EPiC Series in Computing
Volume 107, 2025, Pages 262–271
Proceedings of EUNIS 2025 annual congress in Belfast

# Building a TOGAF based Ontology of HERM

Markus von der Heyde[1+] , Andreas Hartmann[2§]
and Matthias Goebel[3+]
[+] SemaLogic, Weimar, Germany
[§] HTWK, Leipzig, Germany
markus.von.der.heyde@semalogic.de
andreas.hartmann@htwk-leipzig.de
matthias.goebel@semalogic.de

**Abstract**

Integrating ontologies, which structure knowledge for the Semantic Web, Enterprise Architecture Management (EAM) standards such as TOGAF® provide a robust foundation for guiding digital transformation in complex ecosystems. The Higher Education Reference Models (HERM), a widely adopted Enterprise Reference Architecture in higher education institutions, serve as a structured framework worldwide. This paper presents the development of a comprehensive RDF-based ontology for HERM, firmly aligned with TOGAF's Metamodel. It details the ontology's class hierarchies, the challenges of semantic mapping to TOGAF, and the automated transformation process from HERM spreadsheets into RDF representations. The ontology captures English and German terminology, with built-in support for additional languages. All results, including tools and ontology files, are made available via Zenodo, ensuring accessibility and further development within the HERM community.

Keywords: Ontology Engineering, Enterprise Architecture, TOGAF Metamodel, Higher Education Reference Models (HERM), Semantic Mapping, RDF Transformation

## 1 Introduction

In order to facilitate meaningful interactions between humans and machines, knowledge must be represented in a structured, machine-readable format. Ontologies play a crucial role in this process by organising knowledge according to the principles of the Semantic Web, thereby enabling a formalised and interoperable understanding of concepts. Beyond mere syntactic representation, machine-readable

[1] https://orcid.org/0000-0002-6026-082X
[2] https://orcid.org/0000-0003-1340-5325
[3] https://orcid.org/0000-0002-4671-0900

formats must also incorporate semantic interpretation to ensure accurate comprehension of content. By structuring knowledge in this way, ontologies provide a foundation for automated reasoning, interoperability, and enhanced data integration across various domains.

The discipline of Enterprise Architecture Management (EAM) provides standardised methods of planning and structuring the design and construction of complex systems that consist of many different but interconnected elements. The Open Group Architecture Framework (TOGAF) is a widely used Enterprise Architecture Framework (EAF) that provides those methodologies and tools for designing, implementing, and managing enterprise structures. In addition to the Architecture Development Method (ADM), the TOGAF Metamodel defines a structured vocabulary for enterprise-related concepts as well as relationships, ensuring consistency in architectural descriptions. While The Open Group does not provide an official ontology, the community has developed several semantic models to formalise TOGAF concepts, including architecture domains, artefacts, and processes (Gerber et al. 2010). These ontologies establish structured relationships among architectural elements, supporting machine-readable representation and semantic integration within enterprise architecture practices.

A systematic review of Enterprise Reference Architectures (ERAs) has been conducted by Sanchez-Puchol et al. (2017), with the aim of providing an initial overview of standardised architectural description artefacts applicable to specific business domains. The research focused on the characteristics, adoption, design, implementation, and management of ERAs, as well as their overall impact on organisations.

A recent study by Bourmpoulias & Tarabanis (2020) examined the application of Enterprise Architecture (EA) in Higher Education Institutions (HEIs), highlighting key approaches and challenges. The majority of EA practices in education are concentrated at the tertiary level, with a balanced conceptual focus (America and Europe), while research in Asia (mainly Indonesia) has been more oriented towards EA development and strategy.

Furthermore, Sanchez-Puchol et al. (2018) provided an overview of HEI-specific Enterprise Architecture Frameworks, analysing their adoption and long-term viability. Their findings indicate that most Reference Models (RM) were highly specialised and failed to progress beyond initial implementation, with 8 out of 14 cases ceasing development. Meanwhile, the UCISA[4] Capability Model has been integrated into the EA framework maintained by CAUDIT[5], which itself has been extended in recent versions to cover the Application (V3.0) and Technology (V3.1) domains.

With these additions, it appears that this Higher Education Reference Model (HERM) covers most central aspects. It has evolved into the widely accepted and common standard for enterprise architecture in higher education (Nauwerck et al., 2022; Maltusch & Suominen, 2023), and has been adopted by over 1000 institutions worldwide (CAUDIT, 2024). It provides a structured framework for designing and managing the architectural landscape of HEIs. HERM defines four key reference models: Application (ARM), Technology (TRM), Business (BRM) and Data (DRM), each offering a standardised terminology to guide institutional planning and operations. All models are further structured into three hierarchical levels, with the top two levels aligning closely with the organisational/functional structure of HEIs. Developed with a strong orientation toward TOGAF, recent versions of HERM have been refined to align more consistently with the TOGAF Metamodel. However, despite these refinements, a comprehensive ontology of HERM has not yet been established. This paper summarises the work on a TOGAF-based ontology in RDF/Turtle format for the HERM.

[4] Universities and Colleges Information Systems Association, https://www.ucisa.ac.uk

[5] Council of Australasian University Directors of Information Technology, https://www.caudit.edu.au

# 2 Ontology development

Ontology development follows established concepts and methodologies that ensure consistency, interoperability, and alignment with formal knowledge representation principles. The manual construction of an ontology necessitates the collection of abstract and exemplary concepts. The top-down approach commences with high-level abstract concepts, gradually refining them into more specific entities (e.g., foundational ontologies such as Basic Formal Ontology (BFO) by Grenon & Smith (2004) or Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE), as outlined in the overview by Borgo et al. (2022)). Alternatively, the bottom-up approach extracts concepts from existing data sources, such as text corpora or databases, and generalises them into an ontology (e.g., WordNet (Miller et al., 1990s) or DBpedia Ontology (Auer et al., 2007)). In practice, the middle-out approach is also used to combine both approaches, identifying key mid-level concepts first and then refining upwards and downwards.

There are several formal methodologies that have been established to guide ontology engineering in a systematic and structured manner. Ontology Development 101 (Noy & McGuinness, 2001) provides a widely used step-by-step approach for practical ontology creation, while Methontology (Fernández-López et al., 1997) emphasises concept identification, formalisation, and evaluation. In contrast, the NeOn Methodology (Suárez-Figueroa et al., 2012) focuses on reusing and integrating multiple ontologies rather than developing them from scratch.

In addition to manual approaches, semi-automated and fully automated methods have been developed to support ontology creation. Ontology Learning from Text (Cimiano, 2006) applies Natural Language Processing (NLP) techniques to extract concepts and relationships from textual data, enabling automated knowledge structuring. More recent advancements leverage machine learning and knowledge graphs, using embeddings and deep learning to refine and populate ontologies dynamically. An overview of these and more methods has been summarized by ElHassouni & Qadi (2022).

Ontology languages and notation standards have traditionally been standardised to ensure interoperability and consistency in knowledge representation. The Resource Description Framework Schema (RDF/S) provides a simple yet flexible schema for semantic data integration, while the Web Ontology Language (OWL) serves as a W3C standard for formal knowledge modelling. Both of these systems follow the Triple principle of forming a subject-predicate-object constellation to capture the knowledge. Additionally, SHACL and OWL2 Profiles enable constraint validation and logical reasoning, enhancing the expressiveness and applicability of ontologies in the Semantic Web.

The application and combination of these approaches ensures that ontologies are systematically developed, well-structured, and semantically meaningful, supporting interoperability and automated reasoning across various domains.

## 2.1 Converting HERM to RDF

This chapter provides a comprehensive overview of the essential steps required to transform the current HERM into an RDF-based ontology, firmly rooted in TOGAF.

## 2.2 Existing Work

CAUDIT's HERM provided the conceptual material for the ontology, which was presented in the form of spreadsheet tables and additional documentation. The RMs (Application, Business, Data, and Technology) were translated into German. Based on prior work (von der Heyde, 2025), the changes to the Application, Business, and Data models were minimal. The transformation of the TRM was conducted from the beginning.

As The Open Group does not publish TOGAF in RDF using the OWL, a web search revealed several attempts by the community, some of which are outdated. The most recent one captured TOGAF version 9.2, even though the newer version 10 has already been released. Our aim was to identify the most complete RDF-based TOGAF conceptualisation, and we used material from GitHub[6] which also was based on prior work.

Overall, we followed the NeOn Methodology (Suárez-Figueroa et al., 2012), since most of the material existed and our work focused on the consistent alignment of concepts.

## 2.3 Mapping the HERM basic classes

The mapping of the HERM classes of the four core RM was done manually based on the analysis of the existing TOGAF and HERM definitions. To indicate the model context of the RDF terms, we use a colour-coding system: blue for herm_*rm: green for togaf: and grey for any other baseline rdfs: or owl: ontology.

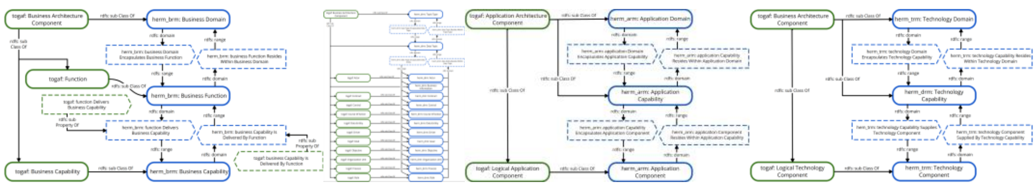

Figure 1: The three levels of the HERMs BRM, DRM, ARM and TRM are modelled using the match to TOGAF concepts. Concept classes are represented by rounded boxes, while dashed arrow-like boxes describe the relationships between them.

As illustrated in Figure 1a, the BRM is anchored in the TOGAF Metamodel. Alongside the generic Business Architecture Component, the togaf: Function and togaf: Business Capability can be utilised to encapsulate the Business Function and Business Capability of HERM. The two corresponding relations between the TOGAF concept can also be adapted to HERM. It should be noted that the Business Domain has no equivalent in TOGAF and therefore the other two relations do not refer to TOGAF concepts.

Figure 1b illustrates the mapping of the DRM to the TOGAF Metamodel. Since Version 3.0 of HERM introduced a mapping of TOGAF-related concepts based on our previous work, we used the corresponding RDF definitions extensively.

As illustrated in Figure 1c, the ARM is anchored within the TOGAF Metamodel. Alongside the generic togaf: Business Architecture Component, the togaf: Logical Application Component can be utilised to encapsulate the herm_arm: Application Component. The relations between the HERM ARM concepts have no equivalent in TOGAF, since the Domain and Capability level do not refer to specialized concepts from the TOGAF Metamodel.

Finally, Figure 1d illustrates the mapping of the TRM. In accordance with the ARM, only the lowest level (herm_trm: Technology Component) can be mapped to TOGAF specifically. The other levels must be rooted using the generic togaf: Business Architecture Component. Furthermore, none of the four relations can be found specifically in the TOGAF Metamodel.

## 2.4 Mapping Class Members

In the four HERMs, the defined items were attributed to the respective classes described in the previous chapter using rdfs: sub Class Of. The unique codes were attributed by terms: identifier and also used as identifiers within the ontology. Where applicable, we used rdfs: label and skos :definition

[6] see https://github.com/cadmiumkitty/togaf-content-metamodel-ontology

as attributing relations for the name of the item and the primary definition. Both were used in English and German, making use of the @en and @de notation.

As illustrated in Figure 2, the conceptual mapping of the HERM ontology for a section of the BRM demonstrates a cascading structure, reflected in the specific relations between the named classes. This could be considered an instantiation of a reference architecture based on the generic concept of the TOGAF enterprise architecture principles. Please note that the Value Chain elements (here: 'Design') were excluded, as explained in more detail in the following paragraph.

The transformation of the text body from the spreadsheet tables to the ontology text containing RDF notations was performed automatically. The tables can easily be adapted to be used for any other language by exchanging the country code from "de" for Germany to "fr" for France for example. The tables (without the actual HERM content) and the resulting ontologies are published on Zenodo for reuse (Goebel et al., 2025).

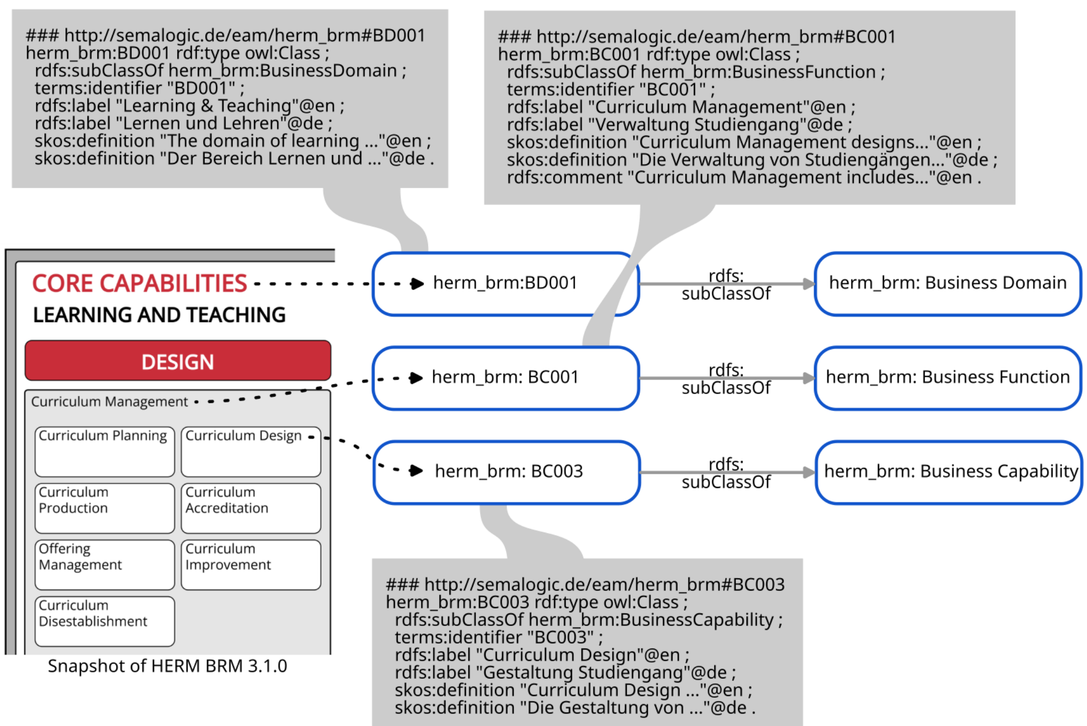


Figure 2: Conceptual mapping of the HERM items to the new ontology. Each item of the BRM is represented by an ontology concept. The classes are defined by the RDF statements shown in the grey boxes.

## 2.5 Limitations and Future Work

The main issues with the proposed mapping are the use of the generic togaf: Business Architecture Component for the grouping „elements" of the four RMs, and consequently the lack of suitable relations. Since the used TOGAF ontology does not offer any generic architectural-based relation, we decided to use the unspecific owl: Object Property for all but the relations between herm_brm: Business Function and herm_brm: Business Capability.

Overall, the work on the ontological details of the RMs has once again highlighted the current lack of service-based representation within HERM. However, a variety of items across the RMs try to compensate for this, and are very close to this perspective. Introducing a consistent service level in HERM will require an emphasis on the differentiation in this respect. Further limitations concern the various RMs in individual manors.

The ARM provides application examples, but please note that the current collection is a mixture of vendors, products, contracts, and service offers. We therefore decided to withdraw from modelling those items in the ontology. In a later version, however, it may be possible to apply the togaf: Physical Application Component definition to those named items and provide further context, e.g. synchronized to a Configuration Management Database (CMDB).

Within the BRM, we excluded the mapping of Value Chain elements for two reasons. Firstly, their primary scope was chosen without relation to TOGAF, which results in a semantic mismatch we wanted to avoid in the ontology. Secondly, the current work in progress focuses on establishing value streams instead, and above the BRM, but in close relation to all four RMs of HERM. In addition, new identifiers were created for the BRM to name the herm_brm: Business Domains (BD001…BD003). Please note that these identifiers may be subject to change as soon as the new release (presumably 3.2) introduces them officially.

As mentioned above, the mapping of the DRM is extensively using the TOGAF mapping introduced in V3.0. However, some parts of the DRM currently do not consequently differentiate business information from simple metadata. Though we keep the ontology consistent with the current HERM, we are proposing a redesign of this mapping in upcoming releases: The usage of Data Entity in HERM covers conceptually all herm_drm: DExxx entries, and, while using the already proposed mapping of items that are not clearly related to other concepts, we reduce the coverage to a few. However, in our opinion it would be much more effective to derive directly from the herm_drm: Business Capability perspective both, the correct usage of logical data entities and the identification of the correct differentiation between business information and metadata. This work will be addressed in later stages of the project and hopefully provide good reasons for improving the DRM. Our aim is to achieve a clearer understanding and conceptual match between togaf: Data Entity and togaf: Logical Data Component.

With regard to the TRM, we also refrained from transferring the provided examples of technologies into the ontology for very similar reasons to those given for the ARM examples. In this case, we would expect a consolidated list of Technology Product Examples to be matched to togaf: Physical Technology Component. We then expect the TRM to be more specific about Technology Components, and where such components will be used within Technical Services.

# 3 Applications

A recent paper proposed the use of formal ontologies to facilitate the generation of EA artefacts (Guerreiro & Sousa, 2023).Their manual classification of concepts by artefact is labour-intensive; however, as they rightly point out, once this mapping is established, the effort required for any subsequent updates can be reduced.

To demonstrate this scenario using the new HERM ontology, automatic text mapping was performed on natural language documents (von der Heyde & Goebel, 2025). In this use case, the ontological defined terms were used with a novel integration of generative and symbolic AI, called "hybrid AI", to extract data from numerous documents describing use cases (Erdmann et al., 2022). The results were visualised using heatmaps and demonstrate the high potential of NLP and symbolic AI for automated, ontology-based text analysis.

In addition, Hartmann et al. (2025) demonstrated the further application of those matching results in a generic, but carefully applied solution architecture. Ultimately, the utilisation of automatic matching for related areas will empower HEIs to ascertain their EA baseline with greater efficiency, as was previously the case. As EA is expected to have a fundamental effect on the digital transformation of HEIs (Gomes et al., 2020; Alghamdi, 2021), the new ontology will help organisations to start and maintain their digital journey.

# 4 Summary and Outlook

Ontologies play a crucial role in the structuring of knowledge for the Semantic Web, while Enterprise Architecture (EA) methodologies, such as included in TOGAF, guide digital transformation in complex ecosystems. The Higher Education Reference Model (HERM) is a globally adopted Enterprise Reference Architecture that supports over 1000 institutions (CAUDIT, 2024). To enhance its usability, we have introduced an RDF-based ontology of HERM, aligned with TOGAF and capturing both English and German concepts. Additionally, we have provided spreadsheet-based tools to facilitate ontology updates and multilingual extensions (Goebel et al., 2025).

The forthcoming HERM 3.2 update is anticipated to implement pivotal structural modifications, encompassing the segmentation of the Business Reference Model into three tiers and the substitution of value chains with a yet to be published value stream approach, integrating all HERM Reference Models to institutional business value. Moreover, the redesign of the Data Reference Model will enhance HERM's relevance. These refinements were made possible through ontological modelling within the TOGAF Standard, demonstrating the value of formalising enterprise architecture concepts.This contribution aims to enhance HERM's usability and support the higher education architecture community.

# Acknowledgements

This work was funded in part by the European Union - NextGenerationEU through the German Federal Ministry of Education and Research (BMBF) as part of the Digital Education initiative under grant number 16NB001. The views and opinions expressed are solely those of the authors and do not necessarily reflect the views of the European Union, European Commission or the Federal Ministry of Education and Research. Neither the European Union, the European Commission nor the Federal Ministry of Education and Research can be held responsible for them.

We would like to thank the reviewers for their constructive feedback on the draft of this paper. This article was written using ChatGPT 4o, Deep-L Write and Google Docs as of February 2025. The statements and wording have been carefully checked to ensure that they are objective and understandable. The authors take full responsibility for the content.

# References

Alghamdi, A. (2021). Enterprise Architecture in Higher Education: Processes, Principles, Challenges, Success Factors and Agility [PhD Thesis, University of Ottawa]. http://dx.doi.org/10.20381/ruor-25981

Auer, S., Bizer, C., Kobilarov, G., Lehmann, J., Cyganiak, R., & Ives, Z. (2007). DBpedia: A nucleus for a web of open data. In: International semantic web conference (pp. 722-735). Berlin, Heidelberg: Springer Berlin Heidelberg.

Borgo, S., Ferrario, R., Gangemi, A., Guarino, N., Masolo, C., Porello, D., Sanfilippo, E. M., & Vieu, L. (2022). DOLCE: A descriptive ontology for linguistic and cognitive engineering. Applied Ontology, 17(1), 45–69. https://doi.org/10.3233/AO-210259

Bourmpoulias, S., & Tarabanis, K. (2020). A systematic mapping study on Enterprise Architecture for the Education domain: Approaches and Challenges. 2020 IEEE 22nd Conference on Business Informatics (CBI), 2, 30–39.

CAUDIT (2024). Higher Education Reference Models (V3.1.0). CAUDIT. https://www.caudit.edu.au/EA-Framework

Cimiano, P. (Ed.). (2006). Ontology Learning from Text. In Ontology Learning and Population from Text: Algorithms, Evaluation and Applications (pp. 19–34). Springer US. https://doi.org/10.1007/978-0-387-39252-3_3

ElHassouni, J., & Qadi, A. E. (2022). Ontology Engineering Methodologies: State of the Art. In M. Lazaar, C. Duvallet, A. Touhafi, & M. Al Achhab (Eds.), Proceedings of the 5th International Conference on Big Data and Internet of Things (pp. 59–72). Springer International Publishing. https://doi.org/10.1007/978-3-031-07969-6_5

Erdmann, S.; Degen, G.; Wisniewski, S.; Peil, R.; Schunder, T.; Dinier, J.; Lehmler, J. (2023). Szenarienübersicht aus dem BIRD-Projekt. Zenodo. https://doi.org/10.5281/zenodo.10075886

Fernández-López, M., Gómez-Pérez, A., & Juristo, N. (1997). Methontology: from ontological art towards ontological engineering. American Association for Artificial Intelligence.

Gerber, A., Kotzé, P., & Van der Merwe, A. (2010). Towards the formalisation of the TOGAF Content Metamodel using ontologies. 12th International Conference on Enterprise Information Systems (ICEIS), Funchal, Madeira, Portugal. ResearchSpace. http://hdl.handle.net/10204/4075

Goebel, M., von der Heyde, M. & Hartmann, A. (2025). A TOGAF based Ontology of the Higher Education Reference Models (HERM) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.14899282

Gomes, R., da Cruz, A. M. R., & Cruz, E. F. (2020). EA in the Digital Transformation of Higher Education Institutions. 2020 15th Iberian Conference on Information Systems and Technologies (CISTI), 1–6. https://doi.org/10.23919/CISTI49556.2020.9141086

Grenon, P., & Smith, B. (2004). SNAP and SPAN: Towards Dynamic Spatial Ontology. Spatial Cognition and Computation. https://doi.org/10.1207/s15427633scc0401_5

Guerreiro, S., & Sousa, P. (2023). A Systematic Approach to Generate TOGAF Artifacts Founded on Multiple Data Sources and Ontology. In T. P. Sales, J. Araújo, J. Borbinha, & G. Guizzardi (Eds.), Advances in Conceptual Modeling (pp. 95–106). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-47112-4_9

Hartmann, A., von der Heyde, M., Nguyen, D., Zimmermann, H. & Lucke, U., (2025). The Architecture of a National Digital Education Ecosystem. EUNIS 2025 Annual Congress, Belfast.

Maltusch, P., & Suominen, E. (2023). Creating strategic and operational insight for management by using a Higher Education Capability model. In J.-F. Desnos & M. López Nores (Eds.), Proceedings of the European University Information Systems Conference 2023 (EPic Series in Computing, Vol. 95, pp. 37–48). EasyChair. https://doi.org/10.29007/4wf1

Miller, G. A. (1990). Nouns in WordNet: A Lexical Inheritance System. International Journal of Lexicography, 3(4), 245–264. https://doi.org/10.1093/ijl/3.4.245

Nauwerck, G., Maltusch, P., Le Strat, V., & Suominen, E. (2022). Towards a sector specific Enterprise Architecture model – introducing HERM. EJHEIT - Good for All in the Digital World, 2022–1. https://www.eunis.org/download/2022/EUNIS_2022_paper_39.pdf

Noy, N. F., & McGuinness, D. L. (2001). Ontology development 101: A guide to creating your first ontology (Stanford knowledge systems laboratory technical report 1–KSL-01-05). Stanford. https://protege.stanford.edu/publications/ontology_development/ontology101.pdf

Sanchez-Puchol, F., Pastor-Collado, J. A., & Borrell, B. (2017). A First Literature Review On Enterprise Reference Architecture. MCIS 2017 Proceedings, 15--34. https://aisel.aisnet.org/mcis2017/15/

Sanchez-Puchol, F., Pastor-Collado, J. A., & Borrell, B. (2018). First in-depth analysis of enterprise architectures and models for higher education institutions. IADIS International Journal on Computer Science & Information Systems, 13(2), 30. http://hdl.handle.net/2117/133634

Suárez-Figueroa, M. C., Gómez-Pérez, A., & Fernández-López, M. (2012). The NeOn Methodology for Ontology Engineering. In M. C. Suárez-Figueroa, A. Gómez-Pérez, E. Motta, & A. Gangemi (Eds.), Ontology Engineering in a Networked World (pp. 9–34). Springer. https://doi.org/10.1007/978-3-642-24794-1_2

von der Heyde, M. (2025). Tools to support the automatic creation of heatmaps in enterprise architecture using HERM (Version 0.4) [Bash]. vdH-IT. https://doi.org/10.5281/zenodo.6411337

von der Heyde, M., & Goebel, M. (2025). Ontology based mapping of HERM. Proceedings of EUNIS 2025 Annual Congress in Belfast. EUNIS 2025, Belfast.

# Author Biographies

Since 2011, Dr. Markus von der Heyde has been advising colleges, universities, and public cultural and research institutions on a wide range of digitalization topics (governance, organization, strategy, research data management, information security, IT service management) as part of vdH-IT, and conducts independent research on these topics. Since 2018, he has been an Adjunct Professor at the School for Interactive Arts and Technology (SIAT) at Simon Fraser University, Vancouver. In 2020, he founded SemaLogic UG to use semantic and structural logic technologies to automatically map and validate natural language regulatory texts.

Prof. Dr.-Ing. Andreas Hartmann is a professor of Applied Computer Science with a focus on distributed applications and their security at HTWK Leipzig. Prof. Hartmann’s research interests lie in the fields of enterprise architecture, IT architecture and IT governance, digital transformation, cloud infrastructures, and IT security. He is the chair of the faculty's examination board and a member of organizations such as The Open Group, EUNIS, ZKI, and CIO e.V. In teaching, he offers courses on web technologies, distributed applications, complex systems, digitization, and IT architecture management.

Matthias Goebel has been active in numerous IT projects for the introduction or optimisation of SAP systems and SAP-based applications since 2000. For more than 10 years he managed the SAP divisions of various companies with regard to the company-wide SAP strategy and architecture. Application-related focal points are enterprise application integration, programme and DB-based performance optimisation, data warehousing and the redesign and modification of digitally supported processes.