

Governing AI by Standards: Mapping AI Governance Themes in ISO/IEC and National AI Standards

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Abstract

Technical AI standards are increasingly playing a crucial role in ethical development and deployment of AI systems. Although voluntary in status, technical standards have been introduced as instruments for demonstrating regulatory compliance, particularly under the EU AI Act. Consequently, the body of AI standards has been growing both in response to the rapid advancements in AI capabilities and emerging regulatory requirements. While AI standards are proliferating, there is limited systematic empirical understanding of AI success criteria and governance mechanisms these documents define. In this paper, we address this gap by combining thematic analysis and unsupervised topic modelling techniques to analyse a curated corpus of 36 AI standards. The corpus includes standards issued by international standardisation bodies, specifically by ISO/IEC Joint Technical Committee (JTC) 1/SubCommittee (SC) 42, which is the primary international body for AI standardisation, and a smaller sample of national AI standards from the German standards body (DIN), covering the period between 2018 to 2025. Our analysis identifies 371 unique prevalent concepts, which are further categorised into 11 distinct themes indicating how technical standards formulate *successful AI*. Drawing on prior research and sociology of expectations, the identified themes are categorised into 4 meta-themes (AI Technical Issues, AI Uses, AI Risks and Harms, and AI Governance) set against a micro-meso-macro framing, to determine where standards locate the institutional responsibility for AI systems.

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Introduction

Technical Artificial Intelligence (AI) standards are emerging as key instruments for governing safe and trustworthy AI. Their significance is further growing as standards have been introduced as instruments for regulatory compliance, particularly in the context of the European Union’s (EU) AI Act (European Commission 2024), where adherence to “*harmonised standards*” is explicitly linked to a presumption of conformity, making standards a central pathway for demonstrating regulatory compliance without being

legally mandated (Mazzini and Scalzo 2022). As a consequence of rapid advancements in AI capabilities and emerging regulatory requirements, the body of AI standards has been growing substantially. Most significantly at the international level, the organization for Standardisation (ISO) has established a specialised committee for AI standardisation: ISO/IEC Joint Technical Committee (JTC) 1/SubCommittee (SC) 42¹, which has published 42 standards with a further 49 under development, as of May 2026. At the same time, in response to the European Commission’s request for harmonised standards under the AI Act (Commission 2023), the European standardisation bodies, particularly CEN and CENELEC JTC 21², have been actively developing European norms and standards for AI. Following an “*international first*” approach, JTC 21 prioritises adopting ISO/IEC standards as European harmonised standards where existing international standards are in alignment with EU requirements. At the time of writing, no harmonised standards in regard to the AI Act have been published in the Official Journal of the EU. There are also standardisation activities at the national level as standardisation authorities, such as the British Standards Institute (BSI)³ and the German Institute for Standardization (DIN)⁴, are developing AI-specific standards.

While AI standards are proliferating across these international, European, and national levels, there is limited systematic empirical understanding of AI success criteria and governance mechanisms these documents define. This research aims to address this gap by **identifying prevalent themes linked to AI success in existing ISO/IEC JTC 1/SC 42 standards and a sample of national standards, published between 2018 and 2025**. To this end, we first compile a corpus of relevant standards published within this period. We then employ a mixed-method approach that integrates *thematic analysis*, originating from social sciences, and *unsupervised topic modelling algorithms* to identify key themes that signal success criteria for AI within the corpus. Combining thematic analysis and

¹<https://www.iso.org/committee/6794475.html>

²<https://jtc21.eu/>

³<https://www.bsigroup.com/>

⁴Deutsches Institut für Normung in German, <https://www.din.de/en>

topic modelling ensures that nuanced concepts within documents are captured through human-based analysis, while enabling discovery of new patterns across our large and diverse document set through an unsupervised machine learning algorithm. We synthesise the findings from thematic analysis and topic modelling to identify and categorise recurring themes and success indicators across technical AI standards through lens of sociology of expectations.

The remainder of this paper is structured as follows. First an overview of standards types, the organisations that develop them, standardisation outputs, and standardisation activities in regard to the EU AI Act is provided. The *Related Work* section situates this study within the broader literature. The *Methodology* section describes the mixed-method approach employed in this work. The *Findings* section presents the codes identified through thematic analysis and the topics surfaced via BERTopic. The *Discussion* section examines the key AI success themes and insights emerging from the analysis and reflects on the key findings. Finally, the *Conclusion* section provides a summary of key takeaways and directions for future work.

Standards Development Landscape

Types of Standards

Technical standards are a subset of standards more generally – but all standards aim to have an “ordering effect” (Busch 2013; Timmermans and Berg 2010; Lampland and Star 2009) to shape social action. They are not neutral, but “Each standard and each category valorizes a point of view, and silences another” as Bowker and Star (Bowker and Star 1999) point out. The literature on standards distinguishes between *de facto*, *de jure* and **voluntary consensus** standards (White 2019). *De facto* standards refer to practices or products that become accepted through use or market dominance (e.g. the QWERTY keyboard or VHS video).

De jure standards are based on regulations and laws which are mandated by national, regional, or international bodies. Therefore, such standards must be complied with, and they are often monitored using audits and documentation. *De jure* standards are more “performative” and must be actioned in the world. Finally, voluntary consensus standards are narrower in scope and are developed by industry associations, unions, and other bodies such as the International Organization for Standardisation (ISO). The latter are developed via a deliberative process of consensus making by experts and interested parties. They can be both normative and performative.

Voluntary technical standards focus on developing a shared terminology or vocabulary, design specifications, procedures, and performance metrics. As (White 2019, 2021) points out, standards are often nested (overlapping, interacting with existing standards), interlinked and integrated, distributed unevenly, as they also aim to embody ethics and values. Standards aim to guide multiple actors in the process of standardisation and, accordingly, once embedded and adopted, can be difficult to reverse or change. This leads to what social scientists have called “path dependence” (David 2001) and others to technological momentum (Smith and

Marx 1994). This is not to say that standards are technologically determinist, but rather to point to the fact that considerable effort, time, and resources must be expended to develop *de jure* and voluntary standards, and once these are developed, the actions of a network of documents, people, and organisations are crucial to ensuring they are enacted and that they become instruments of governance (Thévenot 2009; White 2021).

Some types of standards play a role in national, regional, or international legislation or treaties, where the relevant standards outputs are referred to as *de jure* standards. Within the EU, a process exists for adopting standards from specific Standards Developing Organisations (SDOs) as harmonised European Norms that support the implementation of EU legislation and, therefore, are considered part of the EU legislative *acquis* and recorded in the Official Journal of the EU. For example, the EU AI Act relies on “harmonised standards” to provide concrete technical details for implementation of its requirements. Under the presumption of conformity (Art. 40, Regulation (EU) 2024/1689, 2024 (European Commission 2024)), compliance with provisions of the AI Act can be demonstrated through conformity with harmonised standards listed in the Official Journal of the EU.

ICT Standards Developing Organisations

There are a wide range of Standards Developing Organisations (SDOs) worldwide and they vary in their membership schemes, constitutions, standards development and approval processes, and areas of competencies. There is no overall authority tasked with coordinating the development of standards, so it is not uncommon for multiple standards bodies to develop outputs with overlapping objectives and scope.

Standardisation activities within SDOs are typically structured to reflect the need for some degree of consensus for an activity of economic and/or societal importance. The importance of standardisation is reflected in the fact that many nation states designate and often fund a National Body responsible for representing national interests in standards development, e.g. the National Standards Authority of Ireland (NSAI)⁵, the British Standards Institute (BSI), or the German Institute for Standardization (DIN). The importance of standards is further reflected in the ability of an SDO to mobilise experts to convene and follow a structured process of development and consensus building. Typically, such experts are supported by their employers to contribute their time to standards development projects at SDOs, and as a result the collective expert contributions underpinning the consensus represented in standards can be weighted toward the view of organisations with the resources and motivation to support expert contributions. The economic and societal importance of Information and Communication Technology (ICT) means that many SDOs have this as a major or a primary area of activity.

Figure 1 depicts some of the major SDOs active in the ICT domain. They can be broadly categorised as those whose members are primarily national bodies and those whose members are fee paying individuals or organisations. The

⁵<https://www.nsai.ie/>

primary source of *de jure* ICT standards is the Joint Technical Committee 1 (JTC1), which was established by the International Standardization Organization (ISO) and the International Electro-technical Commission (IEC) in 1987 to develop, maintain, and promote standards in the fields of Information Technology (IT) and Information and Communications Technology (ICT). Expert contributions are made *via* national standards bodies and documents are often used as technical interoperability and process guideline standards in national policies, international treaties, as well as being widely adopted by companies worldwide. Within Europe, the equivalent national body membership organisations are CEN (European Committee for Standardisation) and CENELEC (European Electrotechnical Committee for Standardization). The primary international SDO in the telecommunication sector is the ITU (International Telecommunication Union) which is a United Nations Agency that operates *via* fee paying membership. ETSI (European Telecommunications Standards Institute) performs a similar fee-paying member-driven standardisation function within Europe. CEN, CENELEC and ETSI are officially recognised by the EU and by the European Free Trade Association (EFTA) as being responsible for developing and defining voluntary standards at European level and are enabled to develop standards that can be admitted as harmonised European Norms. The IEEE (Institute of Electrical and Electronics Engineers) is a professional fee-paying organisation that also operates as an SDO through its standards association, where participation is open to IEEE individual members as well as to corporations, academic institutions, associations, non-profits, and government agencies. Other relevant member-driven SDOs are W3C (World Wide Web Consortium), which addresses standards for the WWW stack, and OASIS (Organization for the Advancement of Structured Information Standards), which focuses on market-driven digital interoperability standards.

ISO/IEC Standardisation Outputs

Since this paper focuses on ISO/IEC standards, in the following we provide key types of standardisation documents developed by ISO, namely *International Standards (IS)*, *Technical Specification (TS)*, and *Technical Report (TR)*.

International Standards (IS) are fully mature, consensus-based normative documents developed through the complete ISO approval process. According to ISO, an International Standard provides rules, guidelines, or characteristics for activities or their results, with the objective of achieving an optimum degree of order within a given context, which is adopted by an international standardising/standards organisation and made available to the public (ISO/IEC 2021). International Standards may take multiple forms, including product standards, test methods, codes of practice, guideline standards, and management system standards.

Technical Specification (TS) are normative documents that address work still under technical development or areas where there is an expected, but not immediate, possibility of consensus on an International Standard. A Technical Specification is published for immediate use while providing a mechanism to gather feedback from stakeholders, with the

aim that it may eventually be transformed and republished as an International Standard.

Technical Report (TR) are informative documents that are less mature than the previously mentioned ISO document types. They provide data obtained from surveys, informative reports, best practices, use cases, or information that is perceived as state-of-the-art.

AI Standardisation Activities in Relation to the EU AI Act

As mentioned earlier, the EU AI Act relies on technical standards to provide detailed technical solutions for its implementation and enforcement. In this section, we provide further organisational context on the process of standards development and highlight some of the current uncertainties in the adoption of standards in implementing AI policies and regulations, in particular the EU AI Act.

The widespread concern with the ethical and societal impact of AI technology means that SDOs often need to consider issues of ethical or trustworthy characteristics of AI standards in parallel to the market-driven needs for standardisation. However, different standards bodies vary in their approach to balancing such considerations. ISO and IEC are formally grounded in the principles of the World Trade Organization (WTO) to reduce barriers to international trade. At the same time, they are expected to take an ethical stance. For example, all ISO's New Work Item Proposals (NWIP) must declare their relevance to the United Nations framework of Sustainable Development Goals (SDGs). Some specific standards development activities within JTC 1 include the work of SC 39 on ecological sustainability for and by IT, and of SC 40 on IT Governance. Standards are therefore a mixed common good, expected to have a positive ethical impact on business and industry practice while reducing interoperability barriers to commerce and shared best practice.

The EU Act takes a risk-based approach, modelled on the existing EU scheme known as the New Legislative Framework (NLF), for harmonising product, health, and safety legislation across the EU internal market (Mazzini and Scalzo 2022). Thus, the AI Act benefits from established rules and practices for product regulation laid out in the so-called "Blue Guide" (Commission 2022). The ability to unambiguously verify that a high-risk AI system employs appropriate technical measures to mitigate risks to health, safety, and fundamental rights relies on investigation of technical documentation, test results, and instructions for use. These artefacts are therefore central to the consistent and effective implementation of the Act, and the efficiency with which they can be produced and assessed is vital to minimising the regulatory burden of complying with the AI Act (Golpayegani et al. 2024). However, the Act is limited to essential high-level requirements for technical measures and how they should be undertaken is stated in horizontal terms, independent of sectoral context. Instead, in common with some other regulations under the NLF, the AI Act allows compliance with requirements to be demonstrated by AI providers in terms of a presumption of conformity gained by adherence to separate technical standards. These technical standards can be either "harmonised standards" developed by



Figure 1: High-level landscape of ICT-related Standards Developing Organisations

European Standards Organisations (ESOs) or, if that is not possible or insufficient, then *via* “common specification” to be developed by the European Commission (EC) (Tartaro 2023). The EC has already issued a request for harmonised standards in 10 areas to the ESOs, addressing different aspects of the required technical measures (Commission 2023). A Joint Technical Committee of the ESO’s CEN and CENELEC (JTC 21) has been chartered in response to the need to develop European Standards for AI. Despite the link in EU legislation between the implementation of AI regulation and the adoption of AI standards, the literature has already raised several concerns or uncertainties about this approach:

- Limited representation in standards development: Standards development is a meticulous, lengthy, and highly technical process. Therefore, the bulk of participation comes from large multinational companies that sustain teams of suitably-experienced experts, whereas other less well-resourced experts from NGOs, SMEs or academia struggle to maintain effective levels of contribution (Cucuru 2019). This raises concerns that the harmonised standards produced by CEN-CENELEC JTC 21 may not sufficiently represent the interests of citizens and SMEs in favour of the large companies that the Act must also regulate (Veale and Borgesius 2021).
- Lack of free access to harmonised standards (Golpayegani, Pandit, and Lewis 2023): Standards bodies such as ISO/IEC and CEN-CENELEC rely on charging for access as a means of funding to maintain their convening and quality assurance functions, and harmonised standards are typically high-demand items. However, as harmonised standards essentially enter EU law and are key to enforcing important consumer protections, pay-wall access became untenable and resulted in court actions (Kamara 2022). The European Court of Justice delivered a judgment in Case C-588/21 P (PublicResource- Org, Inc and Right to Know CLG v European Commission, 2024 (CJE 2024)) that there was an overriding public interest in free access to harmonised standards, and in response ISO/IEC have asked to annul this decision

(Case T-631/24, pending), thereby casting uncertainty regarding the sustainability of the current model for harmonised standards.

- Developing standards with reference to legal requirements and ethical norms: ISO/IEC and CEN-CENELEC guidelines prohibit addressing legal compliance so as to avoid introducing barriers to trade in these specifications. Harmonised standards address this by including a specific annex to map provisions in the standard to specific legislative requirements. This arms-length treatment and the perceived lack of democratic legitimacy in standards development means that issues of fundamental rights and ethics are limited to non-normative technical reports.
- Integrating horizontal and vertical standards development: Grounding harmonised standards in international ISO/IEC standards supports regulatory certification regimes based on the ISO 17000 series, enabling authorised bodies to certify conformity to a given regulation and its harmonised standards through a “notification” scheme. Complementing this scheme is the harmonised management system standard (MSS) template, which facilitates organisations to integrate multiple MSSs into a unified management system, e.g. combining ISO/IEC 27001 for information security and ISO/IEC 42001 for AI. This, however, offers no guarantee that similar concepts or control measures included from different ISO/IEC standards committees are not in conflict, as they are often developed at different times and as committees addressing horizontal technologies such as AI are typically chartered separately to those addressing sectorial standards. The ideal solution for a Joint Committee to be formed between separate committees is tricky as there are two sets of consensus forming and voting communities involved which makes it typically slower to establish and complete standards project. To date, the harmonised standards request to CEN-CENELEC JTC 21 (Commission 2023) has only sought horizontal harmonised standards, thus the development of harmonised standards specific to AI use in a vertical domain such as medical devices may introduce

uncertainties in the timeline and consistency of liaison between these committees on joint specifications.

- Presumption of conformity and demonstrating conformance to non-certifiable standard (Golpayegani, Pandit, and Lewis 2023): Documents carry different normative standing within the ISO process. International Standards contain normative statements, expressed as requirements and recommendations, that an organisation can claim compliance against. However, compliance with the AI Act may require technical solutions provided in Technical Reports (TR), which are non-normative documents that present consensus views on the state of the art of a topic without offering requirements or recommendations against which compliance claims can be made. Therefore, a key uncertainty is how AI providers can demonstrate conformance with non-certifiable Technical Standards to benefit from presumption of conformity.

Related Work

AI is a rapidly growing topic within existing ICT standards development activities and has been the subject of AI-related literature surveys (Schmittner and Shaaban 2023), including for specific issues of AI governance (Cihon 2019), responsible AI (Gadekallu et al. 2025), values in AI development (Torres and Ali-Vehmas 2024) and quality in AI engineering (Oviedo et al. 2024). The existing literature on AI standards has primarily examined their role as policy documents and instruments of technical coordination, regulatory compliance, and risk management and predictions (Brunsson, Rasche, and Seidl 2012; Miller and Rose 2013; Timmermans and Epstein 2010). From a social science perspective, in the development of AI, ISO/IEC standards specify technical requirements while actively shaping how AI systems are imagined, governed, and assessed. These standards translate macro-level political and ethical objectives into operational measurements and technical documentations, thereby, they aim to mediate between laws, technologies, and organisational practices.

Compliance with technical standards often emphasises demonstrable procedures such as documentation, lifecycle management, and internal and external auditability. While ISO standards are not legal documents and compliance is technically voluntary, they are also used as acting in place of regulatory instruments for both organisations and state institutions (Veale and Borgesius 2021). Existing literature has highlighted ambiguity regarding both the legal standing of AI standards and what organisations must concretely do to be considered compliant with them (Yazici 2025). Unlike statutory regulation, standards do not impose legally binding obligations on organisations. However, in practice, compliance with standards often functions as a *de facto* requirement through their integration into regulatory, market, and organisational governance mechanisms.

To the best of our knowledge, the existing body of work on AI standards has not attempted to conduct thematic analysis or employ topic modelling approaches to analyse emerging AI standards. Therefore, this paper contributes to the literature in three respects. Empirically, it provides the

first systematic, text-based analysis of success criteria and governance assumptions embedded within a compiled corpus of 36 AI standards published by ISO/IEC JTC 1/SC 42 and DIN between 2018 and 2025. Methodologically, it demonstrates that a combination of NVivo-supported thematic analysis and BERTopic-based topic modelling offers a scalable yet human-centric approach to analysing large corpora of highly structured technical documents, a combination of which, to our knowledge, has not previously been applied in this domain. Theoretically, it situates the findings within the sociology of expectations and a micro-meso-macro institutional framing, revealing how technical standards embed and distribute governance responsibilities across different levels of the AI ecosystem.

Methodology

Corpus Creation

Our study focuses on technical AI standards issued between January 2018 and August 2025, covering the period when AI governance in Europe was shifting from early trustworthy AI guidelines to recent regulation setting efforts. As noted earlier, the standards selected were from two sources: *Firstly*, AI standards published by ISO/IEC JTC 1/SC 42 in the time window ($n=30$). Figure 2 illustrates the ISO/IEC JTC 1/SC 42 standards included in the corpus, including International Standards (shown in green), Technical Reports (shown in purple), and Technical Specifications (shown in yellow) and their normative dependencies, excluding their dependencies to standards from other committees.

Secondly, to offer a perspective from a relevant European national standardisation activity, AI standards with technical compliance or socio-technical scope made available by the German Institute for Standardisation (DIN) and the German Commission for Electrotechnical, Electronic & Information Technologies (DKE) in English and free of charge under their Publicly Available Specification (PAS) scheme were included ($n=6$). It should be noted that we considered standards developed by CEN-CENELEC JTC 21 as these would include standards specifically developed to address the EC harmonised standards request for the AI Act, however none of these had been finalised within the time window (i.e. 2018-2025). For an additional national standards perspective, AI standards published by the British Standards Institute (BSI) were also consulted, however, the relevant BSI AI standards were found to be either adoptions of existing ISO/IEC JTC 1/SC 42 standards, that were already included in the selected corpus, or were national domain specific standards and behind a paywall. Therefore, standards from BSI were not included in the corpus.

To support reproducibility, the full corpus of standards compiled for this work has been made available as an open resource on Zenodo under the CC BY 4.0 licence, as part of a larger corpus at <https://doi.org/10.5281/zenodo.19628322>.

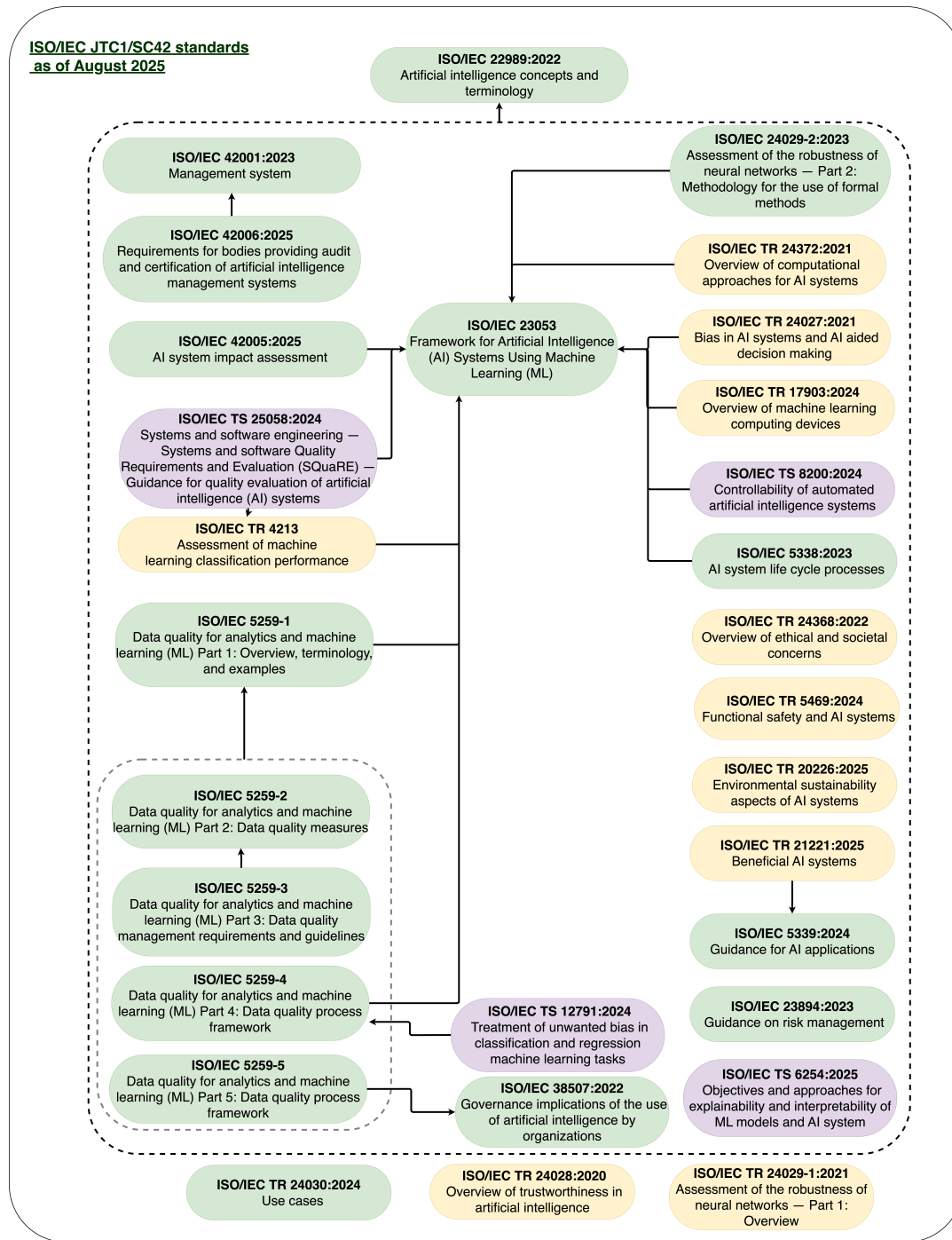


Figure 2: An overview of ISO/IEC JTC 1/SC 42 International Standards (in green), Technical Standards (in purple), and Technical Reports (in yellow) published between 2018-2025.

Combination of Thematic Analysis and Topic Modelling

To identify prevalent concepts within our corpus of standards, we employ a mixed-method approach that combines qualitative thematic analysis (Clarke and Braun 2017; Terry et al. 2017; Braun and Clarke 2021), conducted using

the NVivo software, with BERTopic (Grootendorst 2022), which is an unsupervised machine learning-based topic modelling algorithm. The methodology, shown in Figure 3, was previously developed and evaluated in our prior study on AI policy documents (Golpayegani et al. 2025) and enables analysis of textual content to surface prevalent con-

cepts within each document. Given the substantial volume of standards under examination and the fact that the majority of them are highly structured and technical, NVivo-supported manual thematic analysis was conducted on a selected subset of standards (n=5), while BERTopic was applied to all standards within the corpus (n=36) as it enables scalable coverage⁶.

The five standards for manual thematic analysis were chosen by sampling according to their foundational and thematic significance within the ISO/IEC AI standardisation portfolio. ISO/IEC 22989:2022 (ISO/IEC 2022a) was included as it establishes the core concepts and terminology underpinning the broader family of AI standards developed by ISO/IEC JTC 1/SC 42, while ISO/IEC 42001:2023 (ISO/IEC 2023) on AI management system was selected as it is a key reference point for compliance, including in relation to the EU AI Act. Three Technical Reports (TR) were also included on the basis that they directly address issues central to the socio-technical dimensions of AI success: trustworthiness (ISO/IEC TR 24028:2020 (ISO/IEC 2020)), ethical and societal concerns (ISO/IEC TR 24368:2022 (ISO/IEC 2022b)), and environmental sustainability (ISO/IEC TR 20226:2025 (ISO/IEC 2025b)).

The results of topic modelling (topics) and thematic analysis (codes) were subsequently integrated and manually analysed by a multidisciplinary team (refer to *Positionality Statement* section for their profile) to interpret findings and identify emerging themes related to AI success across the corpus of standards. Informed by sociology of expectations, each theme is then categorised using a micro-meso-macro analytical framework, reflecting the scale at which the expectations embedded in that theme are most appropriately addressed: (i) by individuals or organisations (micro), (ii) at a sectoral or national policy level (meso), or (iii) at a supra-national level (macro).

Findings

Codes from Thematic Analysis of Five Selected Standards

The NVivo-supported thematic analysis of the selected sample of ISO/IEC AI standards provides insights into the current governance priorities embedded within the international standardisation landscape. The top key codes identified from each standard are listed in Table 1. While the sample is partial and cannot be taken as a comprehensive representation of all AI-related standards developed by ISO/IEC JTC 1/SC 42, the results nevertheless illuminate several consistent patterns.

Across the standards examined, *risk* consistently emerges as one of the most frequently referenced concepts. Similarly, the concept of the *AI system lifecycle* constitutes a recurring code across all standards. This suggests an understanding that AI systems require continuous governance and monitoring. This lifecycle framing is further reinforced by the sub-

⁶The Python snippet used for topic modelling is available on GitHub under the MIT licence at <https://github.com/DelaramGlp/forsee.topicmodelling>

Standard	No. of codes	Key codes identified through NVivo-supported manual thematic analysis
ISO/IEC 22989:2022 AI concepts and terminology (ISO/IEC 2022a)	23	Data Science, Stakeholders, Life Cycle, Knowledge, Autonomy, Trustworthy AI, Explainability, Risk, Transparency, Robustness
ISO/IEC 42001:2023 AI Management system (ISO/IEC 2023)	45	Technical Documentation, Risk, Monitoring, Impact Assessment, AI Management, Data Science, Safety and Security, Life Cycle, Society, Explainability
ISO/IEC TR 24028:2020 Overview of trustworthiness in AI (ISO/IEC 2020)	33	Trustworthy AI, Stakeholders, Explainability, Risk, Cybersecurity, Data Training, Privacy, Autonomy, Society, Validation
ISO/IEC TR 24368:2022 Overview of ethical and societal concerns (ISO/IEC 2022b)	49	Ethical AI, Stakeholders, Explainability, Privacy, Risk, Transparency, Safety and Security, Monitoring, Harm Prevention, Employment and the Future of Work
ISO/IEC TR 20226:2025 Environmental sustainability aspects of AI systems (ISO/IEC 2025b)	35	Sustainable Development, Environmental Protection, Carbon Footprint, Waste, Energy Consumption, Life Cycle, Impact Assessment, Data Training, Supply Chain, Raw Materials

Table 1: Summary of codes identified from thematic analysis

stantial attention given to technical documentation, which is positioned as both an accountability mechanism and evidence for demonstrating conformity. Furthermore, nearly all the analysed standards incorporate references to stakeholders, suggesting an acknowledgment that AI systems require collaborative governance.

Codes associated with the widely-referenced principles of *trustworthy AI*, such as explainability, transparency, privacy, fairness, and accountability, appear across the standards, although with varying degrees of emphasis. This suggests that while high-level principles are present across all documents, their depth and specificity may depend on each standard's scope.

Notably, *environmental* considerations feature prominently in ISO/IEC TR 20226 on environmental sustainability aspects of AI and appear, albeit to a lesser extent, in other standards. Codes such as carbon footprint, energy consumption, waste, and sustainable development signal an emerging integration of ecological concerns as a part of operational dimensions alongside more established ethical and technical principles.

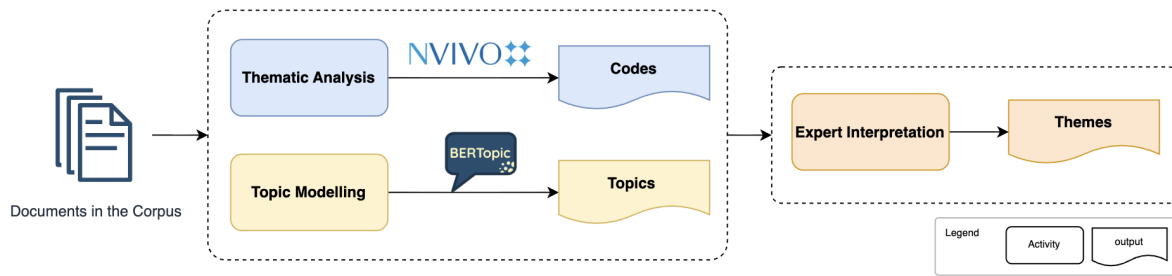


Figure 3: Overall methodology that combines thematic analysis and topic modelling to identify themes

Conversely, compared to risk, documentation, and technical considerations, codes such as *human rights*, *employment impacts*, *future of work*, and *bias/discrimination* appear less frequently and with lower percentage coverage. This suggests that while these issues are acknowledged in certain documents (notably TR 24368 - Overview of ethical and societal concerns), they are not yet uniformly embedded across the standards ecosystem. This may also be characteristic of the restrictions under which projects at SDOs such as ISO/IEC operate, which limits reference to legal requirements.

Overall, the NVivo analysis of the five standards indicates that the current ISO/IEC AI standards framework is predominantly shaped by risk-based governance, lifecycle management, technical documentation, and the operational dimensions of trustworthiness. Ethical, societal, human-centric and environmental considerations are mentioned in specific technical reports, but they tend to receive less consistent emphasis across the documents, and thus are more siloed.

Topics from BERTopic

BERTopic was applied independently to each of the standards within the corpus. The resulting output of BERTopic is a set of keywords representing a topic. The assignment of meaningful semantic labels as topics to the keywords was conducted manually by a legal scholar (Researcher #1 in Positionality Statement) and reviewed by an expert in AI standardisation (Researcher #4). Figure 4 and Figure 5 provide word clouds of topics identified from ISO/IEC JTC 1/SC 42 and DIN standards respectively, highlighting the most prevalent topics across the corpus.

Our analysis showed that some topics are used across many ISO/IEC JTC 1/SC 42 documents, while other topics are siloed into particular standards documents, or rarely used at all. The policy and governance process and procedures, including stakeholders, use cases, training, organisations, risk, and testing, feature heavily, while more sociotechnical concepts do not emerge with only bias and safety and security appearing across a number of documents. Meanwhile, explainability is the key technical principle that appears frequently.

A particularly notable finding emerged from the analysis of ISO/IEC 42005 on AI impact assessment (ISO/IEC 2025a), where the topic of *failure and misuse* appeared, re-

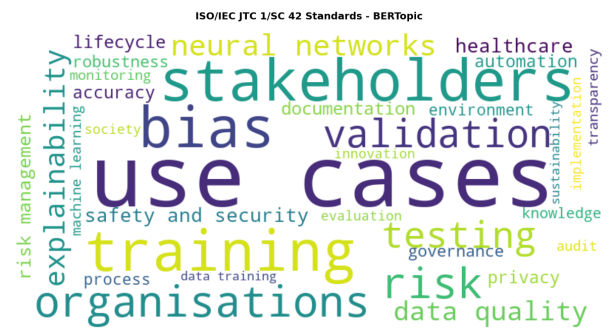


Figure 4: Word cloud of the identified topics from ISO/IEC JTC 1/SC 42 standards

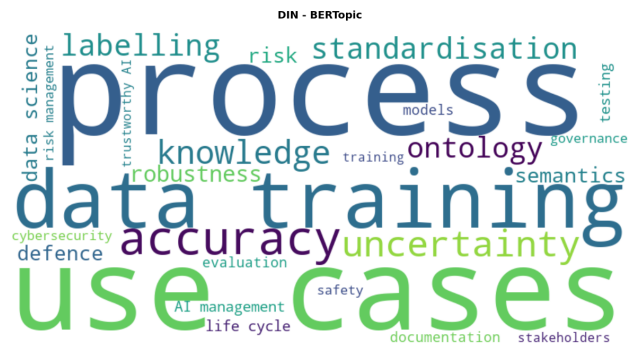


Figure 5: Word cloud of the identified topics from DIN standards examined in this work

ferring to AI systems’ failures and is framed as “failure to meet performance requirements” with potential impacts on human rights or potential physical or psychological harms, as well as scenarios in which a system is compromised by unauthorised users. While only identified in one standard document, this framing of failure offers some insights into the emerging terminology around success and failure.

Key Themes, Insights, and Discussion

The topics and codes from this selected set of ISO/IEC JTC 1/SC 42 and DIN standards reflect the intention of such documents to support consistent practice by organisations in developing, using, and assessing AI systems. These standards offer both operational (i.e. organisational) and technical (i.e. technology-based) measures that can be used to achieve consistent practice. As such, these documents attempt to provide co-ordination across diverse organisations, a shared terminology, and some levels of assurance to those deploying or developing such systems.

The standards within our corpus are voluntary, in that they are not mandated as a requirement for regulatory conformity in relation to an organisation's involvement in AI. Nevertheless, they may be adopted to support regulatory compliance, address broader societal goals, or meet expectations or objectives pursued by value-chain partners, e.g. customers and suppliers, and other stakeholders, such as consumers, rights holders, investors, civil society organisations, and non-normative oversight bodies. In adopting standards that embody consistent practices, organisations may: improve society's confidence that they are following widely-agreed responsible practices; facilitate third-party auditing of those practices; and enable comparison of their practice to those of other standards-following practitioners, including competitors.

From the NVivo codes and BERTopic results, **371 unique concepts** were identified, reflecting the high number and length of documents in our selected set of standards. These concepts were categorised into *11 themes* associated with AI success, as listed in Table 2. As shown in the table, the identified themes are organised within four meta-themes, derived from our prior analysis of supranational AI policy documents (Golpayegani et al. 2025): *AI Technical Issues*; *AI Uses*; *AI Risks and Harms*; and *AI Governance*. Within each meta-theme, themes are categorised using a micro-meso-macro analytical framing. This framing offers a sense of the expectations of standards bodies as to where and by whom each theme would be best addressed:

- The *micro* categorisation indicates that the concepts would be best addressed by individual organisations, but with some degree of freedom in how they do so and therefore accommodating of diversity and innovation in approaches taken.
- The *meso* categorisation indicates that concepts would be best addressed at the level of specific sectors or within a particular government policy area or at a national level.
- The *macro* categorisation indicates that concepts would be best addressed at a supranational level that spans approaches taken by organisations, sectors, and policy areas. Indeed, the international standards and technical reports recognise that regional variations in approaches are appropriate and will emerge.

The concepts in the **AI Technical Issues meta-theme** (n=109) are grouped into four themes. *Theme 1: AI/ML Engineering* (n=55) assembles concepts specific to the engineering of AI and, in particular, machine learning systems, reflecting the AI-specific focus of the selected stan-

dards. *Theme 2: Data Engineering* (n=20) consists of concepts involved in data engineering, indicating the centrality of data to AI training, validation and testing, and the focus on data quality in the 5-part ISO/IEC 5259 standard. *Theme 3: Knowledge Engineering* (n=11) reflects the role of symbolic (as opposed to statistical) knowledge in AI beyond purely machine learning techniques, though this is also magnified by a standard on this specific topic in the DIN standards selection. *Theme 4: Software/System Engineering* (n=23) reflects concepts that are common to software engineering but not specific to Themes 1, 2, or 3. This reflects the standardisation process in ISO/IEC which prefers the reuse of concepts that are already standardised in other areas unless new concepts are needed, e.g. AI in this case. This is present in the ISO/IEC JTC 1/SC 42 specification related to AI lifecycle and AI Systems and software Quality Requirements and Evaluation, which draw on similar standards for software systems. Themes 1, 2, 3, and 4 represent expectations on actors in the *micro* category, reflecting their technical engineering nature and the intention that these standards are primarily used by organisations developing or deploying AI systems.

The concepts in the **AI Uses meta-theme** (n=54) are grouped into two themes. *Theme 5: Sectoral AI Uses* (n=36) groups concepts related to a potential use of AI in a specific industrial sector, such as agriculture, childcare, education, and finance. This theme therefore represented expectations on issues best addressed at the meso level. *Theme 6: Horizontal AI Uses* (n=18) groups the use of AI described in terms of a system capability or function, rather than being positioned in a specific sector. Examples include image recognition, machine translation, and text summarisation. Within the standards these AI uses are referenced as examples of AI application, rather than being the subject of the standardised specification or requirements. Therefore, the expectations they represent are best addressed across *meso* and *macro* levels.

The concepts in the **AI Risks and Harms meta-theme** (n=75) are grouped into three themes. *Theme 7: AI Risk Sources* (n=21), collects concepts such as black box, data corruptions, and model attack that represent either technical phenomena or external factors that affect the behaviour of AI systems. In either case, there is a clear expectation that the sources of AI risks must be identified and, where possible, addressed as part of risk mitigation processes (made explicit in ISO/IEC 23894 - Guidance on AI Risk Management) so this theme is placed in the micro category. *Theme 8: Harms from AI Risks* (n=40) represents harms that may occur or the states of affairs that may be negatively impacted when a risk materialises, e.g. human autonomy, health and safety, global warming, and employment. While there is an explicit expectation that organisations should identify and work to mitigate such harms, there are limited definitions of assessment techniques or acceptable risk thresholds, with the implicit expectation that these are determined externally, i.e. at a meso or macro level. Therefore, Theme 8 is categorised across the micro, meso and macro levels. A small set of concepts in Theme 8 were also placed in Theme 7 since they could represent both a source of risk and of harm when risks

Meta-themes	Micro themes	Meso themes	Macro themes
AI Technical Issues	Theme 1: AI/ML Engineering (n=55) Theme 2: Data Engineering (n=20) Theme 3: Knowledge Engineering (n=11) Theme 4: Software/System Engineering (n=23)		
AI Uses		Theme 5: Sectoral AI Uses (n=36)	
		Theme 6: Horizontal AI Uses (n=18)	
AI Risks & Harms	Theme 7: AI Risk Sources (n=21)		
	Theme 8: Harms from AI Risks (n=40) Theme 9: AI Risk Management Techniques and Factors (n=14)		
AI Governance	Theme 10: AI Governance Mechanism (n=45)		
	Theme 11: AI Governance Factors (n=33)		

Table 2: Themes identified from ISO/IEC JTC 1/SC 42 and DIN AI standards

have materialised, specifically: bias, corruption, cybersecurity, failure, and supply chain. *Theme 9: AI Risk Management Techniques and Factors* (n=14) contains concepts that would be employed or should be considered when undertaking risk management processes, such as risk mitigation, control process, cost, innovation, and health benefits. As risk management processes are intended to be undertaken at an organisational level, and some of these factors may need to be determined in policies set at a meso and macro level, this theme spans all three levels. This theme reflects ISO's conceptualisation of risk as the effect of uncertainty, which can be both negative and positive.

The concepts in the **AI Governance meta-theme** (n=78) are grouped into two themes. *Theme 10: AI Governance Mechanisms* (n=45) collects concepts such as certification, audit, benchmarking, compliance, that organisations are expected to implement as part of their AI government processes. Therefore, this theme is placed in the micro category. *Theme 11: AI Governance Factors* (n=33), collects concepts such as gender, environmental sustainability, fairness, and uncertainty that should be considered in AI governance. While the expectation is that these factors need to be considered by organisations at the micro level, the broad scope of many of them indicate an expectation that these will be elaborated upon and specified at the meso or macro levels. Thus, this theme is placed across all three levels.

Conclusion

This study examined international AI standards developed by ISO/IEC JTC 1/SC 42 and a smaller convenience sample of national standards from the German standards body (DIN) through a mixed-method approach combining thematic analysis and topic modelling. The interpretation of codes and topics yielded 11 themes linked to AI success.

These themes reveal strong expectations that organisations should and can systematically address technical issues, risk management, and AI governance processes, which are expectations aligned with the types of standards included within the corpus, which primarily targets organisations developing and deploying AI systems and emphasises high-level technical and governance frameworks.

The analysis further revealed a nuanced allocation of responsibility within the standards landscape: while organisations are expected to consider a wide range of potential harms, risk factors, and governance considerations, the standards indicate that defining acceptable risk thresholds and assessing the adequacy of risk management and governance measures remain the purview of organisations and institutions at the meso (sectoral) and macro (supranational) levels, rather the organisations providing or deploying AI. This signals the emergence of a *multiscalar AI governance system* in which procedural requirements and technical metrics are operationalised at the organisational (micro) level, whilst normative values and policy frameworks are established at the regional or national (meso/macro) levels.

Our future work is focused on examining and comparing themes we identified from standards in this paper with the ones from AI policies and regulations issued by supranational bodies, examined in our previous work (Golpayegani et al. 2025), with particular emphasis on how risk governance frameworks are operationalised across the multiscalar AI governance system.

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Positionality Statement

The experts directly involved with identification of codes, topics, and themes are:

- Researcher #1: Holds a PhD in EU law and has 3 years of postdoc experience,
- Researcher #2: Holds a PhD in Computer Science, is an expert in AI risk modelling, EU AI policies, and AI standards, and has 1 year of postdoc experience.
- Researcher #3: Holds a PhD in Communication Studies, a Full Professor of Digital Media and Communication with 25 years experience.
- Researcher #4: Holds a PhD in Computer Science, a Full Professor of Computer Science, with 35 years of research experience.
- Researcher #5: Is a PhD candidate and holds a MSc in Computer Science.

The thematic analysis to produce codes was conducted by Researcher #1. The expert analysis of the BERTopic outputs was conducted by Researcher #1 and was reviewed by Researcher #4. Analysis of codes and topics through the lens of sociology of expectation to identify themes was conducted by Researcher #4, with inputs from Researchers #2 and #5, using the framing provided by Researcher #3. Researchers #2 and #4 have both participated as contributing experts to ISO/IEC JTC 1/SC 42 projects, including ones resulting in some of the standards analysed.

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