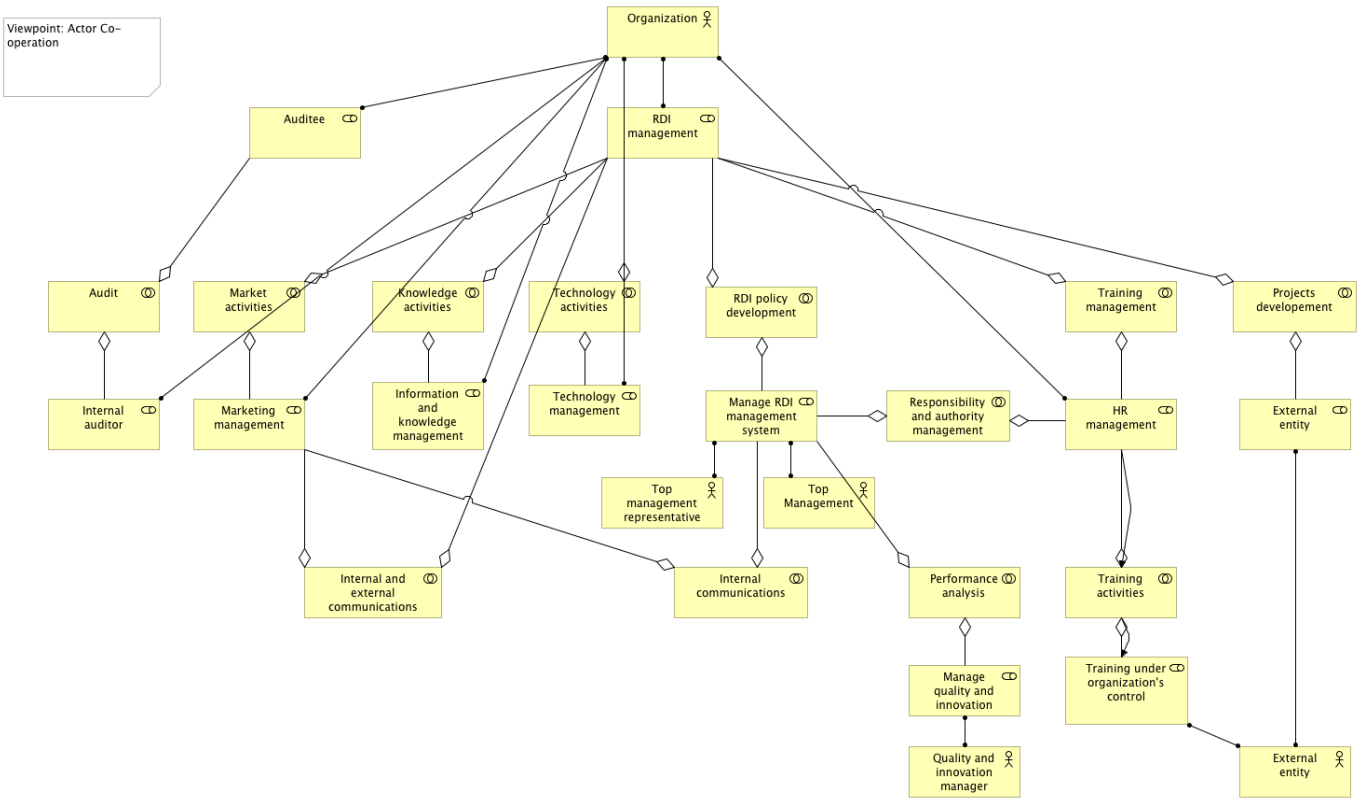
Figure 5. Viewpoint 4.4.2: Competence, Awareness and Training.



It is relevant to stress that some extra viewpoints and artifacts were included in the Reference Architecture as improvement opportunities that enhance the Standard (Appendix 4 and 7).

Finally, using the Reference Architecture's components, we rearranged the overall NP ISO 4457 framework according to relevant Archimate's standard viewpoints (Actor Co-operation, Business Function, Introductory, Organization and Business Process Co-operation viewpoint) and domains (Information domain). As an example, we present the Actor Co-operation viewpoint in Figure 6. The remaining viewpoints are presented in Appendix 4.

Figure 6. Viewpoint: Actor Co-operation.



5.3. Gap between an actual RDI management system and the NP 4457 Reference Architecture

To confirm the adherence of the Reference Architecture against the RDI management system implemented in the organization, we formulated a questionnaire. Since NP ISO 4457 is a process-based framework, it was focused on the elements present in business and process layers. A different questionnaire was developed for each viewpoint, allowing to collect

information on the existence (total, partial or non-existence) of each component of the viewpoint and the way it is structured/executed within the organization.

In this sense a semi-structured interview was developed. We started by sharing our research motivation with the Quality and Innovation Manager. We then identified the findings we wanted to address and the expected results. Finally, we conducted an interview based on a questionnaire for each viewpoint.

From a total of 24 questionnaires built, we present, as an example, the Planning of RDI projects Business Process viewpoint and part of the respective questionnaire, in Figure 7 and Table 1 respectively (the complete version is shown in Appendix 5).

Figure 7. Viewpoint: Planning of RDI projects Business Process.

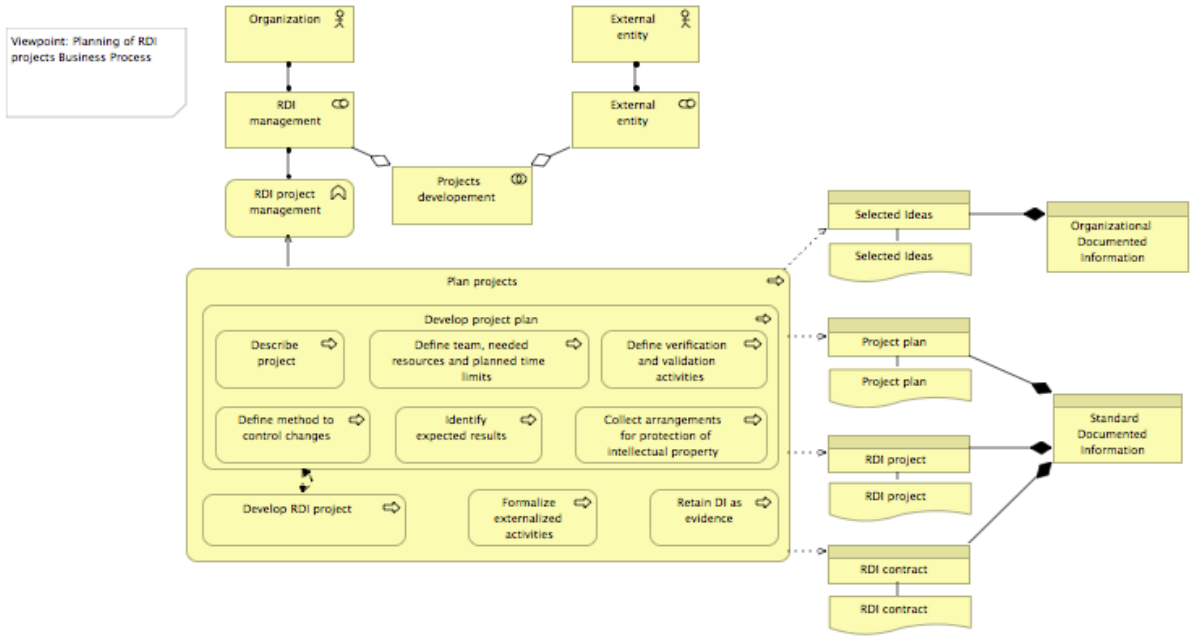


Table 1. Part of the Planning of RDI projects Business Process viewpoint questionnaire

Component	Type	Existence	Organization/Execution
Planning of RDI projects	Process (process view)		
Organization	Business Actor		
External entity	Business Actor		
RDI management	Business Role		
External entity	Business Role		
Projects development	Business Collaboration		

6. Demonstration

The organization selected is a technology and IT services company, based in Lisbon. It is NP ISO 4457 and ISO 9001 certified. However, due to confidentiality reasons, the organization will not be characterized in detail.

After analysing and discussing all viewpoints, we came to the conclusion that there were little differences when compared to the NP 4457 Reference Architecture, which means that the model is very close to reality. These differences were related to a misunderstanding about the clause 4.3.1, which was then restructured and improved, and to six artifacts associated with outsourced activities that were required by the model, but not present in the organization since it doesn't outsource any activity.

Therefore, after the above-mentioned restructuring, all artifacts and correspondent relations were identified in the organization. Such results were very good and aligned with what was expected.

However, it is also relevant to stress that two additional improvement opportunities were detected. Therefore, two collaborations not required by the Standard but implemented in the organization that enhance the Standard were added to the existing model.

Another relevant fact is related with the Interface management and knowledge production management viewpoint (clause 4.3.1). Although the organization had all artifacts, they don't recognize some of them since they do the process in an intuitive and simplified way, which highlights another benefit of the model: the identification of structures and mappings not visible in organizations.

All differences and correspondent improved viewpoints are presented in Appendix 6 and 7.

7. Evaluation

To evaluate the NP 4457 Reference Architecture, we used the "The Moody and Shanks Framework", whose purpose is to evaluate and improve the quality of models (Moody and Shanks, 2003).

The quality factors proposed by this Framework, which define the characteristics of a model that determine its overall quality, can be used to evaluate the NP 4457 Reference Architecture, enabling us to achieve the following results: **Completeness** refers to whether the model contains all user requirements, specifically, that all NP ISO 4457 clauses can be mapped on the NP 4457 Metamodel. Since all clauses were mapped on the Reference Architecture, we can say that our model contains all clauses; **Integrity** refers to the definition of business rules or constraints from the user requirements to guarantee model integrity. In this case, it refers to the possibility to add requirements on top of the NP 4457 Reference Architecture set of artifacts. Such ability was confirmed when new requirements (i.e. improvement opportunities) were added on the top of the existing ones; **Flexibility** is defined as the ease with which the model can cope with business and/or regulatory change. It particularly refers to the ease on how the NP 4457 Reference Architecture can be used as a base to define a theoretical RDI management system. Such flexibility can be confirmed by the adherence test made, in other words, with the mapping within the organization's RDI management system; **Understandability** is defined as the ease with which the concepts and structures in the model can be understood. Such ability can be confirmed since all elements used in our model are recognized and understood by people from these fields (i.e. fields related with NP ISO 4457, EA and Archimate); **Correctness** refers to whether the model is valid (i.e. conforms to the rules of the modelling technique). Our model was build using both the EA and Archimate rules and conventions, which proves its correctness; **Simplicity** means that the model contains the minimum possible entities and relationships, more precisely, that the NP 4457 Reference Architecture contains the minimum possible

constructs (i.e. minimum redundancy). Since our model maps NP ISO 4457 direct clauses, the level of redundancy is the one that comes from the NP ISO 4457; **Integration** is defined as the consistency of the model with the rest of the organisation's data. Such consistency can be confirmed by the adherence test made; **Implementability** is defined as the ease with which the model can be implemented within the projects' time, budget and technology constraints. In this case, it refers to the ease with which the NP 4457 Reference Architecture can be implemented, supporting RDI operations in an effective and efficient way. Since the model helps identifying the EA artifacts needed to be developed by the organization to comply with the NP ISO 4457 requirements, it accelerates the gap analysis between the current RDI management system and the situation represented by the model (Moody and Shanks, 2003).

After analyzing these results, we can conclude that the NP 4457 Reference Architecture meets all quality factors, proving the quality of the overall model.

8. Conclusion

The growing importance of innovation has increased the use and relevance of NP ISO 4457, since it defines the requirements of an effective management system for RDI, allowing organizations to reach their innovation objectives (NP ISO 4457, 2007).

On the other hand, EA is becoming increasingly recognized as the only worldwide standard that can produce holistic designs that are agile and all-encompassing (Bernard, 2012).

However, as most standards and best practices are created in isolation, are very resource intensive and their scope is not all-inclusive, organizations end up facing the challenge of deciding how to adopt them and what are the overlaps, contradictions and gaps (Bernard, 2012).

With this thesis, we tried to overcome such problems by integrating the NP ISO 4457 with EA. This way, we developed a Reference Architecture that helps organizations to conform to the NP ISO 4457 requirements, by determining how "processes and resources are organized and

realized" (Lankhorst et al, 2009: 18). This is a tremendous and unique contribution, since the Reference Architecture can be applied to every organization in a generic way.

Throughout these pages, it was explained how we mapped NP ISO 4457 concepts in EA terms and how we modulated them, resulting on the NP 4457 Reference Architecture. Then, it was possible to rearrange it according to Archimate's standard viewpoints and domains, providing us an architectural view on the impact of implementing a RDI management system. Finally, it was explained how the model was validated on a real organization, by evaluating the fit between their RDI management system and our NP 4457 Reference Architecture.

This way, it was demonstrated that NP ISO 4457 clauses can be related with motivational aspects of the EA and the EA architecture layers (process and business) and that the Standards' concepts can be mapped in EA artifacts, which answered the research question number one: "What are the mapped concepts between the Standard and EA".

It was also demonstrated that a single Metamodel is able to encompass the relation between NP ISO 4457 and EA, and that all 24 clauses can be modelled in EA, constituting 37 viewpoints, each one based on this Metamodel. Creating this way the NP 4457 Reference Architecture. With this, research question number two was answered: "How can these be represented by a Reference Architecture".

Finally, it was demonstrated that a real NP ISO 4457 RDI management system could be mapped with the NP 4457 Reference Architecture without any change, being considered any deviation a non-conformity. This enabled us to answer research question number three: "If an organization has an RDI management system based on NP ISO 4457, the NP 4457 Reference Architecture is a reference model for the RDI management system."

As a conclusion and answer to the main research question "How NP ISO 4457 can be integrated with EA", it is relevant to reinforce the possibility to represent all NP ISO 4457 clauses and requirements using our Metamodel, and that the resulting NP 4457 Reference Architecture can

be applied to every organization that needs to manage the Standard's requirements in their EA. Moreover, and answering to the fundamental questions for DSRM – "What utility does the new artifact provide?" and "What demonstrates that utility?" (Hevner et al, 2004: 91), it is possible to add that the value of our proposal also arises from its contribution to avoid duplication of efforts and resources, as well as accelerating the gap analysis, eliminating misalignment and enabling the identification of structures and mappings not visible in organizations.

As for the used methodology, it was proven adequate, since it allows the construction and validation of a theoretical model, in an iterative way, enabling continuous improvement.

However, it is relevant to stress that some limitations related to the need to apply the Reference Architecture to different organizations were identified. Not only apply it to a wider range of organizations with different areas of activity, but also to NP ISO 4457 uncertified organizations.

As to future work, it should be focused on modeling similar standards and developing alignment mechanisms between them. It may also be interesting to examine the relationship between Quality Management (QM) and Innovation, by comparing and integrating both ISO 9001 and NP 4457 Reference Architectures. This way, extending Kim's findings and surpassing some of the limitations identified in his work, such as the need to develop more objective measurements and to explain how and why QM practices result in innovation (Kim et al, 2012).

To sum up, with this thesis we tried to increase the understanding of both EA and NP ISO 4457 and develop a useful and powerful model that enables organizations' alignment and increase their ability to cope with a world where "Innovation is the only way to win" (Steve Jobs[1]).

[1] https://business-sa.com/Editorial-Content/What-really-fosters-innovation

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