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Article

Research on Model-Based Systems Engineering Approach for Information Technology Standard System Planning

Yangyang Zhang [1], Xiuming Yu [1], Xiaojian Liu [2,*], Jianxun Guo [1], Wenyuan Zhang [1] and Can Zhang [1]

[1] China Electronics Standardization Institute, Beijing 100007, China; zhangyy@cesi.cn (Y.Z.)
[2] College of Computer Science, Beijing University of Technology, Beijing 100124, China
* Correspondence: liuxj@bjut.edu.cn

Abstract

Planning an information technology (IT) standard system requires balancing multiple complex factors. These include industrial chain layout, technological iteration, practitioner application scenarios and cross-domain integration. Such planning demands high industrial adaptability, technical foresight and implementation operability, yet mature and systematic methods are currently lacking in this field. To address this issue, this paper proposes a Model-Based Systems Engineering (MBSE) approach for IT standard system planning by integrating complex system decomposition and integration principles. A multi-perspective (industry, practitioner, business, product, standard) and multi-view (industrial chain, practitioner, product, technical process, management process, standardization object, standard) modeling framework is constructed, and an MOF-based meta-model system for each view is designed to realize full-process visual modeling from industrial ecosystem analysis to standard system implementation. As a conceptual and methodological study, this approach makes up for the perspective limitations of traditional planning methods. Multi-view hierarchical and collaborative analysis ensures the standard system to be in line with industrial reality with foresight and operability, providing systematic methodological support for standard-setting organizations, industrial alliances and enterprises in the IT field, and expanding the application boundary of MBSE in standard system planning.

Keywords: standard system; model-based systems engineering; multi-perspective modeling; multi-view modeling; KARMA

1. Introduction

Planning a standard system in the information technology domain requires balancing multiple complex factors, including industrial chain, technological iteration trends, practitioner scenarios, and cross-domain business integration needs. It must align with the collaborative development realities of the industrial ecosystem while also considering the forward-looking nature of technology applications and the operational feasibility of standard implementation. This presents numerous difficulties and challenges. Firstly, the rapid evolution of technologies and the incessant emergence of new technologies have engendered uncertainties in technical pathways. This renders the task of standard planning a delicate balancing act between foresight and pragmatism. The lagging of standards will impede industrial development, while the adoption of overly advanced standards may hinder progress. Secondly, in-depth cross-domain integration means that information technology intersects extensively with multiple fields such as industrial manufacturing, finance, and healthcare. The significant differences in business scenarios and technical

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requirements across various fields have made it far more difficult to develop standards that cater to diverse scenarios. Third, the complex hierarchy of the industrial chain, spanning from hardware equipment and software to services and applications, involves multiple stakeholders, including suppliers, demanders, regulators, and third parties, each with distinct demands. Balancing the interests of multiple parties to achieve full-chain coordination through a standard system is no easy task. The interplay of these factors has rendered the planning of standard systems in the information technology field an extremely complex systems engineering endeavor.

As an effective methodology for addressing complex system problems, systems engineering emphasizes a holistic perspective to conduct comprehensive analysis and optimization of a system's elements, structure, functions, interrelationships, and environment. The Model-Based Systems Engineering (MBSE) further enables digital representation, analysis, and verification of complex systems by establishing multi-dimensional models, providing strong support for system planning, design, implementation, and management. As one of the core technologies of MBSE, multi-view modeling can construct multiple complementary view models based on different concerns of a complex system, thereby comprehensively depicting the diverse characteristics of the system.

Essentially, the standard system in the information technology field is a complex system involving industrial chain coordination, business process support, technical process implementation, and management mechanism guarantee. Therefore, it is theoretically well-founded to introduce the concepts of systems engineering and multi-view modeling for its scientific planning. To meet the needs of planning and designing information technology standard systems, this study proposes an MBSE approach. This approach is applicable to the planning and design of standard systems in the information technology field, tailored to various application scenarios and technical characteristics, such as industrial software standard systems, software engineering standard systems, and artificial intelligence standard systems. By constructing a multi-view modeling framework (covering the industrial chain view, practitioner view, product view, technical process view, management process view, standardization object view, and standard view), the approach systematically illustrates the target domain from the dimensions of industrial ecosystem, stakeholders, business scenarios, product components, technical processes, and management processes. Subsequently, through the correlation and cross-analysis between various views, it derives and infers standardization objects and standard requirements. This multi-view collaborative modeling approach breaks the locality and one-sidedness of traditional standard planning, comprehensively covering the industrial background, business requirements, technical implementation, and management demands of a standard system. This approach aims to make up for the perspective limitations of traditional planning methods, enabling end-to-end visual modeling and collaborative optimization of the standard system from industrial ecosystem analysis to implementation.

Theoretically, this study expands the application scope of MBSE in the field of standard system planning and enriches interdisciplinary research on complex systems modeling and standard system theory. Practically, it provides a systematic and intuitive standard system planning methodology for standardization organizations, industry alliances, and enterprises in the information technology sector. Based on multi-perspective modeling, this approach incorporates industry development trends and technological iteration directions derived from industrial chains, practitioners, business operations, and products as core inputs for standardization objects and standards modeling. This endows the resulting information technology standard system with foresight. Furthermore, the modular design of the multi-view framework allows relevant views to be modified and iterated independently to address changes in technology roadmaps, industrial chain models, or business scenarios.

Through logical connections between various viewpoints, dynamic updates to the standard system are achieved. This dynamic adjustment mechanism avoids the need for complete reconstruction of the standard system due to localized changes, enabling the standard system to dynamically adapt to industrial development. Consequently, this approach assists stakeholders in constructing a well-structured, highly collaborative, forward-looking, and dynamically adaptive IT standard system, thereby more effectively supporting the industry's innovation development, ecosystem collaboration, and market competitiveness.

The remainder of this paper will focus on this multi-view modeling framework, elaborating on the modeling content, approach, and interrelationships of each view. Combined with a case study, it will further analyze the specific application of the approach in the planning of the "industrial software standard system", thereby providing a complete research demonstration of the MBSE for information technology standard system planning.

2. Related Works

With the growing complexity of modern industrial systems—characterized by extended industrial chains, interdisciplinary technological integration, and diversified stakeholders—existing research has gradually exposed problems such as a single perspective and insufficient coordination. Most current standard system planning adopts a linear hierarchical structure, while the depiction of relationships overlooks cross-cutting collaboration. For example, the vertical hierarchical division of "foundation-key technology-application" emphasizes the vertical connection between standards but neglects the horizontal correlation of standards across different fields and relationships. To address these research gaps, the integration of systems engineering theory with standardization work has attracted increasing attention [1–3]. These studies have initially explored the application of MBSE in standard system construction, and verified the feasibility of MBSE in solving the complexity of standard system planning through case studies in manufacturing and energy and environmental engineering fields. However, they only realize the primary migration of MBSE basic methods to the standard system field, and lack the construction of domain-specific multi-perspective/multi-view modeling framework and standardized meta-model system for the characteristics of IT field with rapid technological iteration and in-depth cross-domain integration. In view of this research gap, this study constructs an MBSE-based multi-perspective modeling framework and multi-view collaborative modeling method specially adapted to IT standard system planning, and designs the MOF-based meta-model system for each view, which forms a complete and operable methodological system for the application of MBSE in IT standard system planning, and further enriches and improves the research results of MBSE in the field of standard system planning.

Established MBSE frameworks including INCOSE, MagicGrid and IBM Harmony have formed systematic theoretical and methodological systems for complex system modeling, with core focuses on the digital modeling, verification and iterative optimization of engineering systems, industrial products and enterprise business systems. Their common design logic of "holistic decomposition–multi-dimensional modeling–cross-view collaboration" provides the core theoretical reference for this study. This study introduces the systems engineering theory of multi-view modeling into standard system design and constructs a "multi-view integrated standard system architecture" based on multi-view modeling tools, breaking the limitations of a single perspective and achieving full-dimensional element coverage.

The concept of multi-view modeling originated from the field of enterprise information system architecture in the 1980s, with its core driving force being to resolve the problem of "cognitive differences in systems among different stakeholders". In 1987, the Zachman Framework proposed by John Zachman [4] marked the systematic emergence of multi-perspective modeling. Its core idea is to depict complex systems through multiple complementary perspectives to achieve a comprehensive understanding of the system. After the 1990s, the TOGAF Architecture Framework put forward by The Open Group [5] built on the Zachman Framework and solved the challenges of integrating and visualizing multi-perspective information. During the same period, the DoDAF Framework proposed by the U.S. Department of Defense [6] applied multi-perspective modeling to military systems. Through the coordination of operational views, system views, and technical views, it achieved precise matching between operational requirements and technical implementation, further expanding the application scenarios of multi-perspective modeling. Since the 21st century, multi-view modeling theory has been deeply integrated with Model-Driven Engineering (MDE) and complex system theory. The Unified Architecture Framework (UAF) [7] is an integrated and optimized framework developed upon the aforementioned framework, further enhancing the integration and synergy of operational, system, and technical views in complex system modeling. UAF inherits the core concept of multi-perspective modeling for complex system architecture description. Its modeling system offers greater comprehensiveness in addressing multi-domain requirements alignment and system implementation for large-scale complex systems. Consequently, it is widely applied in architecture design for defense systems, major engineering projects, and other complex systems domains demanding high levels of cross-domain coordination and hierarchical management.

Zachman, TOGAF, DoDAF, and UAF prioritize holistic architecture design for complex systems as their core objective, without tailored customization for the planning characteristics and core requirements of standardized systems. They lack specialized modeling dimensions and element designs dedicated to exploring standardized objects, hierarchical construction of standardized systems, and dynamic adaptability in standard implementation. Consequently, they cannot achieve end-to-end modeling spanning from industrial ecosystem analysis to the implementation of standard system.

The ISO/IEC/IEEE 42010:2011 standard [8] first standardized the definitions of "perspective" and "view" at the international standard level, clarifying that a perspective provides construction specifications for a view, and a view is the instantiation result of a perspective, laying the foundation for the standardized application of multi-perspective modeling. With the development of complex system theory, multi-view modeling has gradually expanded from its initial application in enterprise information system design [9,10] to various fields such as industrial planning and systems engineering [11–13]. When the complexity of a system to be modeled exceeds a specific threshold, multi-view modeling becomes a commonly used method [14]. Its core lies in decomposing the overall model into multiple "views", where each view focuses only on specific aspects of the system while ignoring irrelevant content. For instance, in enterprise architecture, managers focus on the achievement of business goals, while technical personnel pay attention to the feasibility of technical views, enabling precise description that meets the needs of different stakeholders [15]. Moreover, each view corresponds to an exclusive "perspective", which allows humans and machines to interact with the modeled object from multiple dimensions [16]. Drawing on this multi-perspective and multi-view model, the proposed approach designs differentiated perspectives and modeling elements targeting the diverse concerns of different stakeholders in standard system construction, realizing accurate description and collaborative connection of various concerns and improving the scientificity of the standard system.

3. Methodology

According to ISO/IEC/IEEE 42010:2011, perspectives represent the core review dimensions for experts/practitioners across different fields in standard system planning. Views represent concrete modeling aspects derived from the decomposition of each perspective, embodying the logical framework of perspectives through tangible modeling expressions. These two elements form a hierarchical relationship of top-level logical framework and concrete modeling implementation.

3.1. Multi-Perspective Modeling Framework

Characterized by rapid technological iteration, in-depth cross-domain integration, and complex industrial chain hierarchies, the planning and design of standard systems in the information technology field have become an extremely complex systems engineering endeavor. The "indivisibility" and "cognitive limitations" of complex systems determine that a single perspective cannot fully depict the essence of the system. Integrating MBSE with the complex system decomposition and integration ideology of systems engineering, this study adopts a strategy of "focusing on specific dimensions from separate perspectives and achieving synergy across multiple perspectives". It decomposes the complex system of information technology standard systems into multiple complementary dimensions of concern, and then achieves systematic cognition through the correlation and integration among these dimensions, thus providing a scientific analytical framework for standard system planning.

For a target industry or domain, this study constructs a multi-perspective modeling framework consisting of the industry perspective, practitioner perspective, business perspective, product perspective, and standard perspective, as illustrated in Figure 1. Each perspective focuses on the industrial demands of a specific dimension relatively independently. It also forms a complete depiction of the "standardization object" through implicit logical correlations. This achieves full-dimensional coverage, from industrial ecosystems to product components and from organizational roles to the standards themselves. The modeling and methodology implementation of each perspective rely on the cross-domain collaboration of corresponding experts, including industrial ecosystem specialists, user organization experts, business process experts, functional architecture experts, and standardization experts. Based on the modeling results from their respective perspectives, experts from various fields conduct cross-perspective discussions. They verify the logical consistency and completeness among different perspectives and identify conflicts and gaps between them. Ultimately, through the collaborative integration of multi-perspective models, they comprehensively analyze the standardization requirements and potential optimization directions of the target industry domain. This provides multi-dimensional and verifiable decision-making basis for the systematic planning of standard systems.

- **Industry perspective**: Industrial ecosystem experts focus on the systematic characteristics of the industrial chain, conduct in-depth analysis of the hierarchical structure, subject interaction modes, and industrial development trends of the industrial chain, clarify the industrial collaboration scenarios that the standard system needs to support, and define the coverage boundaries and collaboration requirements of the standard system at the industrial ecosystem level.
- **Practitioner Perspective**: Industry practitioners start from the micro-dimension of roles, deconstruct the responsibility boundaries, capability requirements, and typical working scenarios of organizational roles within the target industry/domain, extract the direct application requirements of standards from different roles, and ensure that the standard system is aligned with the actual practical work scenarios of roles in the organization.

- **Product Perspective**: Product experts focus on the technical implementation dimension of products, product components, or services, decompose their functional module composition, interactive interface design, and technical performance requirements, clarify the supporting logic such as interface compatibility and functional interoperability that need to be guaranteed by standards at the functional level, and identify the implementation foundation of the standard system at the technical implementation layer.
- **Business Perspective**: Business process experts take the full cycle of business operations as the research object, disassemble the process nodes, activity logic, and input–output relationships of core businesses, identify the key points that need to be standardized in business links, and establish functional support points for the standard system at the business level.
- **Standard Perspective**: On the basis of the above perspective modeling, standardization experts systematically sort out potential standardization objects such as product-related, process-related, and management-related ones from the top-level design dimension of the standard system, plan the classification framework and hierarchical relationships of the standard system, and provide a systematic blueprint for the hierarchical division, category integration, and mutual recognition mechanism design of the standard system.

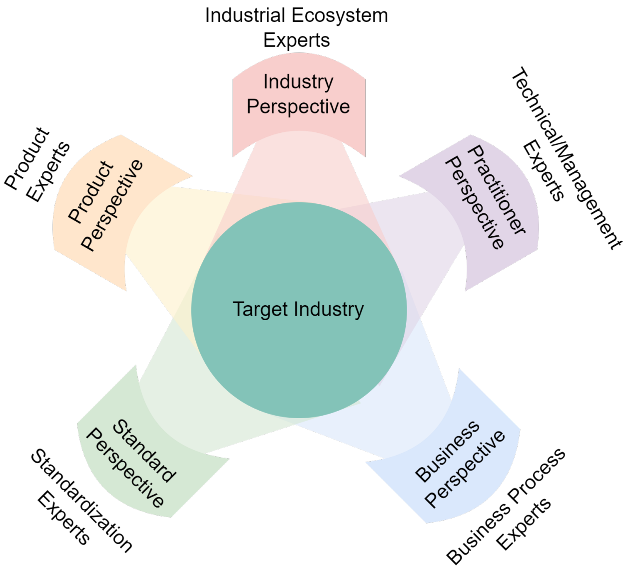

Figure 1. Multi-perspective modeling framework.

This multi-perspective collaborative methodology breaks the cognitive limitations of a single domain. Through the systems engineering idea of "dividing to conquer and integrating to optimize", it provides an analytical framework with both depth and breadth for the planning of information technology standard systems. It ensures that the standard system is not only rooted in the industrial ecosystem and aligned with business needs, but also forms a closed loop in terms of function realization, user application, and the inherent logic of standards themselves, ultimately supporting the scientificity and systematicness of the standard system.

3.2. Multi-View Collaborative Modeling

Building on the multi-perspective modeling framework, this study further designs a multi-view collaborative modeling approach, which decomposes each perspective into specific views, including the industrial chain view, practitioner view, product view, technical process view, management process view, standardization object view, and standard view. Through information flow and logical verification between the various views, a complete chain from industrial ecosystem analysis to standard system implementation is established. This ensures that the planning of the standard system is not only forward-looking and collaborative at the industrial level, but also operable at the business, technical, and management levels, ultimately forming a standard system with clear hierarchy, close correlation, and strong support.

The main modeling content of each view and the relationship of information flow and logical verification between views are shown in Figure 2:

- **Industrial Chain View**: From the industry perspective, this view models the upstream and downstream ecosystem of the industrial chain, depicting the roles and business relationships of industrial chain participants such as suppliers, demanders, regulators, and third parties, as well as the supply–demand relationship of products/services. It defines the industrial boundaries of the standard system, clarifies the collaboration logic of industrial entities, and serves as a top-level abstraction for the practitioner view, product view, technical process view, and management process view.
- **Practitioner View**: From the practitioner perspective, this view models the specific role relationships and responsibilities (e.g., managers, technical engineers, operation and maintenance personnel) of each entity in the industrial chain view. As the executors of various businesses, it provides modeling clues for decomposing and modeling business scenarios in the technical process view and management process view.
- **Product View**: From the product perspective, this view models the component and interaction relationships of products/services, clarifies the functional module capabilities and interface specifications that need to be supported by standards, and also provides modeling clues for the technical processes involved in the research and development of specific products/services.
- **Technical Process View**: From the business perspective, this view targets technology-related business scenarios, focuses on the technical implementation activities of products/services, and models the objectives, responsible parties, inputs/outputs, and activity tasks of technical processes.
- **Management Process View**: From the business perspective, this view focuses on management-related business scenarios, centers on the management support activities at the organizational level, and models the objectives, responsible parties, inputs/outputs, and activity tasks of management processes.
- **Standardization Object View**: From the standard perspective, using the products/services and business activities modeled in the product view, technical process view, and management process view as clues, this view sorts out potential standardization objects and the correlation between these objects across different dimensions. The industrial chain view, practitioner view, product view, technical process view, and management process view together constitute the source of standardization requirements. The standardization object view identifies the standardizable elements from these requirements and converts them into a specific standard list in the standard view.
- **Standard View**: From the standard perspective, this view conducts cross-mapping analysis of product/service, technical, and management standardization objects and their correlations modeled in the standardization object view, forming specific standard classifications and a standard list. It thus completes the transformation from standardization requirements to the final standard system.

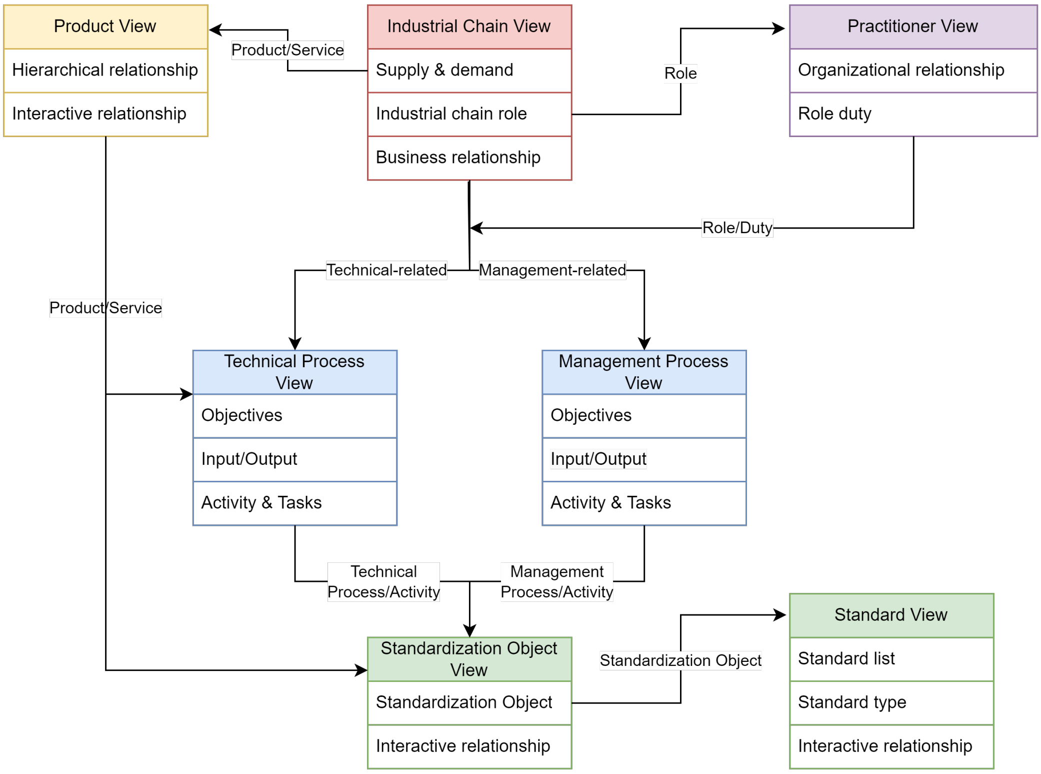

Figure 2. Multi-view collaborative modeling.

4. Multi-View Modeling Approach

4.1. MOF-Based Modeling Mechanism

The Object Management Group (OMG) has formulated the Meta Object Facility (MOF) with a classic four-layer metadata architecture (physical entity layer M0, model layer M1, meta-model layer M2, meta-meta model layer M3), which provides a standardized modeling framework for the formalization of complex system models. On the basis of this mature MOF architecture, this study innovatively defines a customized modeling mechanism for information technology standard system planning (as shown in Figure 3), with the core novel contribution lying in the adoption of the GOPPRR meta-meta model [17] for M3 level modeling. This is a key design tailored for the characteristics of standard system planning, which distinguishes our work from general MOF-based modeling applications.

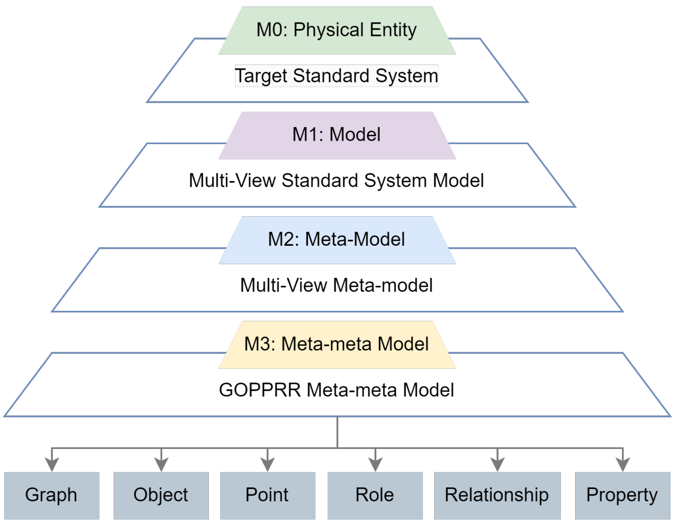

Figure 3. MOF-based modeling mechanism.

The GOPPRR meta-meta model includes six categories of core elements (Graph, Object, Point, Role, Relationship, Property), and we apply these six elements as the fundamental abstraction basis to construct the dedicated meta-model system for standard system planning. The targeted design logic for each GOPPRR element in our research is as follows: (1) *Graph*: the topological container and visual modeling canvas; (2) *Object*: the class elements in the graph; (3) *Point*: the input/output ports of the object; (4) *Role*: the elements generated after object instantiation; (5) *Relationship*: the connections between roles; (6) *Property*: the attributes of objects, relationships, and roles. For M2 modeling, the unified modeling language KARMA [18] is adopted, which supports the formal modeling of meta-models and models as well as model transformation. For details refer to Section 4.2.

4.2. Multi-View Meta-Model Design

We designed a set of view-specific metamodels that conform to the GOPPRR meta-meta model defined in Section 4.1. Each metamodel corresponds to one view in the multi-view framework, namely the industrial chain view, practitioner view, product view, technical/management process view, standardization object view, and standard view. These metamodels specify the required modeling elements and their relationships for formalizing each view, but reuse the basic definitions of Graph, Object, Point, Role, Relationship, and Property from the GOPPRR meta-meta model to maintain consistency. By instantiating the unified meta-meta model into view-specific metamodels, a systematic and coherent modeling support for the whole process of IT standard system planning is formed. Table 1 presents the count of designed meta-models.

Table 1. The count of designed meta-models.

Meta-Meta Model	Graph	Object	Point	Relationship	Role	Property
Count of meta-models	7	8	2	9	17	14

4.2.1. Industrial Chain View Meta-Model

The industrial chain view models the upstream and downstream ecosystem of the industrial chain from the industry perspective, with a focus on depicting the various roles in the industrial chain and the supply–demand business relationships. The main meta-model elements of the industrial chain view are illustrated in Figure 4. Three object meta-models—*Actor*, *Business*, and *Product*—along with their corresponding attribute meta-models are designed to describe the roles in the industrial chain as well as the two types of supply–demand elements: business and product. Three relationship meta-models—*Supply*, *Demand*, and *Correlation*—are designed to characterize the supply–demand relationships between businesses, products and industrial chain roles, as well as the correlation among supply–demand elements.

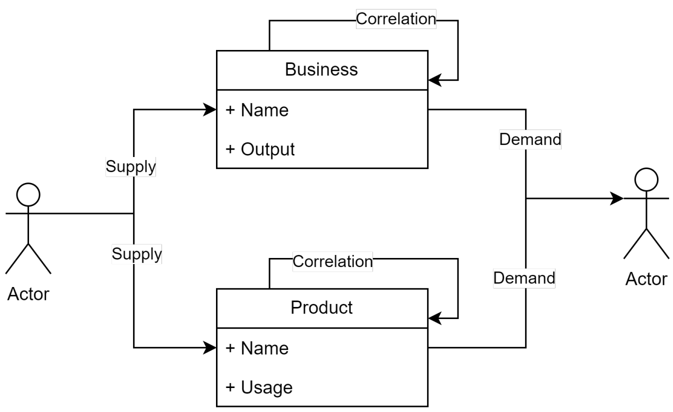

Figure 4. Industrial chain view meta-model design.

4.2.2. Practitioner View Meta-Model

The practitioner view takes *Actor*, the specific element in the industry, as the core object meta-model (e.g., technical engineers, managers, operation and maintenance personnel), and is paired with the *Duty* entity meta-model to sort out the responsibility system corresponding to different roles. The main meta-model elements are shown in Figure 5. The *Duty* meta-model includes three attribute meta-models: *Name*, *Output*, and *ProcessDescription*, which specify the specific work content of practitioners. The *Actor* and *Duty* are associated through the *Correlation* relationship meta-model, describing the responsibilities undertaken by practitioners; the *Categorize* relationship meta-model is applied between Duty elements to realize the classification of responsibilities.

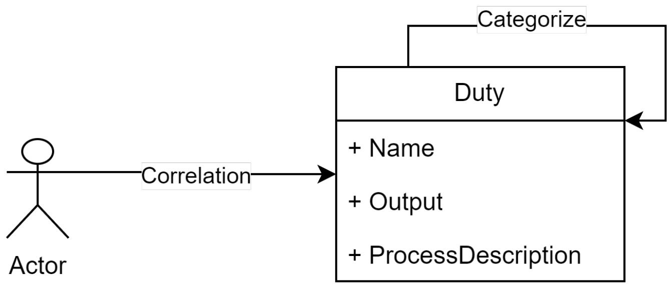

Figure 5. Practitioner view meta-model design.

4.2.3. Product View Meta-Model

The product View takes *Product/Service* as the core object meta-model, and defines its attribute meta-models such as *Name* and *Usage*, as well as point meta-models including *Input* and *Output*, to clarify the basic characteristics of products/services. The relationship meta-models are as follows: *Actor* is associated with *Product/Service* via the *Correlation* meta-model, modeling the association logic between roles and products/services; *Product/Service* elements are classified through the *Categorize* meta-model to support the hierarchical modeling of component relationships; the *ObjectFlow* meta-model is used between the *Input* and *Output* point meta-models to model the object flow among products/services, depicting the interaction relationships and interface requirements. The main meta-model elements of the product view are presented in Figure 6.

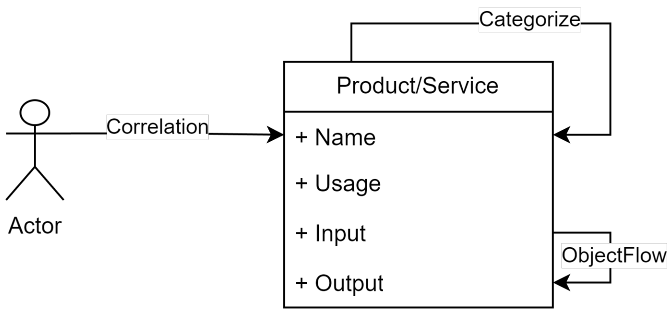

Figure 6. Product view meta-model design.

4.2.4. Technical/Management Process View Meta-Mode

The technical process view models technical-related process activities, focusing on the technical implementation activities of products/services; the management process view models management-related process activities, focusing on the management support activities at the organizational level. Both views are dedicated to modeling process activities, and thus their meta-model designs are consistent. The technical/management process view takes *Activity* as the core object meta-model, and defines its attribute meta-models such as *Name*, *Goal*, *PersonInCharge*, and *ActivityContent*, as well as point meta-models including Input and Output. The relationship meta-models consist of two types: *ControlFlow* illustrates the control logic between *Activity* elements, supporting the modeling of process timing and dependency relationships; ObjectFlow characterizes the object flow between Activity elements, reflecting the transfer relationships of resources and outcomes in the process. The main meta-model elements of the technical/management process view are shown in Figure 7.

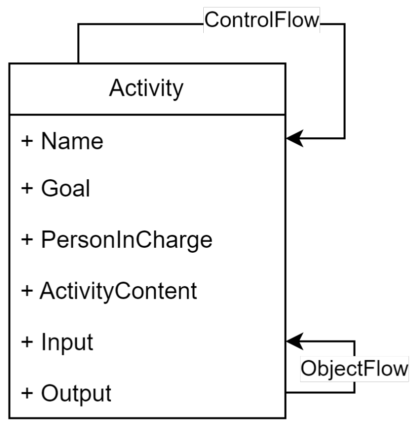

Figure 7. Technical/management process view meta-model design.

4.2.5. Standardization Object View and Standard View Meta-Model

The main meta-model elements of the standardization object view and the standard view are illustrated in Figure 8, with details as follows:

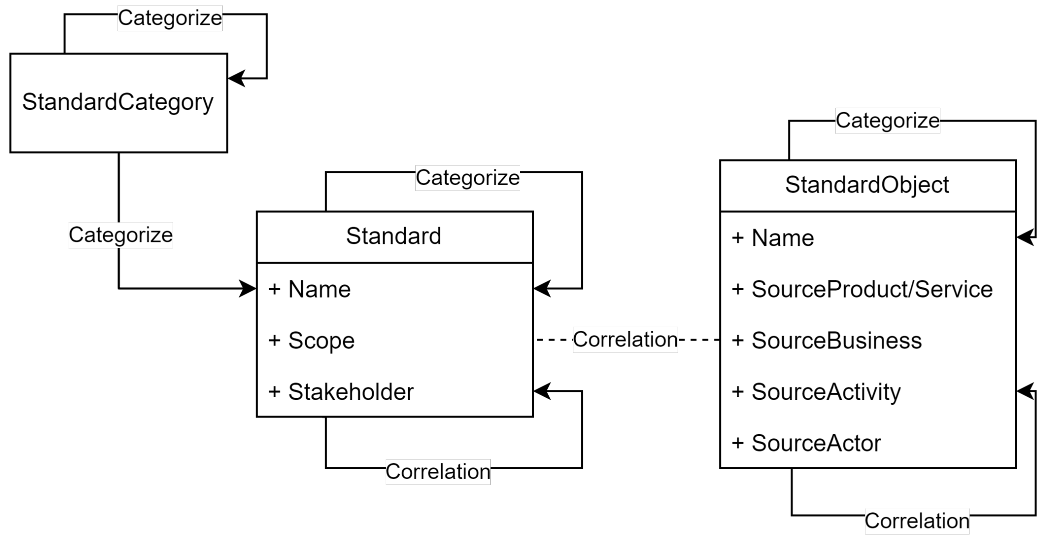

Figure 8. Standardization Object and Standard view meta-model design.

The standardization object view takes *StandardObject* as the core object meta-model, and defines its attribute meta-models including *Name* and four major demand sources: *Product/Service* (corresponding to *product* elements), *SourceBusiness* (corresponding to *business* elements), *SourceActivity* (corresponding to *technical/management process* and *activity* elements), and *SourceActor* (corresponding to *Actor* elements). This design realizes the unified sorting of standardizable elements across all views. Meanwhile, *StandardObject* elements are classified via the *Categorize* relationship meta-model, and the *Correlation* relationship meta-model is used to depict the association relationships between standardization objects across different dimensions, laying the foundation for demand integration.

The standard view takes *Standard* as the core object meta-model, and defines its attribute meta-models such as *Name*, *Scope*, and *Stakeholder* to specify the core information of standards, while establishing an affiliation relationship with the *StandardCategory* object meta-model. The relationship meta-models include two types: the *Categorize* relationship meta-model associates with *StandardCategory* to achieve the classified management of standards; the *Correlation* relationship meta-model associates *StandardObject* with itself to realize the cross-mapping association of related standardization objects. The modeling of the standardization object view and the standard view ultimately generates an implementable standard list, supporting the closed-loop construction from standardization requirements to the standard system.

4.3. Multi-View Modeling Approach

The core of the proposed modeling approach for standard system planning lies in the hierarchical relationship and cross-perspective collaboration of eight views. Following the systems engineering philosophy of "dividing to conquer and integrating to optimize", it achieves systematic industry analysis and standard system construction, as illustrated in Figure 9.

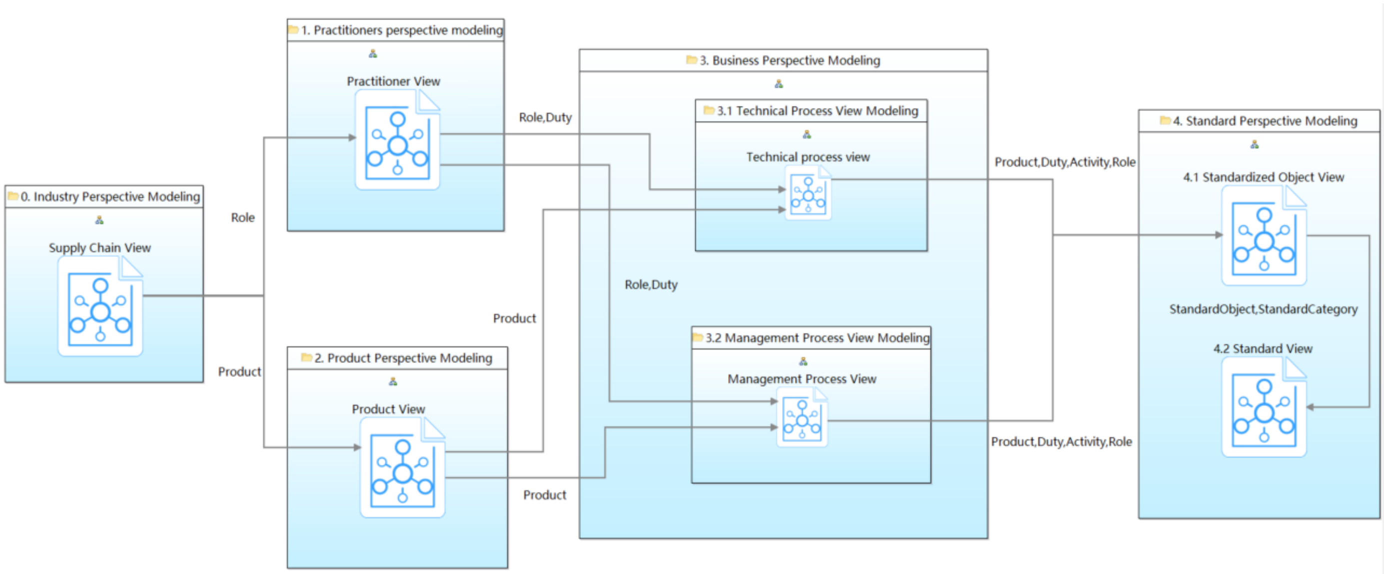

Figure 9. Multi-view modeling approach.

First, industrial ecosystem experts depict the roles (including suppliers, demanders, and regulators) and supply–demand relationships from the industry perspective, clarify the collaboration logic of industrial entities, and establish a top-level abstract model to define the boundaries for other views. On this basis, functional architecture experts and business experts decompose the product/service components and business responsibilities within the industry from two dimensions—the product perspective and the practitioner perspective (i.e., "human" and "object"). Then, in the business perspective, the product/service models from the product view and the business responsibilities from the practitioner perspective are cross-mapped and refined into various business scenarios. These scenarios are then modeled separately in the technical process view and the management process view in terms of activity tasks, rights and responsibilities, as well as inputs and outputs, thus achieving closed-loop decomposition of "scenario-process". On the basis of the above perspective and view modeling, standardization experts sort out potential standardization objects and their correlations across products, technologies, management, and personnel from the perspective of "standardizable elements", and build the standardization object view. Finally, through the modeling of the standard view, these objects are mapped into specific standard classifications and lists, completing the transformation from standardization requirements to the implementation of the standard system.

5. Case Study

To verify the scientific validity and practical feasibility of the proposed approach, we implemented the theoretical approach into operable modeling practice by virtue of the Airdraw modeling tool built on the unified modeling language KARMA [18]. The tool enables the multi-perspective modeling framework covering the industry perspective, practitioner perspective, business perspective, product perspective, and standard perspective, as well as the meta-model system corresponding to the industrial chain view, practitioner view and other views. This achieves full-process visual modeling capabilities ranging from requirement decomposition to standard implementation. This case selects industrial software as the research object, which is a typical field featured by rapid technological iteration, in-depth cross-domain integration, and complex industrial chain hierarchies. It conducts targeted research focusing on the standardization pain points of CAD software, thus completing the systematic planning of the CAD software standard system. The constructed standard system not only fully covers the full-dimensional requirements of CAD software spanning technical implementation, business application, and industrial collaboration, but also realizes the vertical connection and horizontal coordination between standards through the multi-view collaboration mechanism. It effectively addresses the problems of single-perspective and insufficient coordination in traditional standard systems, and verifies the operability and feasibility of the proposed approach in IT standard system planning. This work provides solid standard support for technical interoperability, ecological coordination, and large-scale innovation in the CAD software industry.

5.1. Industrial Chain View Modeling

The industrial chain view mainly focuses on describing the systematic characteristics of the industrial ecosystem, and is generally constructed by industrial ecosystem experts. In the industrial software scenario, the modeling of the industrial chain view centers on the research and development and application of industrial software. It identifies three types of roles—suppliers, developers, and application developers—as well as categories of industrial software products, including research and development and design, production and manufacturing, and operation and management software. On this basis, three core relationships—Supply, Demand, and Correlation—are used to connect various modeling elements, establishing a complete value transmission chain from software and hardware supply, to industrial software development, and then to industry application.

This modeling clearly presents the functional positioning and supply–demand relationships of various elements in the industrial chain, and intuitively restores the full-process collaboration logic of industrial software from supply support to application implementation. It provides a concrete basis for the standard connection and collaborative adaptation of all links in the industrial chain during the planning of the CAD software standard system. The modeling of the industrial chain view for industrial software is shown in Figure 10. As a top-level abstraction, the industrial chain view defines the industrial boundaries for subsequent views such as the practitioner view and product view.

5.2. Practitioner View Modeling

The practitioner view is mainly dedicated to describing the responsibility boundaries, capability requirements, and working scenarios of various practitioners, and is generally developed by the practitioners themselves. In this case study, developers and industry applicators are taken as examples for separate modeling.

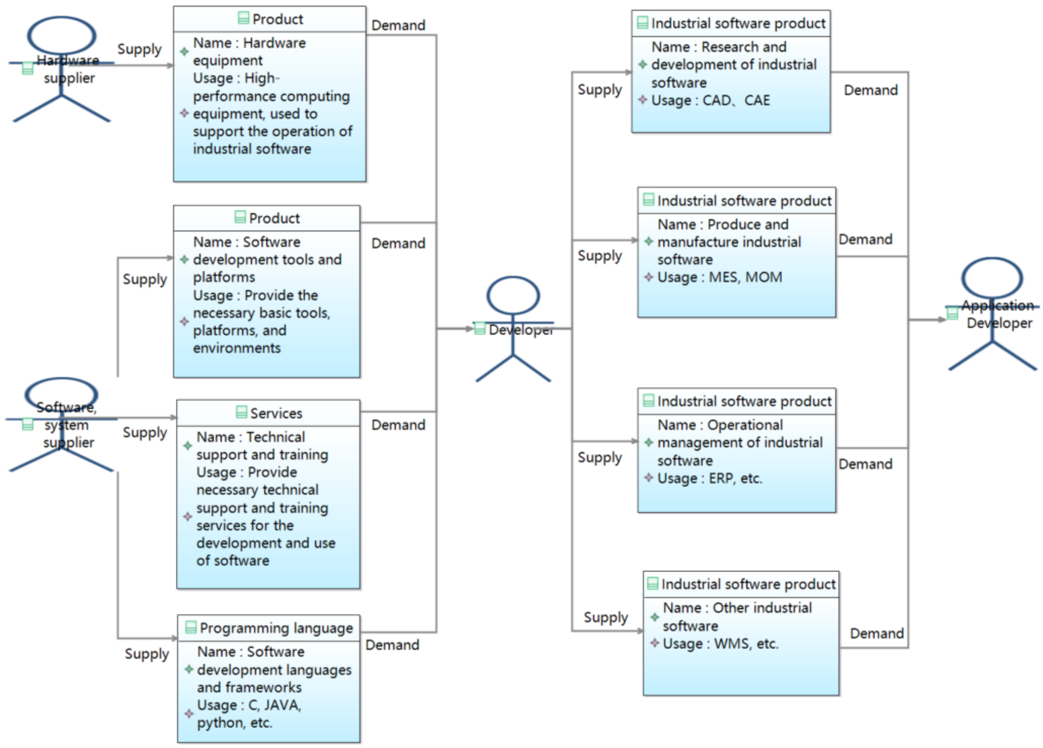

Figure 10. Industrial chain modeling for industrial software.

As shown in Figure 11, the practitioner view for developers models specific roles in industrial software development scenarios, including architects, development engineers, and test engineers, along with their corresponding responsibilities, work scenario descriptions, and work outputs. As shown in Figure 12, the practitioner view for industry users models the roles, responsibilities, work scenario descriptions, and work outputs of designers, managers, and software trainers involved in industrial software application scenarios.

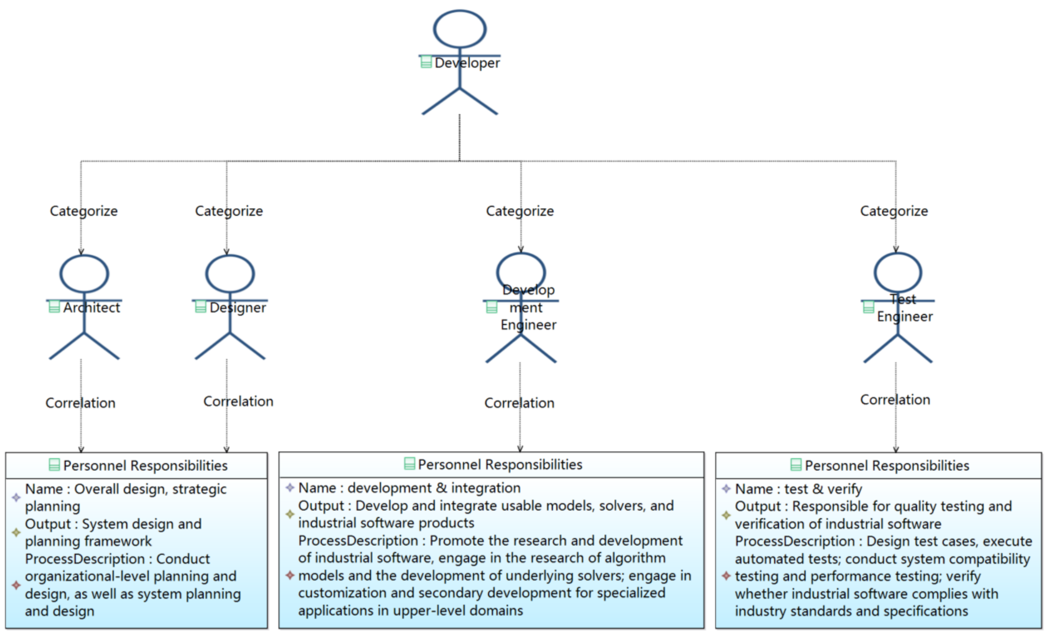

Figure 11. Practitioner view modeling for developers.

Targeting the core roles defined in the industrial chain view, the practitioner view completes the role refinement and systematic analysis of job responsibilities from an independent perspective. It clarifies the specific requirements of practitioners when undertaking resources from suppliers, the core tasks involved in industrial software product development, and the collaboration boundaries with other stakeholders. This transforms the abstract "practitioner" roles in the industrial chain view into a concrete responsibility system. By decomposing job responsibilities, the practitioner view builds a bridge connecting the "macro industrial chain logic" and "micro execution standards". It provides a framework for further analysis of the technical process view and management process view, and also offers a precise basis for formulating practitioner capability standards and workflow standards in subsequent standard system planning. This ensures that the standard system not only aligns with the collaborative needs of the industrial chain, but also possesses the practicality for on-the-ground implementation.

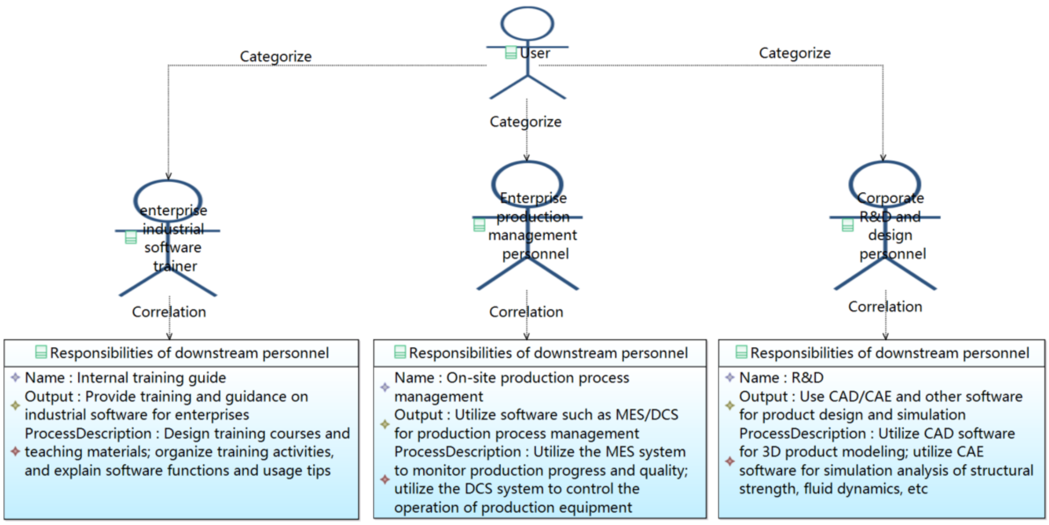

Figure 12. Practitioner view modeling for industry users.

5.3. Product View Modeling

The product view targets the core product elements modeled in the industrial chain view, focusing on modeling the affiliation relationships and functional interaction relationships of products. In this case study, typical categories of industrial software—including research and development and design, production and manufacturing, and operation and management software—are taken as examples to model the representative products and core functions of each category. The modeling of research and development and design industrial software products is shown in Figure 13, that of production and manufacturing industrial software products in Figure 14, and that of operation and management industrial software products in Figure 15.

The product view serves as a detailed analysis of the supply–demand product elements in the industrial chain view. With full-chain supply–demand collaboration as its core, the industrial chain view regards "industrial software products" as the key elements connecting supply and demand. Focusing on this critical element, the product view completes classification refinement and attribute decomposition from an independent perspective, clarifying the category division, core functional boundaries, technical characteristics, and applicable scenarios of industrial software products. This transforms the abstract "product elements" in the industrial chain view into a concrete product system. By refining the product standards and functional requirements on both the supply and demand sides, the product view not only ensures the completeness and accuracy of product element descriptions in the multi-view architecture, but also provides the demand source for formulating product technical standards and functional standards in subsequent standard system planning.

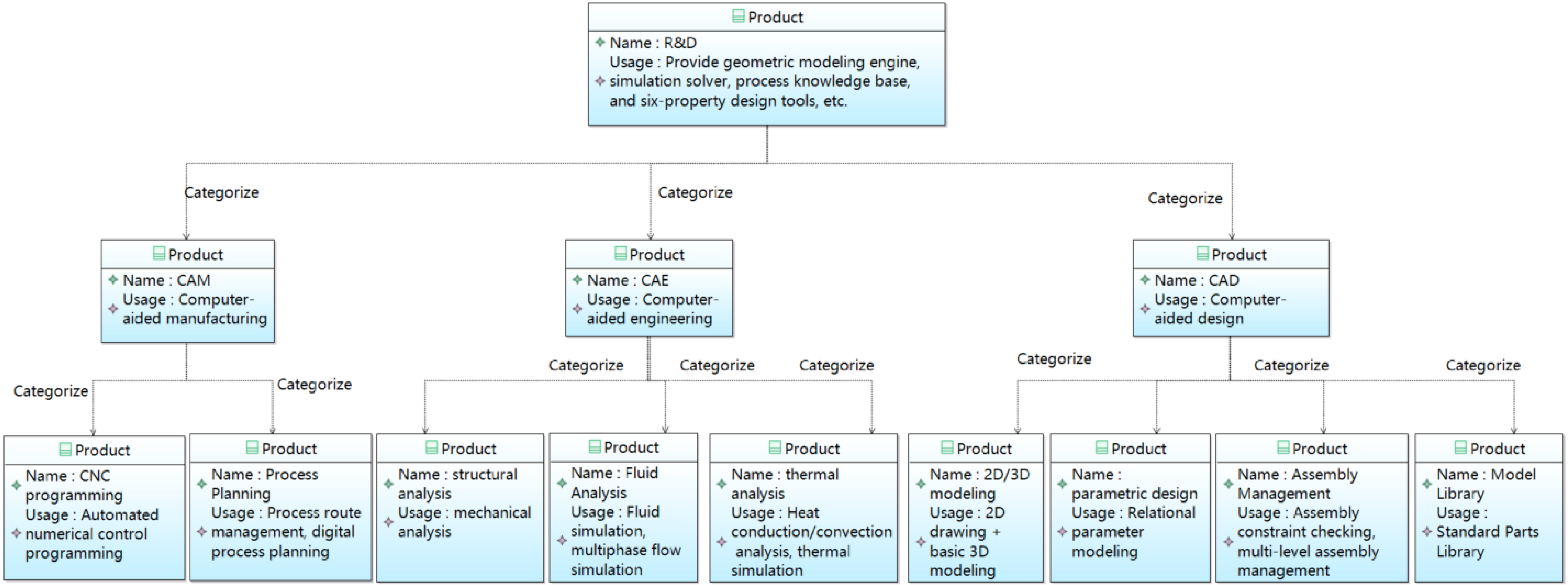

Figure 13. Modeling of research and development and design industrial software products.

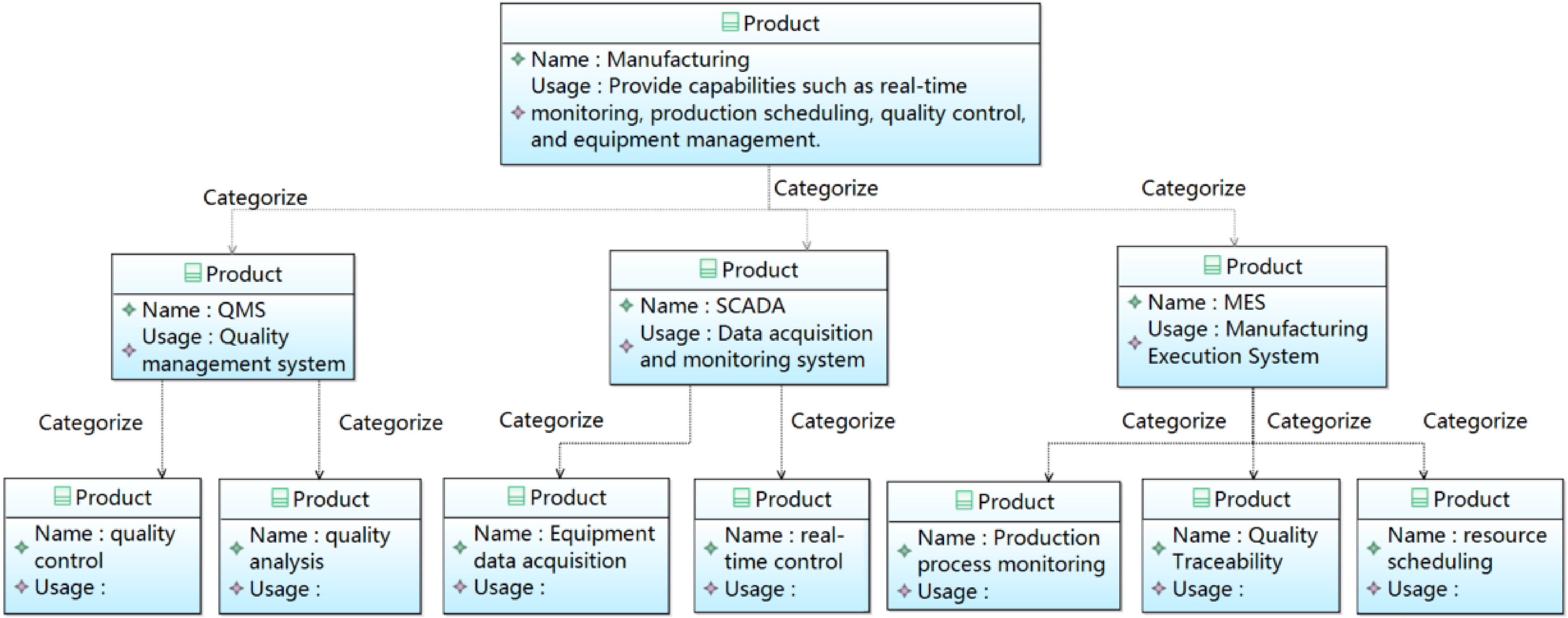

Figure 14. Modeling of production and manufacturing industrial software products.

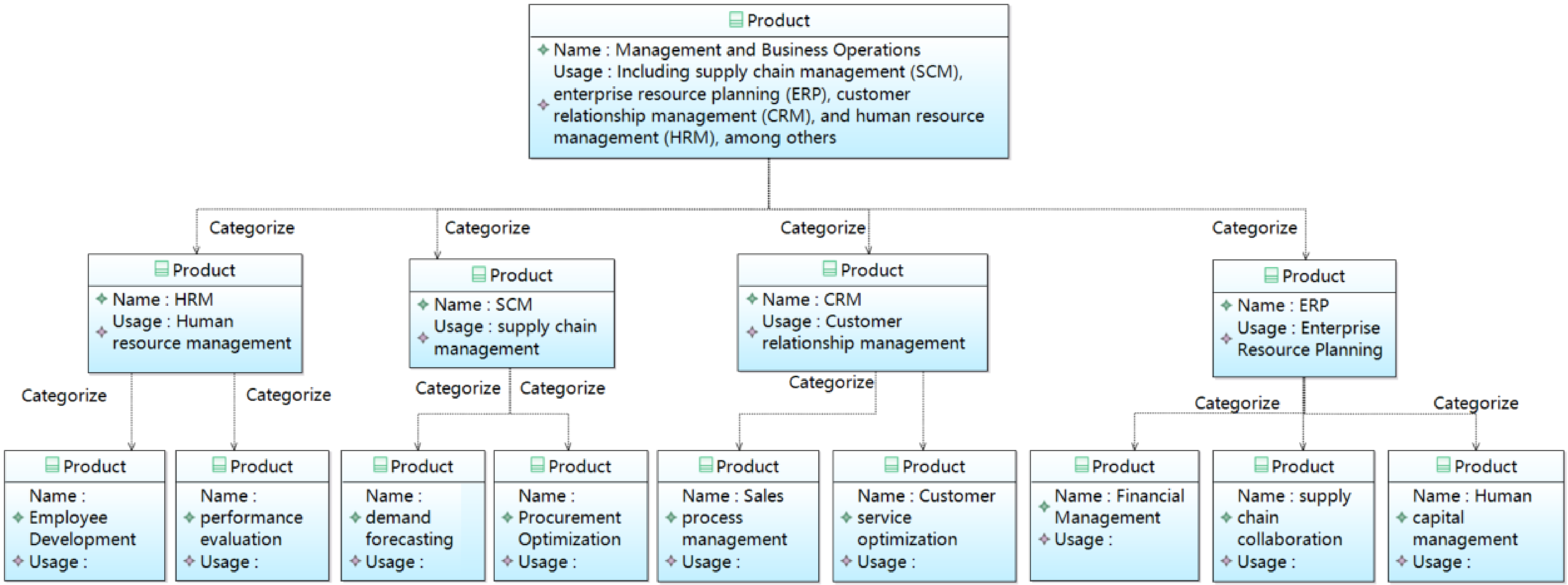

Figure 15. Modeling of operation and management industrial software products.

5.4. Technical and Management Process View Modeling

The business perspective mainly analyzes the technical and management processes of various businesses in the industry, decomposing the process nodes, activity logic, and input–output relationships of core businesses. It can generally be considered from two dimensions: technical processes and management processes. In this case study, we referred to the standardized trends of the system life cycle process [19]. The modeling of the life cycle processes of industrial software is presented in Figure 16. On the basis of the life cycle modeling in Figure 16, specific processes are further refined and modeled as needed; for instance, the modeling of the development technical process is shown in Figure 17.

The process view represents a further decomposition and refinement of the business elements and job responsibilities defined in the industrial chain view and practitioner view. It converts the abstract business processes in the industrial chain view and the job responsibilities in the practitioner view into concrete activity chains and task flows, providing precise process-dimension basis for the subsequent sorting of standardization objects and construction of the standard system.

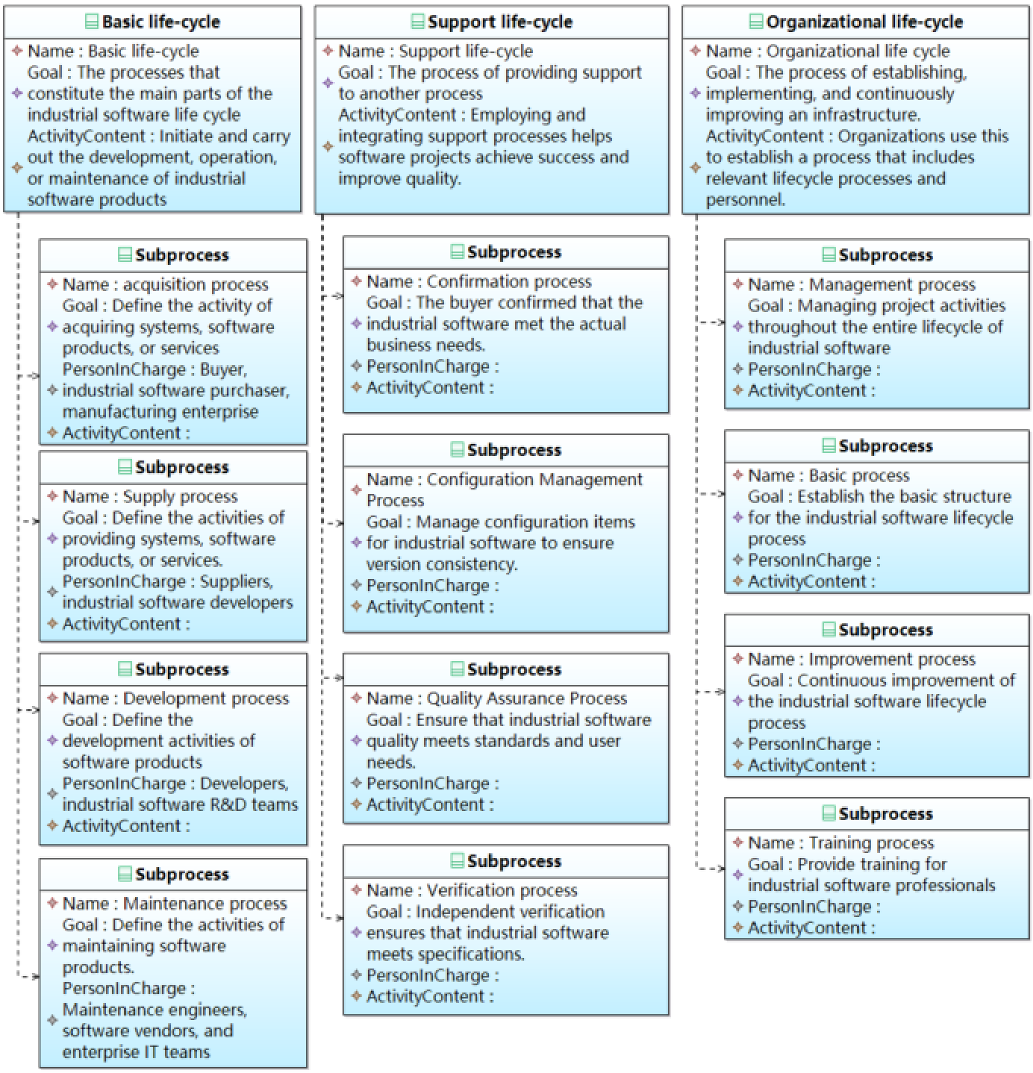

Figure 16. Modeling of the life cycle processes of industrial software.

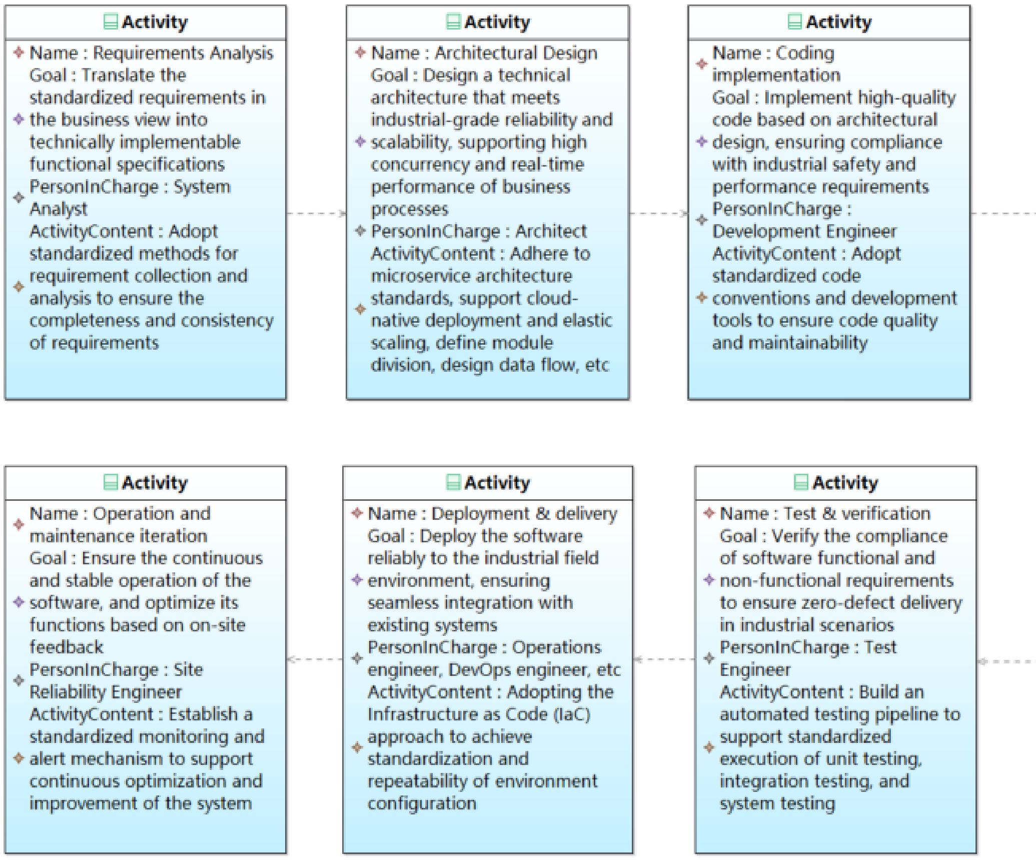

Figure 17. Modeling of the industrial software development technical process.

5.5. Standardization Object View Modeling

The standardization object view serves as the core hub connecting the upstream multi-views and the downstream standard system. Based on the modeling results of the industrial chain view, practitioner view, product view, and technical/management process view, standardization experts sort out and extract standardizable elements for modeling. In this case study, we have identified multi-dimensional standard objects within CAD based on multi-view modes, encompassing industrial application, product, and technology. CAD industrial application and product standardisation object modeling is shown in Figure 18. Technology standardisation object modeling is shown in Figure 19.

During the modeling process, the industrial chain view, practitioner view, product view, and technical/management process view together constitute the source of standardization requirements. "Standardizable" elements are identified from these requirements, and the demand source of each standardization object is clarified, such as *SourceProduct* corresponding to the product view, *SourceActivity* corresponding to the technical/management process view, and *SourceActor* corresponding to the practitioner view. On this basis, standardization objects are divided into four categories: general functions, core functions, industry-specific applications, and process management. These categories cover key objects, including CAD general data exchange, geometric modeling, industry-specific interface specifications, and configuration management, with the correlation between different categories of standardization objects depicted in detail.

The core value of this view lies in the systematic integration of requirements from all upstream views. It transforms scattered business demands, technical requirements, and practical work needs into concrete, standardizable core objects. This not only ensures the comprehensiveness and accuracy of standardization requirements, but also provides a direct basis for the classified construction and logical correlation of the standard system in the subsequent standard view, realizing the transformation from multi-dimensional requirements to standardization implementation.

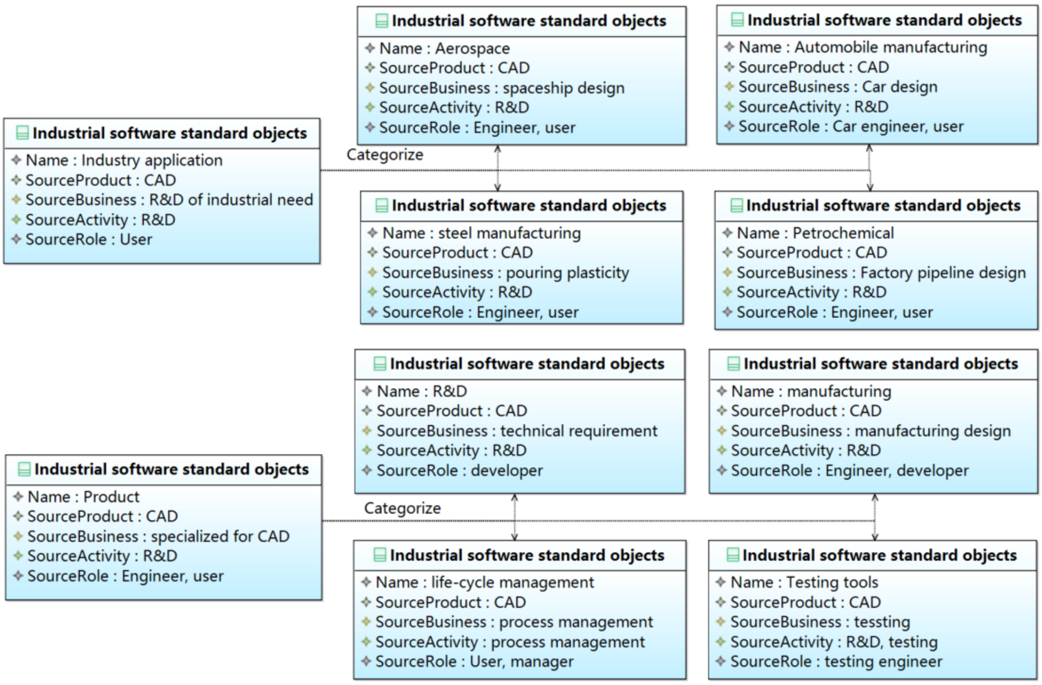

Figure 18. Modeling of the CAD Industrial Applications and Product Standardization Objects.

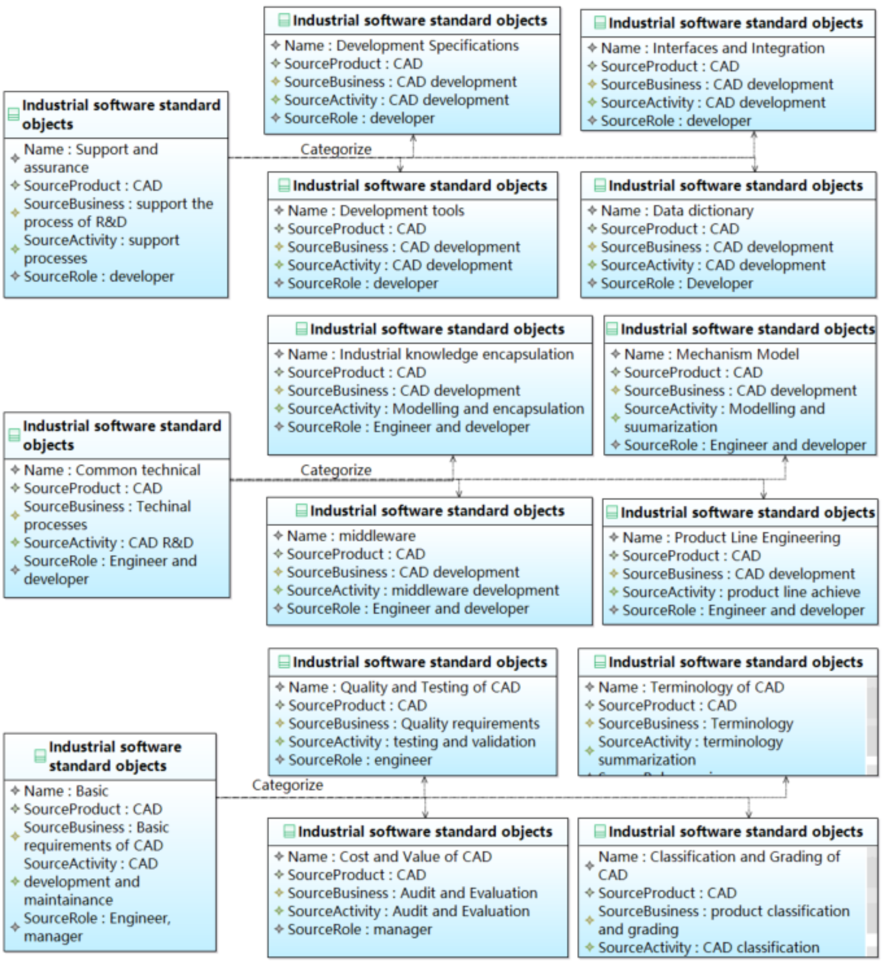

Figure 19. Modeling of the CAD Technology Standardization Objects.

5.6. Standard View Modeling

With the standardizable elements sorted out in the standardization object view as the core input, the standard view focuses on the classification framework, hierarchical relationships, and mutual recognition mechanism of the standard system. Led by standardization experts, it ultimately constructs a CAD software product standard system structured as "Basic standards–General standards–Specialized standards", as shown in Figure 20:

- General standards serve as specialized guidelines for resolving diverse issues arising during the development, deployment, integration, and operational maintenance of CAD software. They provide technical support and assurance for product research and development implementation. These standards primarily encompass common technological categories such as industrial knowledge encapsulation and middleware, alongside supporting elements including interfaces, data dictionaries, and implementation and operational maintenance frameworks.
- Specialized standards are professional specifications designed to deepen understanding of product characteristics and promote the in-depth application of relevant products across various industries. The formulation of specialized standards should fully consider the application patterns and characteristics of different products in diverse scenarios, providing reference guidelines for product development and user application. These primarily encompass sub-category standards for product development and design, production control, operation and maintenance services, alongside various industry-specific application standards.

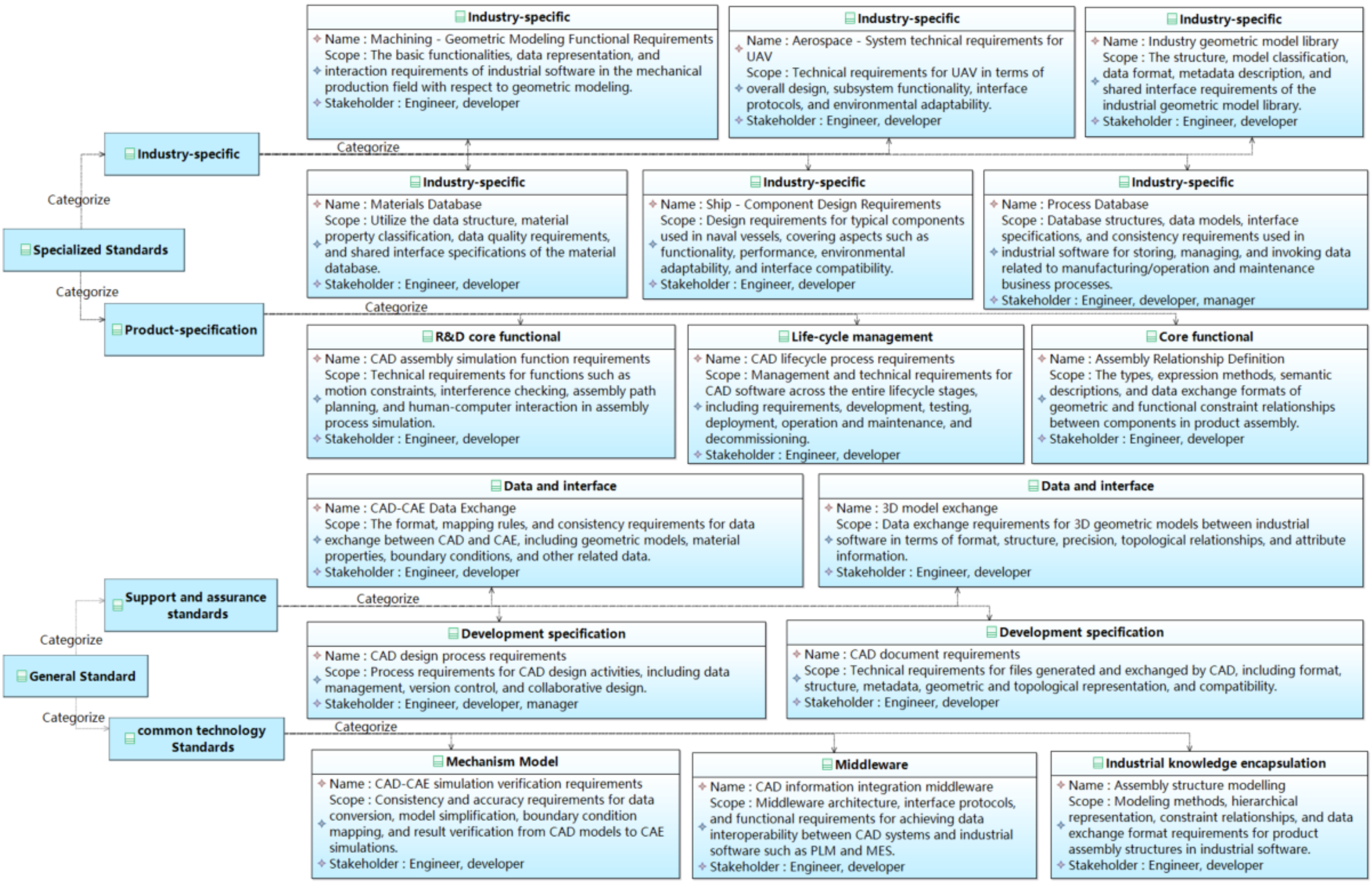

Figure 20. Modeling of the CAD Standard System.

The hierarchical classification of standards is realized through the *Categorize* relationship, and the collaborative correlation between different types of standards is depicted via the *Correlation* relationship, forming a logically rigorous and comprehensively covered CAD software product standard system. Through the vertical connection and horizontal coordination between standards, the modeling of this view ensures that the standard system is not only aligned with industrial reality, but also equipped with foresight and operability. It thus provides systematic standard support for technological research and development, industrial collaboration, and large-scale application of CAD software products.

6. Discussion

6.1. Practical Value

The present study proposes a multi-perspective and multi-view modeling framework. This framework addresses the challenges of conventional IT planning, which arise amid rapid technological evolution, extensive cross-domain integration, and intricate industrial chain structures. This framework facilitates a comprehensive visual modeling process, encompassing industrial ecosystem analysis and standard system implementation. The practical value is verified in the CAD software standard system planning case. In the actual application of the CAD case, the multi-perspective approach can break down cognitive limitations and information barriers, leading to the integration of information across different viewpoints. For example, in the CAD case, if the product perspective is missing, the resulting standards framework will lack standardization objects and requirements specific to the product. Such requirements cannot be addressed by other perspectives, as they lack the necessary understanding of this dimension. The situation is similar to having no product experts in the standards system planning team. The planning risks posed by this situation are obvious.

In our approach, based on the MOF meta-model mechanism and KARMA language, a practical methodological system has been constructed. This is a logical closed loop from demand mining to the sorting of standardization objects and further to the construction of standard system, which improves the systematicness and operability of standard planning. Concurrently, the modeling concepts of each perspective formulated within the CAD software case can furnish a reusable operational reference for standard system planning in disparate information technology domains. Moreover, they can offer methodological support to standard-setting organizations, industrial alliances and enterprises to execute top-level design of standard systems.

6.2. Generalizability and Scalability

The core framework and metamodel proposed in this paper are both constructed based on the common requirements for standard system planning within the information technology domain. They demonstrate strong generalizability and transferability across sub-domains such as artificial intelligence, software engineering, and industrial internet. When applied to different fields, no structural adjustments to the metamodel are required; only targeted domain modeling needs to be conducted in conjunction with the specific industrial characteristics and standardization needs of each field. The five perspectives and seven views established by this methodology comprehensively cover the core dimensions of the entire process in IT standard system planning, from industrial ecosystem analysis to standard implementation. This aligns with the core logic of standard system planning across all IT subfields. Furthermore, based on the MOF mechanism and the GOPPRR meta-model system, the meta-model design adopts a generalized architectural approach. The CAD field modeling represents merely one instance of this meta-model application. When applied to other sub-domains, the core architecture remains unchanged. Only the implementation and refinement of domain-specific modeling are required. During domain modeling, granularity can be flexibly adjusted according to each domain's industrial chain complexity and standardization focus points.

6.3. Core Differences from Traditional Methods

The fundamental distinctions between this approach and traditional standard planning methods in the field of information technology are primarily reflected in two aspects: design logic and implementation means. In terms of design logic, traditional planning mostly adopts a linear hierarchical design idea, focusing on the vertical correlation between standards. However, it is difficult to take into account the horizontal coordination across domains and industrial chain links. In contrast, this approach combines vertical hierarchical connection and horizontal cross-domain coordination of the standard system through multi-view collaborative modeling and information flow. This combination is more adaptable to the multi-subject and multi-scenario demands in complex fields. In terms of implementation means, traditional planning is dominated by document-based descriptive design, lacking dynamic analysis and visual verification means. This approach relies on visual modeling tools to realize the digital modeling of the whole standard planning process, facilitating the collaboration of all participants and the iterative adjustment of models, thus improving the planning efficiency. It is important to acknowledge that this approach does not constitute a negation of conventional planning methodologies; rather, it is a methodological optimization and supplementation for planning issues in complex scenarios. The fundamental principles of this approach are consistent with the tenets of systematicness, coordination and applicability as they pertain to standard system planning. Furthermore, the application of traditional methods in complex scenarios is expanded through this approach.

6.4. Limitations

This study has successfully completed the framework construction and case demonstration of the MBSE approach for information technology standard system planning. However, it still has certain limitations that need to be improved in subsequent research. Initially, it is evident that the verification scenarios of the approach are relatively singular. The demonstration of the application is exclusively conducted using CAD software in the industrial software domain as the object, and no prior experimentation has been undertaken in disparate subfields of information technology. Consequently, the cross-domain adaptability of the approach necessitates further validation. Secondly, the identification and sorting of standardization objects in the modeling process is primarily reliant on the expertise of specialists in various domains, with no integration of intelligent technology to facilitate demand mining. Consequently, there is a necessity to enhance the efficiency and accuracy of identification when confronted with substantial demands and highly intricate scenarios.

7. Conclusions and Future Work

Focusing on the complexity and urgency of standard system planning in the information technology field, this study proposes an MBSE multi-view modeling approach. Through theoretical construction, approach design and case verification, a complete demonstration from methodology to practical implementation has been accomplished. The proposed approach effectively addresses the pain points of single-perspective and insufficient coordination in traditional standard system planning. We define collaboration boundaries from the industry perspective, clarify practical work requirements from the practitioner perspective, consolidate technical foundations from the product perspective, anchor functional support from the business perspective, and coordinate system architecture from the standard perspective. This achieves full-dimensional coverage of the standard system elements. Information flow and logical verification between various views ensure that the standard system is deeply aligned with industrial reality, business needs, and technical implementation. The modeling approach based on the MOF mechanism and KARMA language provides standardized and visual technical support for standard system planning.

Case verification in the industrial software field shows that the proposed approach has significant practical value. The constructed standard system not only fully covers the standardization requirements of CAD software from technological research and development to industrial application, but also improves technical interoperability and industrial collaboration efficiency through vertical connection and horizontal coordination between standards. It provides a reusable practical paradigm for standard system planning in similar information technology fields.

Despite the certain achievements made in this study, there are still areas for expansion and optimization. In terms of application scope, the approach can be further extended to more information technology subfields such as artificial intelligence and industrial internet to verify its cross-domain adaptability. In terms of modeling accuracy, big data and machine learning technologies can be integrated to optimize the identification and deduction process of standardization objects, thereby improving the precision of standard demand mining. In terms of dynamic optimization, a dynamic update mechanism for the standard system can be established, and the content and structure of standards can be adjusted in real time in combination with industrial development missions and technological evolution, so as to enhance the timeliness and foresight of the standard system. In the future, we will continue to improve the universality and operability of the approach, promote its application in more complex information technology fields, and provide stronger support for the construction of standard systems in the digital economy era.

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