# ArchiMate Metamodel for Environmental Management Systems ISO 14001 Standard

Martin Rod [1,2]

[1] *Prague University of Economics and Business – Faculty of Management, Jarosovska 1117/II, Jindrichuv Hradec, 377 01, Czechia*
[2] *Czech Academy of Sciences – Institute of Information Theory and Automation, Pod Vodarenskou vezi 4, Prague, 182 00, Czechia*

**Abstract**

The research paper deals with the ISO 14001 standard to integrate and improve the operation of environmental management systems (EMS), which are currently being actively adopted or maintained by companies worldwide. Utilizing EMS is either due to internal factors or external pressures, with the prevailing reason of customer, community, and company image. For easing the use of the EMS, a metamodel based on the ArchiMate language is developed. ArchiMate is a widely accepted open standard designed to model enterprise architecture. ArchiMate facilitates holistic, structured understanding and enables communication about the enterprise and its parts between different stakeholders. The contribution of this paper lies in: Firstly, the creation of an ISO 14001 metamodel based on the UML (Unified Modeling Language) domain diagram. Secondly, model mapping between this UML metamodel and the resulting ArchiMate metamodel. Finally, the resulting metamodel is ready to be used by enterprises in practice. Moreover, the metamodel could be further modified and enhanced for, e.g., domain-specific industries.

**Keywords**

ISO 14001, ArchiMate, environmental management system, mapping, metamodeling



## 1. Introduction

Being green is perceived very sensitively today, especially in Western society. Until recently, the European Union has been preparing and further approved a green deal, which is supposed to restrict significantly non-green companies [1]. Although the current state of the green deal is uncertain due to the recent turbulent times, being green is still perceived positively. Moreover, this stance affects the efficient processing of internal resources without creating externalities. It also enables to meet any restrictions imposed by the government. Finally, yet importantly, the customer's overall perception allows companies to increase the demand for products and services from the position of marketing communication in terms of corporate social responsibility. This last-mentioned aspect of positioning the organization to be better accepted by the consumers could be seen as the primary motivator [2].

One way to show (and be environmentally responsible) is to implement the corresponding standard of the Environmental management systems (EMS).

ISO 14000 family of environmental management systems consists currently of ten published standards: ISO 14001:2015, ISO 14002-1:2019, ISO 14004:2016, ISO 14005:2019, ISO 14006:2020, ISO 14007:2019, ISO 14008:2019, ISO 14009:2020, ISO 14052:2017, ISO 14053:2021. Those standards range from general information to specific areas such as material flow cost accounting in organizations or further specified in supply chains [3].

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EMAIL: martin.rod@vse.cz (A.1)
ORCID: 0000-0003-3336-265X (A.1)

However, adopting and maintaining functional EMS could prove to be a difficult task as the communication between different stakeholders and the measurable way to defend the financial benefits of the EMS financially is one of the main barriers [4]. For this purpose, a metamodel based on the ArchiMate language is developed. ArchiMate is a widely accepted open standard designed to model enterprise architecture. Furthermore, ArchiMate facilitates holistic, structured understanding and enables the communication between different stakeholders about the enterprise and its parts.

This paper focuses on the ISO 14001:2015 Environmental management systems — Requirements with guidance for use (for short ISO 14001, standard or just ISO) that defines the scope of the EMS in an organization and provides definitions for terms, critical processes for the successful implementation of the EMS, and techniques. For further information on the standard see chapter 2.1.

## 2. Research Background

This section discusses the background of this work. First, the ISO 14001 standard is introduced. Then, the language of ArchiMate is described. Next, attention is paid to similar works creating metamodels. From here, the methodology of this paper follows.

### 2.1. ISO 14001 Standard

ISO 14001 standard from the year 2015 standard is a successor to the prior version published in 2005. The current standard consists of main eleven chapters:

- Chapter 0 – Introduction
- Chapter 1 – Scope
- Chapter 2 – Normative references
- Chapter 3 – Terms and definitions
- Chapter 4 – Context of an organization
- Chapter 5 – Leadership
- Chapter 6 – Planning
- Chapter 7 – Support
- Chapter 8 – Operation
- Chapter 9 – Performance evaluation
- Chapter 10 – Improvement


**Figure 1**: Link between PDCA cycle and the framework structure of the ISO 14001

For mapping purposes and understanding of the concepts, chapter 0, chapter 3, and chapter 4 of the ISO standard should be highlighted. The standard itself builds upon the PDCA (Plan – Do – Check – Act) methodology, fig. 1. See that the chapters of the standard align with this proposition.

## 2.2. ArchiMate

The ArchiMate language is an open standard that aims to ease the process of managing enterprise assets to increase the effectiveness of an organization [5]. ArchiMate could be viewed as a tool enabling model creation as a language. Due to the ArchiMate specification, this creation could be realized via modeling software. – Computer-Aided Systems Engineering (CASE), one of the free modeling software, is Archi [6]. ArchiMate retains its higher-level abstraction, so UML (Unified Modeling Language), BPMN (Business Process Model and Notation), and other means represent the realization of those concepts. From this point of view, ArchiMate is modeling architecture. These other mentioned concepts are used for designing the actual solution.

The ArchiMate language is quite a new language in comparison to the Unified Modelling Language (UML) or the Entity-Relationship Diagram (ERD), which was in the modern form already published in Chen's work in 1976 [7]. Due to this fact, ArchiMate incorporates the best practices from the languages that precede him. ArchiMate is influenced by UML, which integrates and somewhat transforms structural relations (such as aggregation, composition, and inheritance). On the other hand, it does not include multiplicity or class instance notation due to its different abstraction levels [8], [9]. The whole ArchiMate language currently breaks down into multiple layers and aspects. The core version has only three layers and three aspects (fig. 2).

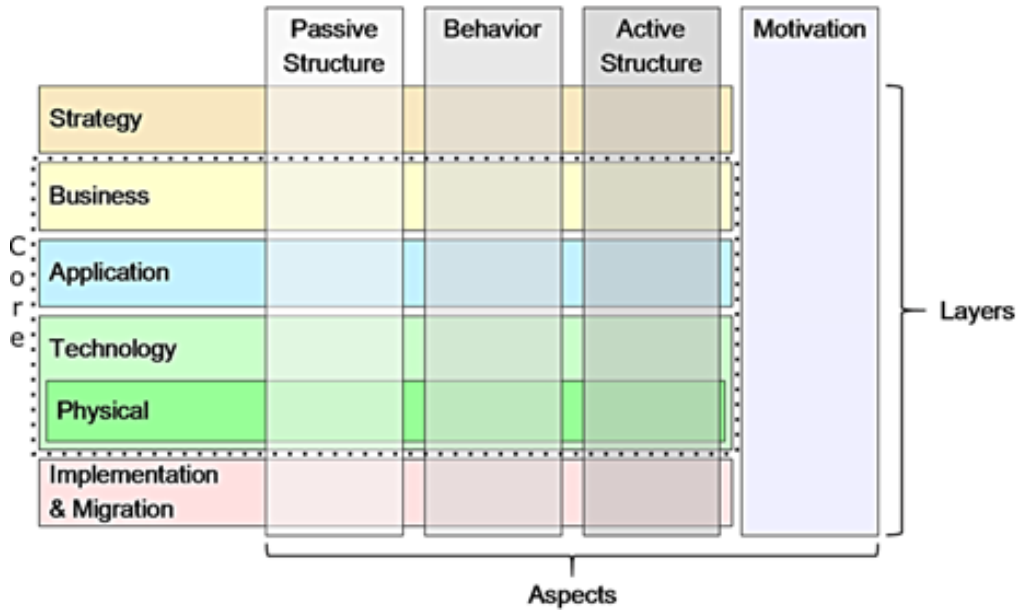


**Figure 2**: Full and Core ArchiMate framework

## 2.3. Methodology

The process of creating the ArchiMate metamodel is separated into multiple steps. Firstly a UML domain metamodel is developed. After that, this model is inspected by the Bunge-Wand-Weber (BWW) model [10] to map the elements (and relationships) to the ArchiMate language.

The BWW model or, more specifically, BWW ontology is a systematic approach to combat conceptual modeling problems. It is a way to achieve correspondence between the conceptual models/elements used and what the model is about. The adoption of the notions of Bunge enriched the work of the Wand and Weber duo. They developed an ontology with a vision to build the foundation

for information systems modeling. As such, this ontological model of information systems, the BWW model, could be used to analyze and evaluate the (UML) and its domain-specifics [11].

A bilingual version of the ISO 14001 standard was used to increase the mapping accuracy. The second language is the author's native language (English/Czech). ArchiMate was used in the original English version, with a translated dictionary of terms available in Czech (the standard itself is not translated into Czech). This paper is inspired by Buchalcevova and her work [12]. However, in contrast to her approach, the overloading of elements and constraints is further investigated. Corresponding situations can be seen in fig. 3.

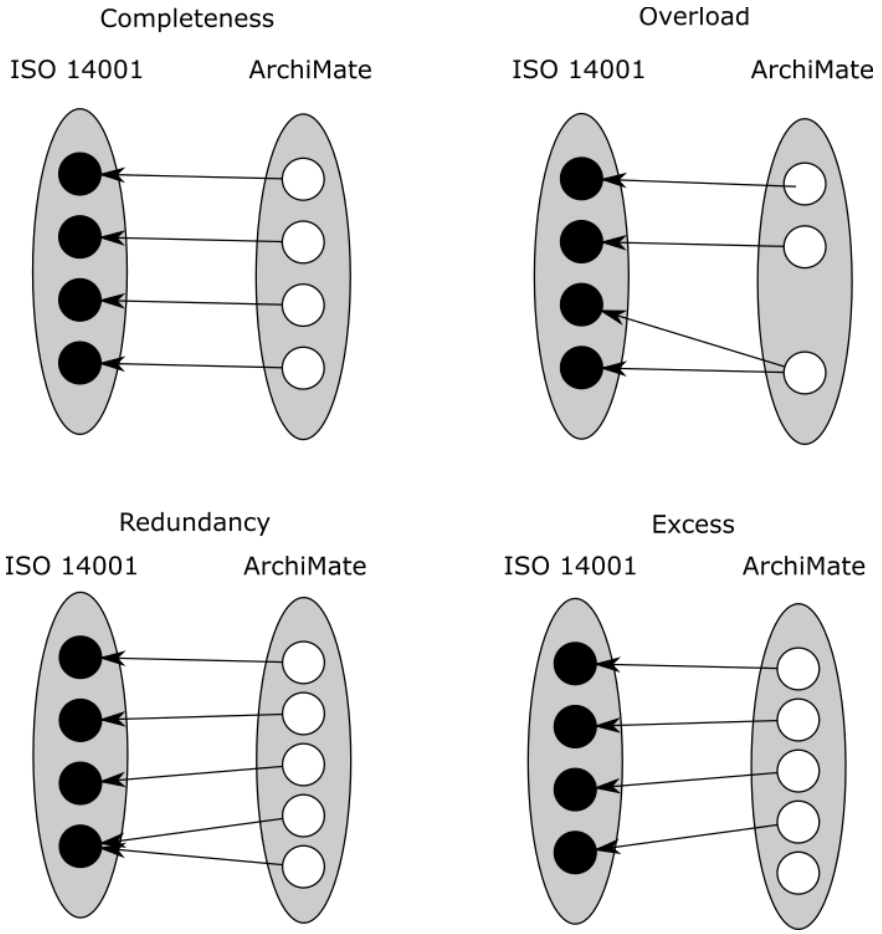


**Figure 3**: Mapping situations between ISO 14001 and ArchiMate language, based on [13]

## 3. UML Metamodel Development

Since the ISO 14001 standard does not contain any metamodel, the UML metamodel was created. In particular, the definitions section (chapter) three was used to create the UML domain metamodel. However, during the process, those concepts that did not have a definition were analyzed, and these were added to the metamodel due to their importance. Furthermore, there was then an overload between elements and binding for the concept of outsourcing. Last but not least, the concept of external organization emerged out of scope (fig. 4).

The UML metamodel consists of 39 elements, from which five are newly added, one is heavily overloaded, and one is out of the scope of the EMS, but its processes that are outsourced from the organizations are not. For that reason, the external organization is kept in the metamodel. This external organization also corresponds with the term “extended enterprise” in the TOGAF (The Open Group Architecture Framework) [14].

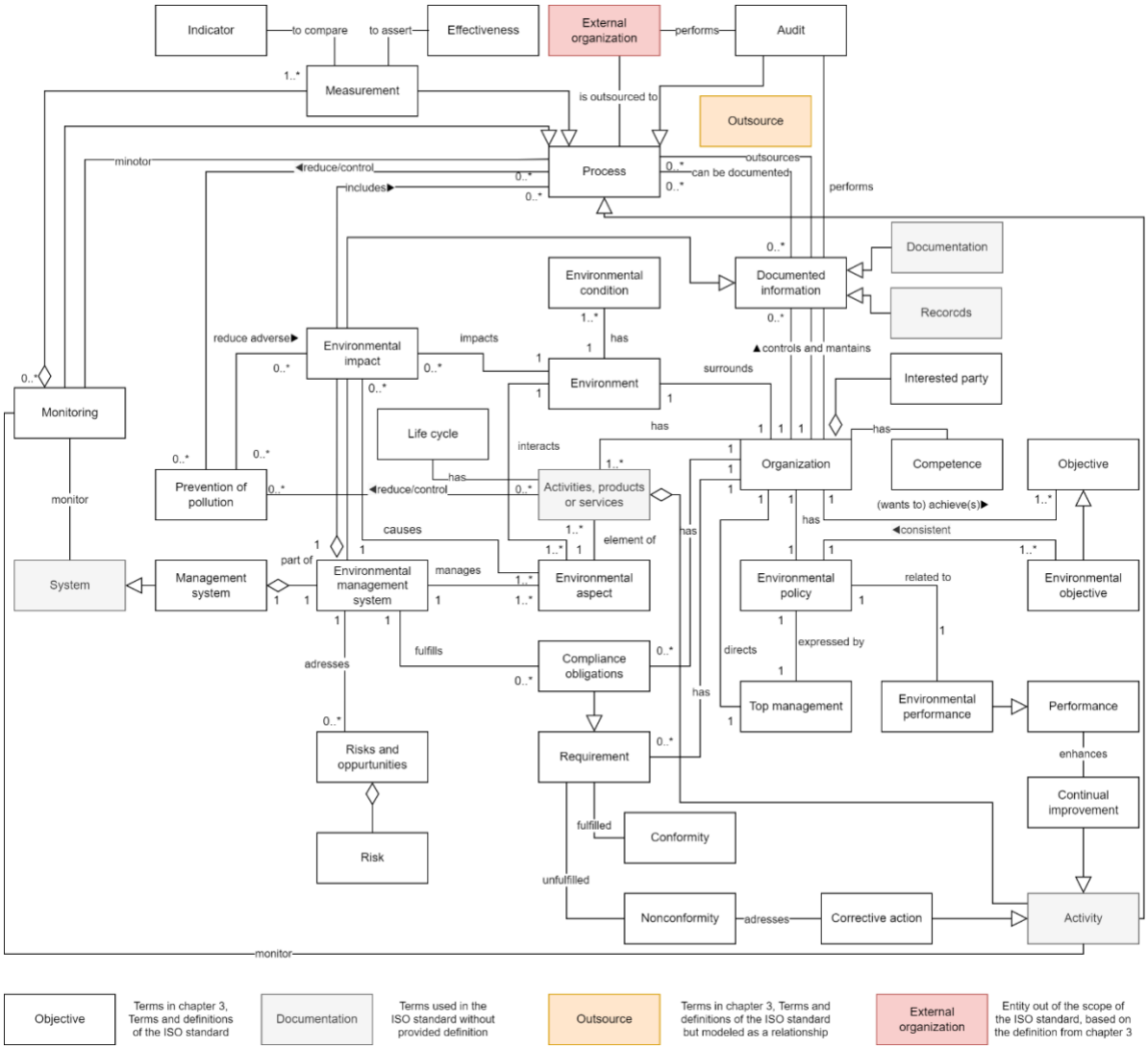


**Figure 4**: UML metamodel of the ISO 14001

## 4. Mapping UML Metamodel to ArchiMate

Tab. 1 provides an overview of the mapping between the elements of the UML metamodel and the ArchiMate metamodel. Mapping of the relationships was done in the same fashion, where the strongest suitable relationship was used. For the final relationships, see the final ArchiMate metamodel (fig. 6).

**Table 1**
Mapping UML metamodel to ArchiMate

| ISO term label | UML metamodel element | ArchiMate element name |
|---|---|---|
| 3.1.1 | Management system | grouping |
| 3.1.2 | Environmental management system | grouping |
| 3.1.3 | Environmental policy | course of action |
| 3.1.4 | Organization | business actor |
| 3.1.5 | Top management | business actor |
| 3.1.6 | Interested party | business actor |
| 3.2.1 | Environment | grouping |
| 3.2.2 | Environmental aspect | grouping |
| 3.2.3 | Environmental condition | assessment |
| 3.2.4 | Environmental impact | outcome |
| 3.2.5 | Objective | goal |
| 3.2.6 | Environmental objective | goal |
| 3.2.7 | Prevention of pollution | function |
| 3.2.8 | Requirement | requirement |
| 3.2.9 | Compliance obligations | requirement |
| 3.2.10 | Risk | assessment |
| 3.2.11 | Risks and opportunities | assessment |
| 3.3.1 | Competence | capability |
| 3.3.2 | Documented information | business object<br>XOR<br>business object AND data object AND artifact |
| 3.3.3 | Life cycle | value stream |
| 3.3.4 | Outsource (verb) | process<br>OR<br>relationship, see below |
| 3.3.5 | Process | process |
| 3.4.1 | Audit | process |
| 3.4.2 | Conformity | assessment |
| 3.4.3 | Nonconformity | assessment |
| 3.4.4 | Corrective action | course of action |
| 3.4.5 | Continual improvement | course of action |
| 3.4.6 | Effectiveness | outcome |
| 3.4.7 | Indicator | assessment |
| 3.4.8 | Monitoring | process |
| 3.4.9 | Measurement | process |
| 3.4.10 | Performance | assessment |
| 3.4.11 | Environmental performance | assessment |

**Table 2**
Mapping additional UML metamodel elements to ArchiMate

| Term label | UML metamodel element | ArchiMate element name |
|---|---|---|
| x.1 | Documentation | Documented information |
| x.2 | Records | Documented information |
| x.3 | Activities, products, or services | grouping |
| x.4 | Activity | process |
| x.4 | Product | product |
| x.5 | Service | business service<br>OR<br>application service<br>OR<br>technology service |
| x.6 | System | grouping |

Due the addition of the other concepts, a second table (tab. 2) is provided in the same way with the additional mapping.

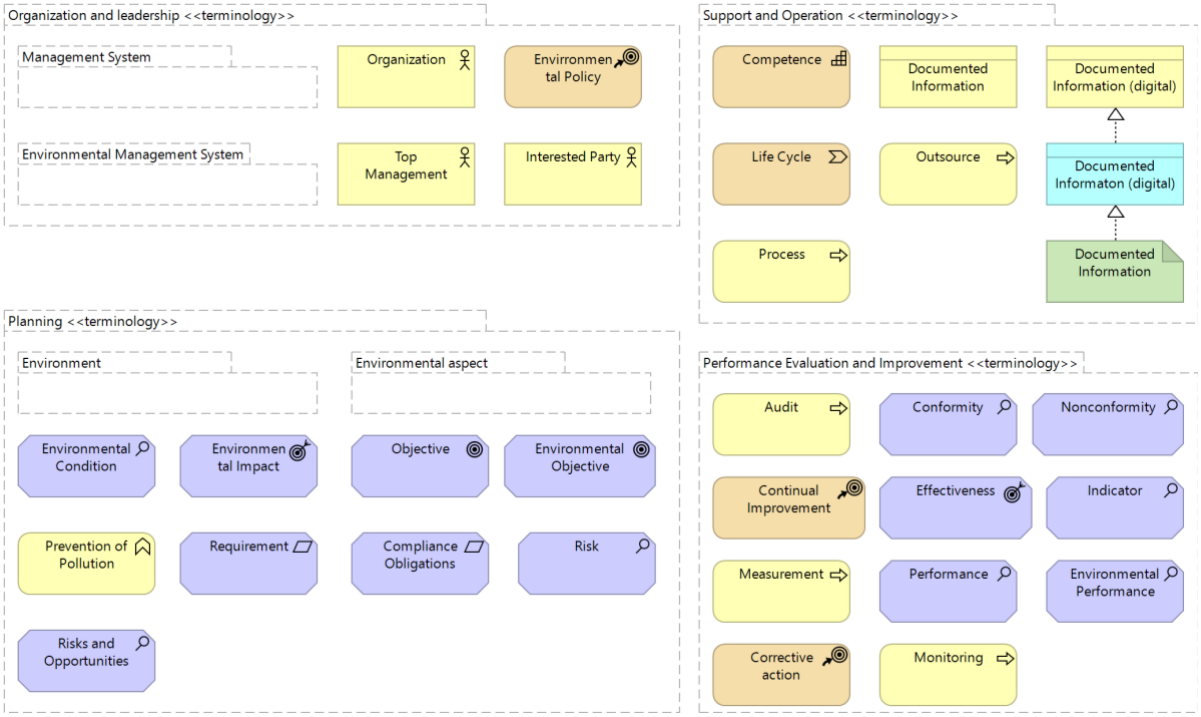


**Figure 5**: Visual representation of the elements in the ArchiMate language

The visual representation of the elements can be seen in fig 5. The elements are grouped into corresponding groups of the ISO 14001 standard:

- Organization and leadership
- Planning
- Support and Operation
- Performance Evaluating and Improvement

## 5. ArchiMate Metamodel Development

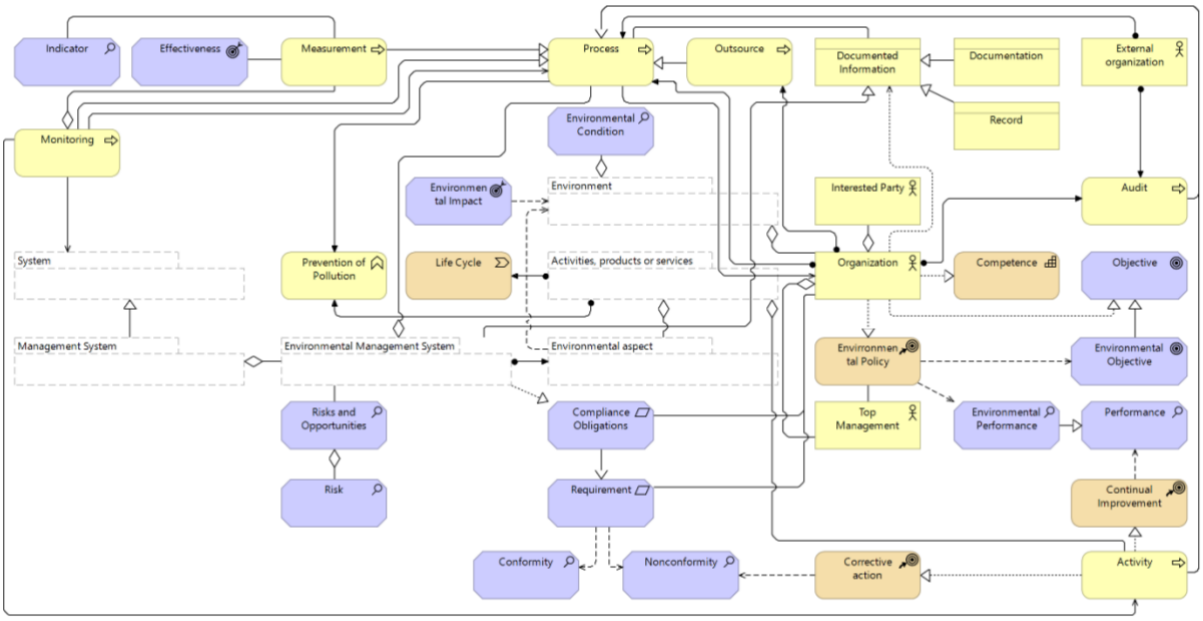


**Figure 6**: ArchiMate metamodel of the ISO 14001

With the finalized mapping, the ArchiMate metamodel of the ISO 14001 is developed (fig. 6). As can be seen, the elements span mainly the strategic and business layers and the motivational aspect. The spatial orientation and position mimic the original UML metamodel, with little changes in the top and the bottom parts of element positioning for a more compact look. Also, the System, Documentation and Records elements and inner grouping of Activities, products, or services are being intentionally omitted. Their addition would visually clutter the presented metamodel in this paper.

If needed, the metamodel could be easily graphically re-orientated. This ability also follows the best practice of enterprise architecture modeling. The rearrangement is helpful because each stakeholder has different concerns; therefore, architects use different viewpoints and corresponding views in practice. The presented layout should be seen as just one of the metamodel graph configurations. The metamodel is then potentially used as an accelerator for the corresponding enterprise architecture's tasks.

## 6. Conclusions

This paper introduced a metamodel for ISO 140001 in the ArchiMate language. The metamodel development took multiple steps starting by creating a domain model in the UML standard. Subsequently, this model was reviewed according to the BWW model. The mapping of UML elements to ArchiMate was then proposed, followed by converting the individual relationships resulting into finalized ArchiMate metamodel.

Although the model is thus verified from a theoretical point of view, it seems more than appropriate to validate this metamodel in practice by ArchiMate language experts and actual users of the ISO 14001 standard who exercise the EMS (in the optimal case, the expert should fulfill both of these criteria. Presented metamodel can be further improved by creating specific viewpoints (a technique in the ArchiMate standard). Also, further exploration of practical usage could be a foundation for developing domain-specific metamodels.

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