Semantic Variation in Hazard Terminology across Safety Standards: An Exploratory Analysis of IEC61508

Thorvaldur Jochumsson[1[0009−0004−9898−9386]] and Kristina Lundqvist[1[0000−0003−0904−3712]]

Department of Computer Science & Engineering, Mälardalen University, Sweden.
thorvaldur.jochumsson@mdu.se
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Abstract. Safety standards introduce key hazard-related terminology through natural language that is inherently context-dependent and prone to ambiguities and inconsistencies affecting knowledge representation, requirements engineering, semantic interoperability, and reasoning.
To provide a deeper understanding of these issues and their origin, this paper presents an exploratory analysis of hazard-related terminology in IEC61508, identifying semantic variation and alternative conceptual representations. The analysis is extended to the hydrogen specification ISO15916 as a representative domain-specific standardisation effort, examining how these issues are reflected at the domain level.
The study provides insights into how hazard-related concepts are represented and how semantic variation arises across IEC61508 and ISO15916. The results show that weak conceptual commitment and vagueness in generic hazard terminology are associated with semantic variation and contribute to ambiguities and inconsistencies in knowledge representation across the standards. These findings suggest that current approaches to hazard-related representation in safety standardisation lack sufficient conceptual clarity and motivate strengthened conceptualisation, explicit conceptual structures, and clearer alignment between generic and domain-specific safety standards.

Keywords: knowledge representation · semantic variation · semantic interoperability · safety standards · IEC61508 · ISO15916

1 Introduction

IEC61508 [7] is a generic safety standard used as a basis for domain-specific standardisation across safety-critical sectors, including the automobile industry [9], process industry [8], and railway sector [2], to name a few. Fundamentally, IEC61508 is intended to enable consistency across different industries by establishing a conceptual framework consisting of shared safety terminology and concepts. Despite this effort, ambiguities and inconsistencies across domain-specific safety representations have been highlighted [6, 11, 13], affecting communication and interoperability across domains. Although ambiguities and inconsistencies have been addressed through ontological alignment between standards [11], their underlying origin remains, to our knowledge, unexplored and is addressed in this paper.

To explore the origin of these issues, this work examines hazard-related terminology in IEC61508, its semantic variation, and alternative conceptual representations. Based on Brigandt's framework [1], semantic variation is analysed through alternative semantic properties associated with terminology across contexts. As such, while terms may remain identical across different inferential roles and epistemic goals presented in the standards, the represented concepts may differ.

This work further examines how such semantic variation is reflected in domain-specific standards, using the hydrogen sector and ISO15916 [10] as a representative case of a safety-critical domain. This enables analysis of how semantic variation is reflected in the generic framework of IEC61508 and domain-specific interpretation, and where ambiguities and inconsistencies emerge within the analysed standardisation.

As such, the primary contribution of this work is an exploratory analysis of semantic variation in hazard-related terminology across generic and domain-specific safety standards, illustrating how such variation contributes to ambiguities and inconsistencies in knowledge representation.

The results show that semantic variation is not only observed between standards but also internally within IEC61508, due to vagueness and weak conceptual commitment in hazard-related terminology. For example, the central concept of hazard can be interpreted as an event, a situation, a property, or an object depending on its role and the purpose of the representation. Similar semantic variation is reflected in the representation of the causal chain leading to hazard manifestation and its consequences.

The semantic variations identified in the generic safety framework IEC61508 are reflected in the domain standard ISO15916, revealing that limitations in the conceptual clarity of hazard-related terminology are not isolated to IEC61508 but extend to domain-specific usage, where they manifest as ambiguities and inconsistencies.

The results highlight the importance of conceptual clarity in generic safety terminology and illustrate how weak conceptual commitment and vagueness contribute to semantic variation, ambiguities, and inconsistencies in safety-related knowledge representation. The work further motivates the use of explicit ontological structures and alignment to support conceptual consistency and semantic interoperability across standardisation efforts.

The remainder of this paper is structured as follows. Section 2 provides relevant background for this work. Section 3 presents the overall methodological approach. Section 4 and Section 5 present the analyses of IEC61508 and ISO15916. Section 6 discusses the implications of the results, and Section 7 concludes the paper.

2 Background

This section provides background relevant to the work presented in this paper. It includes an overview of *semantic variation* as interpreted in this study, a review of previous work addressing *ambiguity and inconsistency in standardisation*, and an introduction to the *ontological type classification* applied in the analysis.

2.1 Semantic Variation

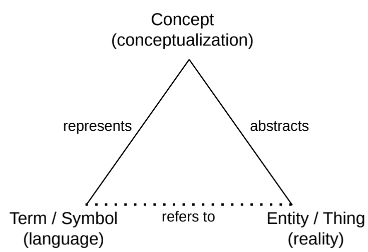

Fig. 1. Ullmann's triangle [14].

The analysis presented in this paper is grounded in the relation between terms, concepts, and the real-world entities to which they refer, as illustrated by Ullmann's triangle, presented in Figure 1. According to the triangle, a term, as part of language, refers indirectly to a real-world entity through the representation of a concept that is, in turn, an abstraction of the entity. For example, the term hazard refers, through a conceptual representation, to real-world phenomena associated with potential harm.

Semantic variation refers to alternative semantic properties, or content, associated with a term and the concept it represents. Brigandt [1] presents a framework that accounts for semantic change and variation based on three components of content: (1) the term's reference, the real-world entity to which it refers, (2) the term's inferential role across contexts of use, and (3) the epistemic goal pursued in the use of the term. As such, a term is subject to semantic variation with respect to what it refers to, how it is used, and the purpose it serves.

In the context of safety standards, semantic variation may arise as alternative conceptual interpretations associated with terminology across different contexts. In accordance with Brigandt's framework, alternative contexts are explored with respect to differences in inferential role, such as analysing the causal sequence of hazard manifestation as opposed to analysing the consequences, and epistemic goal, such as hazard analysis as opposed to requirement specification.

Further, ambiguity and inconsistency in knowledge representation are analysed as consequences of semantic variation. Ambiguity refers to uncertainty regarding which conceptual interpretation of a term is intended within a context, whereas inconsistency refers to incompatible conceptual interpretations adopted across standards and domains.

2.2 Ambiguity and Inconsistency in Standardisation

Generic safety standards are based on terminology representing abstract safety concepts, including hazard-related concepts. These concepts are abstract in the sense that the terminology represents metaphysical or ontological categories rather than concrete real-world phenomena. As a result, such concepts have proven difficult to define and use with precision through the natural language used in the standards.

Previous work has identified ambiguities and inconsistencies within and between domain-specific standards. Schnieder et al. [13] discuss inconsistencies in railway safety and security terminology, while Hogganvik et al. [6] demonstrate that risk-related terminology is interpreted inconsistently across contexts of use. Ontological approaches to addressing such issues have been explored through the development of core safety ontologies aligned with IEC61508-related standards [11].

Although ambiguities and inconsistencies in safety terminology have been identified and addressed through conceptualisation and ontological alignment, the semantic variation and alternative conceptual representations underlying hazard-related terminology remain, to our knowledge, unexplored and are addressed in this work.

2.3 Ontological Type Classification

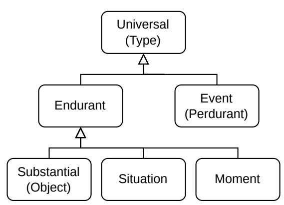

Fig. 2. UFO universal categories used in this work [4].

To analyse semantic variation, this work classifies entities with respect to the fundamental ontological types presented in Figure 2, based on the Unified Foundational Ontology (UFO) [4]. At a high level of abstraction, these types can be divided into enduring (endurant) and perduring (perdurant) entities, where enduring entities maintain their identity over time, whereas perduring entities consist of temporal parts. In this study, perduring entities are referred to as events, collapsing further distinctions within this category. Enduring entities are further distinguished into substantials, moments, and situations. Substantials, referred to as objects in this work, are existentially independent entities, while moments, or properties, depend on other entities, and situations represent configurations of endurants.

In this work, these categories are used as analytical constructs to classify the types of entities represented by hazard-related terminology, referred to as ontological type classification hereafter. The classification procedure is applied top down, beginning with the distinction between enduring and perduring entities by asking whether the referenced entity maintains its identity over time or unfolds through temporal parts. Perduring entities are classified as events, while enduring entities are further classified by considering their existential dependence. Existentially independent entities are classified as objects, while dependent entities are classified as moments when they inhere in other entities, or as situations when they represent configurations of endurants. This enables a structured analysis of the types of entities represented by hazard-related terminology, and how the ontological type classification varies across contexts.

3 Method

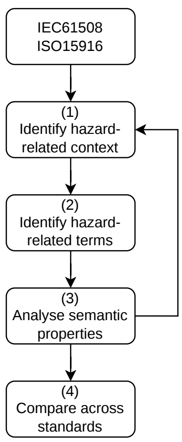

Fig. 3. Procedural representation of the analysis.

The overall approach is an exploratory analysis to identify hazard-related terminology in the standards and analyse how the same terminology is used across different contexts within the standards in accordance with Brigandt's framework [1]. As such, variations and alternative semantic properties associated with the terminology are explored across different contexts. This approach is related to classical ontological engineering practices for conceptual modelling [5, 15], but differs in that it is limited to exploring semantic variation, rather than seeking to define and evaluate a comprehensive ontological structure.

Figure 3 presents a procedural representation of the analysis. The procedure is initially applied to IEC61508 to identify semantic variation within the generic safety standard and is then applied to ISO15916 to explore how semantic variation is reflected in domain-specific standardisation. The analysis is applied iteratively as additional hazard-related terminology and conceptual representations are identified:

(1) Hazard-related sentences are identified, referred to as context hereafter, from the standards under study and categorised with respect to inferential role and epistemic goal in accordance with Brigandt's framework.

(2) Hazard-related terminology relevant to the identified contexts is extracted.

(3) The context and terminology are analysed to identify alternative ontological type classifications of the referred entity using the top-down classification described in Section 2.3.

(4) The resulting contextual categorisations and ontological type classifications are compared across different contexts and standards in order to identify semantic variation and analyse resulting ambiguities and inconsistencies.

The procedure is related to established approaches to ontological analysis [12] and ontology-based conceptual modelling [3], but differs in its purpose. Rather than providing a complete ontological analysis or developing an ontology, it is limited to the initial exploration of the concepts in the analysed standardisation. The procedure addresses methodological concerns of ontological analysis identified by Rosemann et al. [12], including completeness, guidance, and objectivity. Completeness is addressed by defining the scope of the analysis through an explicit dataset, while guidance is provided through Brigandt's framework for semantic variation and the procedural ontological type classification described in Section 2.3. Objectivity is approached by focusing on identifying alternative interpretations rather than establishing a single correct ontological interpretation.

4 Semantic Variation in IEC61508

The complete dataset for IEC61508 explored in this study, composed of 136 different contexts, is available online.[1] The dataset covers a wide range of hazard-related terminology used across different contexts within the standard, often without explicitly clarifying the conceptual relationships between terms.

Table 1 presents representative definitions of hazard-related terminology, providing the intended conceptual interpretation in IEC61508. Table 2 presents representative usages of the terminology in other contexts, enabling comparison between the definitions and how the terminology is applied across the standard. Both tables classify the terminology with respect to inferential role, epistemic goal, and the UFO categories Moment (M), Event (E), Situation (S), and Object (O).

The analysis shows that hazard-related terms that explicitly indicate an ontological type are associated with relatively stable interpretations across the explored contexts. For example, the terms hazardous event and harmful event are consistently associated with the ontological type event. In contrast, the term hazard has a vague definition that only provides explicit ontological grounding through the notion of "source" as an enduring entity. As a result, the term hazard is associated with multiple alternative ontological type classifications, affecting its interpretation across the explored contexts.

Although the terms are consistently associated with the ontological event type, their conceptual roles may remain unclear. For example, hazardous event and harmful event are consistently categorised as events, while the distinction between their inferential roles is not always explicit. In the definitions presented in Table 1, hazardous event is associated with causal analysis as an event that may result in harm, whereas harmful event is associated with consequence analysis through the occurrence of harm resulting from a hazardous situation or hazardous event. However, in the representative contextual usage P4:3.4.1 in Table 2, the terms are used together without explicit clarification of their conceptual distinction, creating ambiguity regarding their respective roles within the hazard-related process. This indicates ambiguity regarding inferential roles despite stable ontological type classification.

[1] https://github.com/jochumsson/semantic-variation/releases/tag/v1.0

Table 1. Representative hazard-related definitions in IEC61508 Part 4, including references to section, analysed terminology, and contextual and ontological type classification.

Ref.	Term	Contextual usage	Epist. goal	Infer. role	M	E	S	O
3.1.1	harm	physical injury or damage to the health of people or damage to property or the environment	definition	conseq. analysis		✓	✓	
3.1.2	hazard	potential source of harm	definition	causal analysis	✓		✓	✓
	harm					✓	✓	
3.1.3	hazardous situation	circumstance in which people, property or the environment are exposed to one or more hazards	definition	causal analysis			✓	
	hazard				✓	✓		✓
3.1.4	hazardous event	event that may result in harm	definition	causal analysis		✓		
3.1.5	harmful event	occurrence in which a hazardous situation or hazardous event results in harm	definition	conseq. analysis		✓		
	hazardous situation						✓	
	hazardous event					✓		
	harm						✓	

Table 2. Representative hazard-related contexts in IEC61508 Parts 1 and 4, including references to part and section, analysed terminology, and contextual and ontological type classification.

Ref.	Term	Contextual usage	Epist. goal	Infer. role	M	E	S	O
P4 3.1.2	hazard	release of a toxic substance	descript.	causal analysis		✓		
P4 3.4.1	hazardous event	prevent the hazardous event (i.e. if the safety-related systems perform their safety functions then no harmful event arises)	descript.	causal analysis		✓		
	harmful event					✓		
P1 Intro	hazard	hazard and risk potentials	descript.	risk analysis	✓		✓	✓
P1 6.2.6	hazardous events	all detected hazardous events are analysed	requirem.	causal analysis		✓		
P1 7.2.2.2	source	the likely sources of hazards, hazardous situations and harmful events shall be determined	requirem.	causal analysis				✓
	hazard				✓			
	hazardous situation						✓	
	harmful event					✓		
P1 7.2.2.3	hazards	hazard duration, intensity, toxicity, flammability	requirem.	hazard analysis	✓			

Overall, the analysis suggests that semantic variation in IEC61508 is closely associated with weak conceptual commitment in hazard-related terminology. This has been illustrated with variation in the ontological type classification of hazard and the inferential roles of hazardous event and harmful event in the explored contexts.

5 Semantic Variation in ISO15916

The complete dataset from ISO15916 explored in this study contains 79 analytically relevant contexts involving hazard-related terminology.[2] Representative subsets of the dataset are presented in Table 3, illustrating concepts interpreted as hazards, Table 4, illustrating contexts related to causal analysis, and Table 5, illustrating contexts related to consequence analysis. The tables present classifications of the safety terminology with respect to inferential role, epistemic goal, and the UFO categories Moment (M), Event (E), Situation (S), and Object (O).

Table 3 presents the four domain phenomena flammability, combustion, detonation, and overpressure, which are initially introduced independently of safety terminology and later interpreted as hazards within safety-related contexts. The analysis shows that no coherent ontological type classification of hazard can be identified across the explored contexts. Instead, the term hazard refers to entities associated with multiple ontological types, including events, situations, moments, and objects, depending on contextual usage and inferential role. These ambiguities reflect the analysis of IEC61508 presented in Section 4, where hazard terminology is associated with weak conceptual commitment and semantic variation.

Finally, an example is taken from section 7.1.3 in ISO15916 where the term hazard is used without further domain grounding in its contextual usage, illustrated by ontological type classifications identical to those associated with hazard in IEC61508. This reflects how weak conceptual commitment in hazard terminology can give rise to ambiguity and potential inconsistencies in general descriptions within the domain specification.

Table 4 presents representative hydrogen-related concepts from the ISO15916 dataset involved in causal sequences associated with the hazards presented in Table 3. Several of these phenomena are not explicitly aligned with generic safety concepts from IEC61508, such as hazard and hazardous situation, and therefore require interpretation by the reader. Consequently, alternative conceptual interpretations emerge. For example, oxygen enrichment can be interpreted both as a moment and as a situation depending on the inferential role and epistemic goal, contributing to semantic variation across contexts. As such, the phenomenon of oxygen enrichment may be addressed inconsistently with respect to IEC61508 requirement P1:7.2.2.2 as a hazardous situation and within P1:7.2.2.3 as a hazard (see Table 2).

Semantic variation affecting one concept may also influence the interpretation of directly related concepts. For example, oxygen depletion can be interpreted

[2] https://github.com/jochumsson/semantic-variation/releases/tag/v1.0

Table 3. Representative contextual interpretations of hazard-related terminology in ISO15916, including references to section, analysed terminology, and contextual and ontological type classification.

Ref.	Term	Contextual usage	Epist. goal	Infer. role	M	E	S	O
3.44	flammability	degree to which a material is ignitable in an oxidizing atmosphere	definition	hazard analysis	✓			
3.13	combustion	reaction process producing heat, radiation, and possibly pressure waves	definition	causal, conseq. analysis		✓		
3.23	detonation	shock-stabilized combustion process propagating faster than the speed of sound	definition	conseq. analysis		✓		
3.72 3.73	overpressure	pressure above atmospheric pressure or above containment limits	definition	hazard analysis	✓			
6.1	flammability	primary hazard associated with hydrogen systems	descript.	hazard analysis	✓			
6.3.1	combustion hazard	uncontrolled combustion of accidentally released hydrogen	descript.	causal analysis		✓		
6.3.2	deflagration detonation transition	transition from deflagration to detonation in confined or congested conditions	descript.	causal analysis		✓		
6.4	pressure hazard	hazards associated with pressure build-up and vessel rupture	descript.	causal analysis	✓			
7.1.3	hazard	identify that a hazard exists and which consequences it can have	descript.	hazard analysis	✓		✓	✓

as a hazardous situation, hazardous event, or hazard depending on whether asphyxiation is interpreted as a hazard or as harm. This illustrates how alternative conceptual interpretations and inferential roles may propagate semantic variation across related hazard concepts and representations.

Table 5 presents representative concepts involved in consequence analysis in ISO15916 related to the hazards presented in Table 3. Compared with hazard and causal analysis, relatively few contexts involving consequence analysis were identified. This reflects the focus of ISO15916 on basic safety considerations rather than detailed application-specific consequence analysis.

Table 4. Representative concepts involved in causal sequences in ISO15916, including references to section, analysed terminology, and contextual and ontological type classification.

Ref.	Term	Contextual usage	Epist. goal	Infer. role	M	E	S	O
3.20	flammable mixture	combustion process moving through a flammable mixture	definit.	causal analysis				✓
3.55	ignition	to cause to burn or to catch fire	definit.	causal analysis		✓		
5.2.2.3	hydrogen release	temperature rise is insufficient to cause ignition of a hydrogen release into atmosphere	descript.	causal analysis		✓		
5.3.5	overpressure	a rapid release of energy that causes an overpressure	descript.	causal analysis	✓			
6.7.3	confined spaces	a risk of asphyxiation exists mainly in confined spaces as a result of oxygen depletion	descript.	causal analysis			✓	✓
6.7.3	oxygen depletion	a risk of asphyxiation exists mainly in confined spaces as a result of oxygen depletion	descript.	causal analysis	✓	✓	✓	
7.2.2.2	oxygen enrichment	oxygen enrichment can increase the flammability and even lead to the formation of shock-sensitive compounds	descript.	causal analysis	✓	✓	✓	
7.3.4.4	rupture	heating by high-velocity jets, as might occur from the rupture of a tank or vessel	descript.	causal analysis		✓		
7.5.9	build-up	avoid the build-up of a flammable mixture	requirem.	causal analysis		✓		

Table 5. Representative concepts associated with consequences in ISO15916, including references to section, analysed terminology, and contextual and ontological type classification.

Ref.	Term	Contextual usage	Epist. goal	Infer. role	M	E	S	O
6.3.4	thermal radiation	thermal radiation from jet fires and fireballs can cause injury and damage	descript.	conseq. analysis		✓	✓	
6.3.3	burns	direct contact with combusting hydrogen can result in burns	descript.	conseq. analysis		✓	✓	
6.3.4	smoke inhalation	smoke inhalation can occur as a consequence of fire	descript.	conseq. analysis		✓		

6 Discussion

IEC61508 provides key hazard concepts and terminology used for knowledge representation across domains and applications. Although IEC61508 provides a common reference, domain-specific standardisation efforts such as ISO15916 adopt alternative interpretations of hazard-related terminology, as illustrated in this paper. While the resulting inconsistencies are mainly visible at the domain level, illustrated through the interpretation of hazard-related terminology in Section 5, this study suggests that an important source of the underlying semantic variation is already present at the generic level in IEC61508. An important source of variation stems from the weak conceptual commitment associated with the term hazard itself, resulting in semantic variation across hazard-related representations, as presented in Section 4.

A representative example is the domain-specific hazard terminology flammability and combustion, presented in Section 5. These terms refer to closely related but distinct real-world phenomena. In this case, flammability refers to an enduring moment, whereas combustion refers to events that unfold in time, such as explosions and fires, yet both phenomena are interpreted as hazard. As such, flammability and combustion illustrate how semantic variation associated with IEC61508 hazard terminology contributes to alternative conceptual interpretations and potentially inconsistent knowledge representations in domain standardisation.

The analysis suggests that hazard-related terminology lacks conceptual commitment for the type of ontological analysis carried out in this work. While this may be expected when representing abstract concepts, hazard-related terminology remains difficult to apply in knowledge representation contexts that require clarity and precision, such as safety analysis, requirements specification, and reasoning. This is demonstrated in Section 5, where it is unclear which safety requirements apply to oxygen enrichment due to ambiguity arising from alternative interpretations.

In the context of standardisation, establishing awareness of semantic variations, ambiguities, inconsistencies, and their implications is an important contribution. It provides a foundation for discussions concerning how such issues should be addressed, whether through conceptual restructuring or ontological alignment, which remains future work. As such, the primary contribution of this work is to increase awareness of how semantic variation in a generic safety standard affects knowledge representation across domain-specific standardisation efforts.

A limitation of this work, and a direction for future work, is its focus on a single domain and on ISO15916, an ongoing standardisation effort. However, related work [6, 11, 13] has identified similar ambiguities and inconsistencies in standardisation across safety-critical sectors. This suggests that the semantic variations identified in this work are not limited to the hydrogen domain or ISO15916, but also affect knowledge representation across domains that build on the conceptual framework in IEC61508.

7 Conclusion

This paper addresses ambiguities and inconsistencies in hazard-related terminology in safety standardisation by exploring semantic variation in the generic safety framework provided by IEC61508. The work is motivated by the observation that hazard-related terminology is used inconsistently across domains and applications, affecting safety knowledge representation across safety-critical domains.

To investigate these issues, the paper presents an exploratory analysis of hazard-related terminology in IEC61508 and in the hydrogen domain specification ISO15916. The analysis examines how terminology refers to different types of real-world entities across contexts, providing a systematic account of semantic variation within and between the standards.

The analysis of IEC61508 shows that key hazard-related terminology, including the term hazard, refers to entities with alternative ontological type classifications depending on context and intended use. The analysis of ISO15916 further shows that similar semantic variation is reflected at the domain level, where hazard-related terminology is interpreted differently across inferential roles and epistemic goals. As a result, the lack of transparent conceptual alignment between generic and domain-specific safety terminology gives rise to ambiguities and potential inconsistencies in knowledge representation.

The results demonstrate that semantic variation in hazard-related terminology represents a limitation for knowledge representation in the safety standardisation explored in this study, which is based primarily on natural language. This work therefore highlights the need for improved conceptualisation efforts and further motivates the use of explicit conceptual structures and ontological alignment between generic and domain-specific safety standards. More broadly, the paper highlights the importance of establishing awareness of semantic variation and its implications as a necessary step towards improving conceptual clarity, consistency, and interoperability across safety-critical domains.

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References

1. Brigandt, I.: The epistemic goal of a concept: Accounting for the rationality of semantic change and variation. Synthese. An International Journal for Epistemology, Methodology and Philosophy of Science **177**(1), 19–40 (2010). https://doi.org/10.1007/s11229-009-9623-8
2. CENELEC: EN 50126:2017. Railway applications. The specification and demonstration of reliability, availability, maintainability and safety (RAMS) (2017)
3. Guizzardi, G.: On ontology, ontologies, conceptualizations, modeling languages, and (meta)models. In: Vasilecas, O., Edler, J., Caplinskas, A. (eds.) Databases and Information Systems IV, Frontiers in Artificial Intelligence and Applications, vol. 155, pp. 18–39. IOS Press, Amsterdam (2007)

4. Guizzardi, G., Benevides, A., Fonseca, C., Porello, D., Almeida, J., Prince Sales, T.: UFO: Unified foundational ontology. Applied Ontology **17**, 167–210 (Mar 2022). https://doi.org/10.3233/AO-210256
5. Guizzardi, G., Falbo, R., Guizzardi, R.S.S.: Grounding software domain ontologies in the unified foundational ontology (UFO): The case of the ODE software process ontology. In: Proceedings of the 12th International Database Engineering and Applications Symposium (IDEAS 2008). pp. 127–140. ACM (2008)
6. Hogganvik, I., Stølen, K.: Risk analysis terminology for IT-systems: Does it match intuition? In: 2005 International Symposium on Empirical Software Engineering. pp. 246–255. IEEE (2005). https://doi.org/10.1109/ISESE.2005.1541810
7. IEC: IEC 61508:2010. Functional safety of electrical, electronic and programmable electronic safety-related systems. Parts 1–7 (2010)
8. IEC: IEC 61511:2025. Functional safety. Safety instrumented systems for the process industry sector (2025)
9. ISO: ISO 26262:2018. Road vehicles. Functional safety (2018)
10. ISO: ISO/TS 15916:2026. Hydrogen technologies — Basic considerations for the safety of hydrogen systems (2026)
11. Kaindl, H., Rathfux, T., Hulin, B., Beckert, R., Arnautovic, E., et al.: A core ontology of safety risk concepts. In: 6th International Conference on Human-Centred Software Engineering (HCSE) / 8th International Conference on Human Error, Safety, and System Development (HESSD). pp. 165–180. Springer, Stockholm, Sweden (Aug 2016). https://doi.org/10.1007/978-3-319-44902-9_11
12. Rosemann, M., Green, P., Indulska, M.: A reference methodology for conducting ontological analyses. In: Atzeni, P., Chu, W., Lu, H., Zhou, S., Ling, T.W. (eds.) Conceptual Modeling – ER 2004. pp. 110–121. Springer Berlin Heidelberg, Berlin, Heidelberg (2004)
13. Schnieder, L., Schnieder, E., Ständer, T.: Railway safety and security: Two sides of the same coin? In: International Railway Safety Conference (IRSC). Bastad, Sweden (2009)
14. Ullmann, S.: Semantics: An Introduction to the Science of Meaning. Basil Blackwell, Oxford (1972)
15. Uschold, M., Gruninger, M.: Ontologies: Principles, methods and applications. The Knowledge Engineering Review **11**(2), 93–136 (1996). https://doi.org/10.1017/S0269888900007797