Abstract: This work aims to introduce a set of rules to be used with organizational concepts. These rules are meant to maintain traceability between enterprise models. The traceability between models allows representing the enterprise architecture by its several dimensions, and can be used as a filter to only visualize the relevant elements in a concrete situation. Another goal of this work is to preserve the syntax used in the enterprise architecture. This means the elaboration of another set of rules with the objective of detecting potential modeling problems. The Zachman Framework was used in this work to achieve these goals. This was due to its division of the modeling models by several dimensions. In this work the dimensions What, How, When, Where, Why and Who are related to modeling concepts. The business process modeling concept is defined as the glue between other modeling concepts. This aggregation allows the traceability between models and the visualization of the architecture through its dimensions. The addition of hierarchical leveling in modeling concepts allows the creation of abstraction levels. These levels can also be used to visualize the architecture, depending on the detail level desired. Also, rules can be applied between abstraction levels with the aim to help the modeling effort and detect modeling errors. These rules where implemented in the program System Architect. To validate this work the System Architect was used as a process repository. Its meta-model was extended and a macro that implemented the rules was written. Afterwards the work was validated with a real case study.

Key-words: Architecture, Business Process, Zachman, Dimensions, Inter-connection, Rules, Representation

1. Introduction

Enterprise architectures are used with these goals in mind: have a set of simplified representations of the reality of the organisation; support traceability between several strategic and technological levels (Towers S 2005); support the detection of problems and possible productivity increases (Eriksson 2001). Architectures use several models to represent the whole architecture and simplify the modelling. However these models only represent small sets of the organisation and the interactions between the several pieces of the enterprise are not captured or represented. In order to have a full representation of the enterprise it is necessary to have, not only the models that compose the architect, but also the relations between them. This interaction between elements allows visualization of the organisation from several logical views. These views represent the relations connecting several business elements. The result is the construction of views that responds to specific concerns of a stakeholder (for example, a security related view, where the information of who has access to what objects is represented, by relating the “people” models with the “information” models).
Other advantage of obtaining the interaction between business objects is the possibility of imposing a set of rules to their relations. These rules aim to help the modelling effort by detecting modelling errors and inconsistencies. In the case of a correct modelling the points detected by the rules can be points of further improvement in the organisation.

The Zachman framework is a framework that can be used for the logical division of the architecture, possessing several dimensions and perspectives that allow the definition of the whole organisation. The dimensions How, Who, What, When, Why and Where are basic interrogatives that can be used by the stakeholders to question the architecture.

2. Process

The concept of “process” is fundamental in this work. Not only it’s an organisation concept that adds value to the enterprise but it is transversal to the entire organisation (Eriksson, 2001, page 68), uses the following classification for business process:

- Has a goal.
- Has specific input.
- Has specific output.
- Uses resources.
- Has a number of activities that are performed in some order, depending on the conditions and events that occur during the execution of the process. The activities within the process can be seen as sub processes.
- Affects more than one organisational unit. It is horizontal rather than vertical in regard to the traditional organisation of the business.
- Creates value to some kind of customer. The customer can be either internal or external to the business.

(Sousa, 2006) uses the most important definition of business process in the scope of this work.

- “A business process can be inferred as a set of connected activities with inputs and outputs, which interact with people, contribute to achieving business goals, take place in a specific location and occur during a period of time”.

The most used properties of business process used in this work are the ones defined by (Sousa, 2006). Therefore a business process:

- Has inputs and outputs.
- Interact with people.
- Contributes to achieve business objectives.
- Occur in a specific place.
• Occur during a specific time.

3. Dimensions of the Zachman Framework

The Zachman framework is composed by six perspectives and six dimensions. These dimensions are basic interrogatives by which the architecture can be viewed. It allows classifying relevant characteristics of several organizational concepts. The dimensions of the Zachman Framework are used in this work to allow the representation of the enterprise architecture through several logical views.

The framework claims to possess all the necessary primitives to the classification of the organisation (Zachman).

The six dimensions are: What, How, Who, When, Why and Where (Zachman, 2006). Table 1 details each dimension.

These dimensions have direct associations with the main business concepts identified during this work.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Focus</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>What</td>
<td>Data</td>
<td>The data of the enterprise and how it is used.</td>
</tr>
<tr>
<td>How</td>
<td>Function</td>
<td>The process of translate the enterprise mission to its business and the definition of its operations.</td>
</tr>
<tr>
<td>Who</td>
<td>People</td>
<td>Who is related with the major artefacts of the enterprise (business process, information and IT) High level cells refers to the organisational units, the low level cells refers to the system users.</td>
</tr>
<tr>
<td>When</td>
<td>Time</td>
<td>The evolution of the artefacts along the time.</td>
</tr>
<tr>
<td>Why</td>
<td>Motivation</td>
<td>The translation of the business goals and business objectives.</td>
</tr>
<tr>
<td>Where</td>
<td>Network</td>
<td>The geographic distribution of the business activities and artefacts.</td>
</tr>
</tbody>
</table>

Table 1 - Zachman Framework Dimensions (Sousa, 2006)

These six dimensions are easy to attach to the concept of business process.

The addition of dimensions to the business processes allows the representation of processes through several views related to the dimensions, execute queries and filter the processes through the dimensions. This means that business processes can be visualized though its actors, informational entities, frequencies, places or any combination of these concepts. A basic example is to see what business processes would be affected with the change of a system or informational entity. Other uses could be related for example with security, though the use of concepts such as actors, processes and informational entities (Who, How and What dimensions).
4. Meta-Model

The meta-model used for this work is represented in Figure 1.

The business process is associated with several business concepts, each one directly related with the dimensions defined above. The System concept models the applications belonging to the organisation. The informational entity object is divided in two types. The input type and the output type distinction were realized because of one of the properties of the process related with the information. Since the processes uses the informational entities as inputs and outputs, it is necessary to reflect that reality. As such, inputs represent informational entities that are necessary in order for the process to be executed. Outputs represent informational entities that result from the execution of the process.

All objects / concepts are defined in a hierarchical mode. This allows constructing and representing the enterprise architecture using several abstraction levels.

**Process**

The own concept of process is associated with the How dimension. This happens because the process can be sub-divided in sub-processes, that details how the process is realized.

**Time**

The time concept is related with the When dimension. Associated with the process, it represents the frequency of execution of the process (for example, one time per week).

**Informational Entity**

Is related with the What dimension. It represents objects that are used, consumed, refined or created in a business process (Macedo 2005). Can be classified as:

- Input. Informational entities that are needed for the execution of a process.
- Output. Informational entities that result from the execution of a process.
**Location**
Related with the Where dimension. Locations are places (geographical or logical) where actors execute their tasks. As such, the meta-model also reflects the inter-connection between actors and locations. This can be further explored in the rules section.

**Actor**
The actor represents who executes the process or who is responsible for the process. They are capable of performing a set of services that defines a role. These services are related with competencies, capabilities, and other attributes of that person that are relevant in the context of activities. It is therefore directly related with the Who dimension. An actor needs to be allocated to locations.

**Objective**
Directly related with the Why dimension, it indicated the objective that processes are meant to achieve. An Objective can be decomposed in sub-objectives. Obtaining the objective is dependent of achieving the sub-objectives. Also, sub-objectives can replace or compensate failed sub-objectives (Eriksson, 2001, pp. 79).

**System**
The System concept is an example of how the meta-model introduced is easily adapted to the necessities of an enterprise. Today enterprises are very dependant on the information systems that support the business, and as such the System concept represent these systems. The system concept is related not with the conceptual perspective of the Zachman framework, but with the logical perspective and with the How dimension, indicating How the systems support the business processes. Because of this relation it can be associated with the business process.

5. **Rules**
The multi-dimensional representation of enterprise architectures allows the construction of a set of rules can be applied to the connections between primitives. These rules act as a set of warnings provided to the modeller, indicating possible modelling errors and incomplete information. The rules are:

- A dimension primitive must be associated with at least one process. When this may not happen due to:

  A modelling error by which the enterprise architecture does not truly represent the organisation reality.
The organisation does not make use of the dimension, and therefore it is a useless and not necessary primitive for the execution of the business.

- Actors that are not associated with any location mean that their position in the organisation is not well defined, and so a warning is generated to verify the situation of the actor.

- In an identical way, locations that don’t have any actors related are locations that either are useless, or that their function is not well defined in the organisation.

- When the locations associated with the process are not consistent with the business process's actor's locations, either the locations associated with the process are wrong, or the location of the actor is inaccurate, or the process does not occur the specified place, and therefore it is a situation that should be verified so that the origin of the warning is resolved.

- Business processes that possess the same dimensions can be considered equivalent or identical when concerning the modelling task and therefore the models should have only one representation of the business process. We can visualize equivalent process though the six dimensions, or with a specific set of the dimensions types, indicating that we want to get the processes that are equivalent in only that set of dimensions (one example is to see what are the equivalent processes that occur in different places, this is done by executing the rule without the Where dimension).

**Level Balancing**

The hierarchical definition of primitives defined by the meta-model allows constructing granularity levels of the models. This, and the inter-connection between primitives, allowed to introduce a set of rules meant to help the balancing of the levels and detect inconsistencies between levels and relations. The rules apply to the following situations:

- When a process has all sub-dimensions of a dimension, those sub-dimensions can be replaced with the father dimension.

- When the sub-processes of a process have all the sub-dimensions of a dimension, the father process can be related with the father dimension.

- When there is a sub-process that contains a dimension more generic that the father process, there is an error. A sub-process function is to detail the steps needed to execute a process, when it uses a more generic primitive than its father, either the modelling of the process is wrong or the definition of how the primitive is uses is wrong.

- When a business process has two or more dimensions of the same type. When this happens, the process may be further detailed in sub-processes that use each of the dimensions distinctly. This is done to maximize the detail existing in the model.
• A leaf process (a process that does not decompose in sub-processes) has non leaf dimensions associated. This means that the process may be further decomposed so that it further details how the dimensions are used, or the leaf dimensions have no reason for existing.

**Processes without a dimension type association**

• **Processes without inputs.** By definition a business process uses inputs for its execution.

• **Processes without outputs.** Business processes that don’t produce outputs are not well modelled or are processes that do not produce anything for the enterprise.

• **Processes without actors.** A process that doesn’t have any actor is a process which is the responsibility of no one.

• **Processes without locations.** A business process needs at least one location, indicating where it is executed in the organisation.

• **Processes without objectives.** A business process without any objective is a process that doesn’t have its objectives and contributes to the enterprise well specified.

• **Processes without time.** Business processes not associated with time are processes that lack information about its frequency of execution in the organisation.

6. **As-Is To-Be**

Although the representation of the “As-Is” and of the “To-Be” was not the focus of this work, it became a secondary objective in this work due to the nature of the multi-dimensionality of this work.

The “As-Is” model is the model that shows the representation of organisation today. The “To-Be” model is the model that shows the way the organisation should be in a particular future due to its objectives, and optimizations.

The phase corresponding to the transition of the “As-Is” model to the “To-Be” model of the enterprise is a critical one. The activities and people have to adapt to a new reality and sometimes there are some “displacements” between how something should be done and how it is represented in a model.

This part of the work tries to help with the representation of this transition.

To help the transition between the “As-Is” model and the “To-Be” model it makes use of the dimensions, concepts and meta-model already employed in this work. The concepts however now have to be associated with the “As-Is” model or with the “To-Be” model. Plus, they should be associated with other concepts of the same class belonging with the opposite model. This means
for example, that if a process in the “As-Is” model is sub-divided in two processes in the “To-Be” model, it must be associated with those two processes.

The tool implemented uses two visualizations to do this: When we want to visualize a business process, the diagram of that process is open and the symbol of the business process turns blue. The related processes diagrams are open and the related symbols become green. This way, one can directly visualize the alterations implied to that process.

When we want to visualize the transition of an other type of dimension (except process), a new window opens with the relations. It shows the business processes that the dimension used to be related with and that are now non-executed, the new business processes that are executed in the “To-Be”, and the business processes related with the old processes. This allows to have a linkage between the “As-Is” model and the “To-Be” model, and to see how the transition affects the operation of that particular dimension.

7. Implementation

The implementation step of this work was realized in the System Architect tool from Telelogic. This tool allows the modelling and construction of enterprise architectures. It has a vast set of diagrams for the modelling of several architectural domains.

One important characteristic of the System Architect is its extension mechanisms. These mechanisms allow adding and altering diagrams, symbols, definitions and properties. The tool also supports Visual Basic for Applications, allowing the construction of macros that extends and adds new functionalities to the tool.

In this work the System Architect tool was used as a business process repository. The usrprops.txt file was extended in order to add the meta-model introduced in this work and new diagrams were created. These were the Information Diagram for the modelling of the informational entities, the Actors diagram for the modelling of the actors and the Time diagram for the modelling of the time concepts. The business processes were related to the other dimensions and a macro was created. This macro was used to visualize the dimensions defined in this work. It also was used to implement the rules defined. The final step was the validation of the work using a real case study.
8. Validation

The case study was INATEL and it provided architectural models so that execution of the rules defined in this work could be done. It provided a good source for business processes, actors, informational entities and time. However, the enterprise did not provided such a good source for the objectives concepts. Also most of the dimensions, mainly the “Who” dimension did not achieve a good hierarchical modelling, mostly because the information provided was mainly the name of the employee, instead of its function and chain of command.

The results obtained were mainly on the identical business processes, business processes without outputs, business processes without inputs and business processes without actors. Several identical business processes were identified and were changed so that only one existed in the models.

Some of identified business processes without inputs, outputs, or actors were subjected to a posterior discussion and these issues were later resolved, while the rest are subject for a more detailed analysis too.

The introduction of the System concept demonstrated the flexibility of the meta-model, it allowed to model the systems existing in Inatel.

9. Conclusions

The usage of hierarchical models to represent the several dimensions present in this work allowed to view the architecture with several levels of abstraction, from a very generic view to a very specific level. Also this allows constructing some rules that help balancing the levels between dimensions.

The meta-model utilized proved to be very effective in the representation of the architectural models and association and visualization of relations between concepts. Not only it allowed levels of abstraction, but since the business process was the unifying element, the models could be represented though the perspective of any of the dimensions, or combination of dimensions. This means that specified views can be realized in the model. Such as a security view, though the use of the “Who”, “Where” and “What” dimensions or view time dependent informational objects.

These associations allied with the properties of the business process concept, allows extracting possible modelling or operation specific problems. The most common problems were, business processes without inputs, business processes without outputs and business processes without actors. Other problems are related with actors not associated with any location, locations without actors, inconsistency between business process locations and the business processes actor’s locations.
The high interconnectivity between concepts that the model delivers also introduces rastreability between the concepts and models of the organisation. Already referred, the System concept exemplified the flexibility of the model employed. This means that it can be adapted to specific needs of a particular enterprise without heavy modifications in the theory.

10. Future Work

During the elaboration of this work some aspects were identified that I think is of interest for future works.

The concept of time used in this work was of the execution frequency of a business process. Despite this, I think it is of interest of also adding time restrictions to the dimension. Although normally found in object constrain languages and in simulation aspects, the adding of restrictions to the time would allow to identification important objects to the business and to analyse the level of use that those objects (and the related objects) are subjected to.

One aspect that might be considered analysing is that of the informational entities and business processes. The representation of business processes through the Business Process Modelling Notation relates the business process and the data Object through associations. During the validation of this work, and when working with the informational entities, I began questioning if it would make more sense to relate the business process not with the data object itself, but with its state. Since the business process alters the informational entities, I think such relation would facilitate management and modelling of the documents and artefacts used in the organisation.

Despite being lightly focused in this work, the transition of the “As-Is” models to the “To-Be” models is an area that deserves a bigger dedication that the one that was used in this work. This is mainly because of the importance and the impact that transition phases have in enterprises when these are in a change context.

Also, of this work resulted a set of rules that are applicable to the connections between primitives of the Zachman Framework. It was not a target of this work the elaboration of rules applicable to meaning of the primitives and therefore associations between primitives which purposes are not the same are not detected. This means that the following inconsistency is not detected: Consider the association between the business process “Construct Car” and the informational entity “Invoice”.

It is obvious that the logical association should use informational entities such as Wheels, engine and chassis. To detect this inconsistency between elements there should be common meta-
information about the business process “Construct Car” and the entities “Invoice”, “Wheels”, “Engine” and “Chassis”.
I believe that the element that allows such meta-information is in the function of each element.

**Bibliography**