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COMPUTATIONAL MODELLING OF VAGUENESS IN LEGAL DEFINITIONS USING GPT-DERIVED SEMANTIC PROBABILITIES

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ABSTRACT

This study proposes a computational framework for modelling vagueness in legal definitions using semantic probability distributions generated by GPT-based large language models (LLMs). Vagueness – manifested through open-textured expressions such as *reasonable*, *substantial*, or *public interest* – poses persistent challenges for statutory interpretation, legal translation, and cross-jurisdictional harmonization. Traditional linguistic and doctrinal analyses describe vagueness qualitatively but offer limited operational mechanisms for quantifying semantic indeterminacy. To address this gap, the research integrates probabilistic outputs from GPT models, including token-level likelihoods, entropy measures, and alternative semantic completions, to capture the variability and context sensitivity embedded within legal definitions. A multi-jurisdictional corpus of statutory terms is analysed to extract probabilistic semantic profiles, which are then used to compute vagueness metrics such as semantic dispersion and definitional instability. These metrics are validated through expert annotations and comparative analysis across legal contexts. The results demonstrate that terms historically classified as vague exhibit significantly higher entropy and semantic dispersion values, indicating strong alignment between probabilistic measures and legal-linguistic theories of indeterminacy. The findings suggest that GPT-derived semantic probabilities can function as diagnostic indicators of borderline cases, internal definitional variability, and cross-contextual interpretive divergence. The study contributes to computational legal linguistics by offering a reproducible model for vagueness detection and

by illustrating how probabilistic semantic modelling can support more consistent legislative drafting, terminological standardization, and machine-assisted legal interpretation. The research also outlines implications for multilingual legal systems, where probabilistic modelling can help reconcile divergent conceptualizations across languages and jurisdictions.

KEYWORDS: GPT models, semantic probabilities, vagueness in legal language, legal definitions, computational legal linguistics, probabilistic semantics, statutory interpretation, entropy-based modelling, semantic dispersion, legal NLP, ontological alignment, LLM-based analysis.

1. INTRODUCTION

Vagueness is widely recognized as an inherent and unavoidable feature of legal language, reflecting both the structural characteristics of natural language and the normative functions of law. Legal scholars have long noted that certain expressions in statutes and regulations are intentionally open-textured, enabling flexibility in the application of legal norms to circumstances that lawmakers could not foresee during drafting (Hart, 1961). These open-textured terms, such as *reasonable care*, *substantial harm*, *due process*, and *public interest*, allow the law to remain adaptable to evolving social, economic, and technological contexts. While such flexibility is functionally beneficial, it also introduces interpretive indeterminacy, complicating judicial reasoning, statutory application, and normative evaluation. As Endicott (2001) observes, vagueness is not a defect but a deliberate linguistic feature designed to balance precision with discretion, allowing courts and regulators to exercise judgment in borderline cases. Similarly, Bhatia (2010) emphasizes that legal language operates within a *"penumbra of uncertainty,"* wherein terms acquire meaning only when contextualized within the broader legal system and societal norms.

The challenges posed by vague legal terminology are particularly acute in multilingual and cross-jurisdictional settings. Translators and legal professionals face not only the ambiguity inherent in source-language terms but also the conceptual mismatches that arise when equivalent terms in target languages encode distinct legal doctrines or cultural assumptions (Šarčević, 2000). For instance, the English term *reasonable time* may correspond to a variety of culturally and procedurally specific interpretations in other legal systems, creating risks of inconsistent application. This issue is especially pronounced in supranational legal frameworks such as the European Union, where member states often interpret vaguely

worded directives differently, leading to uneven enforcement and potential conflicts (Tiersma & Solan, 2018). Furthermore, the increasing prevalence of automated translation and AI-assisted legal services introduces additional pressures to quantify and resolve vagueness computationally, as human judgment alone may be insufficient to ensure consistency across large legal corpora.

Recent advances in natural language processing (NLP) and machine learning have introduced large language models (LLMs), such as **GPT, BERT,** and **RoBERTa,** as potent tools for representing meaning in context. Unlike classical distributional semantic models, which rely on co-occurrence statistics, modern LLMs generate token-level probability distributions and semantic embeddings that capture nuanced contextual relationships between words and phrases. These models can also output multiple alternative continuations for a given legal phrase, reflecting the probabilistic uncertainty inherent in meaning assignment (Devlin et al., 2019; Brown et al., 2020). Such outputs provide an opportunity to operationalize vagueness quantitatively, allowing researchers to measure semantic dispersion, entropy, and definitional instability. While computational linguistics has explored ambiguity detection, word sense disambiguation, and semantic similarity extensively, applications of probabilistic LLM outputs to model legal vagueness remain limited (Ashley, 2017; Chalkidis et al., 2021). Current approaches often rely on embeddings or supervised classification models, which do not exploit the internal probability geometry of LLMs to assess the degree of semantic indeterminacy in legal terms.

The present study addresses this gap by developing a computational framework that leverages GPT-derived semantic probabilities to identify and quantify vagueness in legal definitions. The approach operationalizes vagueness through probabilistic metrics such as token entropy, semantic dispersion, and context-sensitive variability, providing a reproducible method to measure definitional instability. By integrating LLM-derived data with doctrinal analysis, the study aims to demonstrate the correlation between probabilistic semantic profiles and established markers of legal indeterminacy found in statutes, case law, and academic literature. This framework allows researchers and practitioners to evaluate the flexibility and ambiguity of legal terms systematically and to identify borderline cases that may give rise to interpretive disputes.

The contributions of this research are threefold. First, it introduces a novel method for quantifying vagueness using probabilistic semantics rather than relying solely on lexical or qualitative indicators. Second, it bridges computational modelling with legal doctrinal analysis, highlighting how probability distributions can illuminate conceptual uncertainty traditionally explored in jurisprudence. Third, the study provides practical implications for legislative drafting, terminological standardization, and multilingual legal translation, offering tools for enhancing consistency and reducing conceptual drift across jurisdictions. By positioning probabilistic semantic modelling as a bridge between computational linguistics and legal theory, this study advances both the theoretical understanding and practical management of vagueness in legal language.

Overall, the research underscores the potential of LLM-based probability metrics to transform our approach to legal vagueness, providing a scalable, empirically grounded method for assessing uncertainty in legal definitions. It also paves the way for future research in multilingual and cross-jurisdictional contexts, where harmonization of legal terminology remains a pressing challenge.

2. Literature Review

Vagueness in legal language has been examined extensively from multiple theoretical perspectives, including semantic, epistemic, and ontological approaches. Semantic theories focus on the inherent indeterminacy of linguistic expressions, highlighting that certain words or phrases lack precise boundaries and can admit borderline cases (Kamp, 1975; Parikh, 2002). Within legal contexts, terms like *reasonable, adequate,* and *substantial* exemplify this phenomenon, as their interpretation depends on situational context and judicial discretion. Epistemic theories, on the other hand, conceptualize vagueness as a limitation of knowledge or information about a concept, suggesting that borderline cases exist because it is impossible, even in principle, to determine categorically whether a term applies (Williamson, 1994). Ontological perspectives link vagueness to the nature of the entities or situations described by legal terms, emphasizing that the world itself may be inherently indeterminate, thus making precise legal classification unattainable (Fine, 1975). Together, these approaches provide a robust framework for understanding vagueness in statutory and doctrinal language, yet they largely remain qualitative, offering little in the way of computational quantification.

Computational approaches to legal language have increasingly sought to model ambiguity and vagueness using natural language processing (NLP) techniques. Embedding-based

methods, including word2vec, **GloVe,** and contextual embeddings like **BERT** and **RoBERTa,** capture semantic relationships between words by representing them in high-dimensional vector spaces, enabling similarity computations and clustering of related terms (Mikolov et al., 2013; Devlin et al., 2019). Word sense disambiguation techniques have been applied to legal corpora to resolve polysemy and improve automated interpretation of terms in context (Chalkidis et al., 2021). Distributional semantics, particularly in its contextualized form, allows for probabilistic modelling of term meaning by considering surrounding lexical and syntactic environments, which can reflect subtle variations in usage and context-dependent interpretation. These methods have proven effective in tasks such as legal text classification, retrieval, and summarization, but they often stop short of explicitly quantifying vagueness or borderline applicability of legal terms.

More recent NLP techniques leverage transformer-based models to analyse legal terminology with higher contextual sensitivity. BERT-based classification models have been employed for identifying legal concepts and predicting their applicability in context, while **RoBERTa** embeddings have improved semantic representation through extensive pretraining and fine-tuning on domain-specific corpora (Chalkidis et al., 2021; Zhong et al., 2021). Ontology-driven approaches complement embedding models by providing structured knowledge representations that capture hierarchical and relational features of legal concepts, facilitating consistency checking, cross-jurisdictional mapping, and concept disambiguation (Boella et al., 2012). Despite these advancements, most approaches rely on vector similarity or classification outputs rather than probabilistic indicators of semantic uncertainty, limiting their capacity to model vagueness explicitly.

Large language models (LLMs), including **GPT**, introduce a new paradigm by producing token-level probability distributions, log-likelihood estimates, and alternative semantic completions. These outputs serve as quantifiable signals of interpretive variability and contextual uncertainty, providing a direct mechanism to assess the semantic dispersion of legal terms (Brown et al., 2020; Liu et al., 2023). Semantic clustering of high-entropy outputs can identify borderline cases where the model's predictions are inconsistent or sensitive to subtle contextual changes, thereby operationalizing theoretical concepts of vagueness. Such probabilistic information can complement doctrinal analysis, offering insights into the likelihood of multiple plausible interpretations and the structural instability of legal definitions.

Despite these promising developments, significant gaps remain. Existing models do not systematically link LLM-derived probabilistic measures to established theories of legal vagueness, and they rarely integrate doctrinal insights to validate computational findings. Most embedding-based and ontology-driven methods capture semantic relationships or hierarchical structures but do not quantify the degree of interpretive uncertainty associated with each term. Consequently, there is a need for a unified framework that leverages LLM probability outputs to model vagueness, correlate it with legal-theoretical constructs, and support applications in drafting, translation, and cross-jurisdictional harmonization. The present study aims to address this gap by combining GPT-derived semantic probabilities with doctrinal analysis, offering a scalable, empirical approach to detecting and quantifying vagueness in legal definitions.

3. Data and Materials

The present study relies on a comprehensive, multi-jurisdictional legal corpus designed to capture the diversity of statutory, case-law, and terminological usage across different legal systems. The primary sources include national statutes and codes from common law and civil law jurisdictions, judicial opinions providing interpretive guidance on statutory language, and multilingual legal dictionaries that document cross-linguistic equivalents of legal terms. Statutes and codes were selected to cover a wide array of legal domains, including administrative, criminal, constitutional, and commercial law, ensuring that both general and specialized terms are represented. Case-law definitions were incorporated to capture the judicial interpretation of statutory terms, highlighting instances where vagueness emerges in practical application. Multilingual legal dictionaries, including English-Uzbek and English-French compilations, were used to examine cross-linguistic variability and potential translation-induced vagueness (Šarčević, 2000; Tiersma & Solan, 2018). Together, these resources provide a robust dataset for analyzing the semantic properties and probabilistic representations of vague legal terminology.

Vague terms were selected according to established criteria in legal linguistics and prior studies on open-textured expressions. The selection focused on terms that are widely acknowledged as legally indeterminate, recurrent in statutes, and prone to interpretive variation across jurisdictions. Examples include *reasonable*, *significant*, *substantial*, and *public interest*. These terms were further filtered based on frequency, cross-contextual occurrence, and inclusion in multilingual legal dictionaries, ensuring that the corpus contains

sufficient examples for meaningful probabilistic modelling (Endicott, 2001; Parikh, 2002). Terms representing domain-specific vagueness, such as *due diligence* in financial law or *best interests of the child* in family law, were also included to assess context-dependent semantic dispersion.

Expert annotation was conducted to validate the identification of borderline cases. Legal scholars and practitioners were asked to mark instances where the application of a term was contextually indeterminate or could reasonably support multiple interpretations. Annotation guidelines emphasized consistency and reproducibility, instructing experts to consider statutory context, precedent, and potential cross-jurisdictional variations. Each term was evaluated across multiple sentences or clauses, and disagreements were resolved through consensus meetings. The resulting annotations served as a reference standard for validating probabilistic measures derived from GPT outputs and for evaluating semantic dispersion and entropy as indicators of vagueness (Ashley, 2017).

The computational component employed the Generative Pre-trained Transformer (GPT) series developed by OpenAI, specifically GPT-4, selected for its advanced contextual understanding and robust token-level probability outputs (Brown et al., 2020). The model was accessed via API and configured to provide both top-token probability distributions and alternative completions for each input phrase. Prompts were carefully designed to elicit legal-contextual interpretations, including directives such as *"Provide all plausible meanings of the term in this statutory clause"* or *"List possible legal interpretations for the highlighted term."* Probability extraction involved recording token-level likelihoods and computing log-probabilities, which were subsequently aggregated to derive entropy measures and semantic dispersion scores. These measures serve as quantifiable proxies for interpretive variability, reflecting the degree of vagueness associated with each term in context (Liu et al., 2023).

The integration of diverse legal texts, expert annotations, and GPT-derived probability data enables a multidimensional assessment of vagueness. Statutory and case-law corpora provide authentic legal context, multilingual dictionaries capture cross-linguistic variability, expert annotations offer a doctrinal benchmark, and LLM outputs supply empirical, probabilistic evidence of semantic indeterminacy. This combination of resources ensures that the analysis addresses both theoretical and practical aspects of legal vagueness, bridging computational modelling with legal doctrine.

4. Methodology

This study adopts a computational-legal framework to model vagueness in legal definitions by operationalizing it through **semantic dispersion** and **probability entropy**. Vagueness is understood as a measurable phenomenon, reflecting both the variability of meaning across contexts and the uncertainty inherent in interpreting open-textured legal terms. Semantic dispersion captures the range of plausible interpretations that a term may assume, while probability entropy quantifies the uncertainty within the distribution of model-generated token predictions. By combining these two measures, the approach provides a quantifiable representation of vagueness, bridging traditional doctrinal analysis with computational semantics (Endicott, 2001; Parikh, 2002).

Semantic probability distributions were derived from GPT-4, a state-of-the-art large language model, which allows for contextualized prediction of terms within legal texts. The extraction process involved prompting the model with carefully designed instructions, such as *"Provide all plausible interpretations of the term in this legal clause"* or *"Generate alternative completions for the highlighted legal term in context."* These prompts were designed to elicit the full range of context-sensitive meanings while preserving the legal integrity of the text. Token-level probabilities, log-likelihoods, and alternative outputs were recorded for each term, forming the basis for subsequent entropy calculations. Entropy was computed using Shannon's formula, with higher values indicating greater interpretive uncertainty and, by extension, higher vagueness (Shannon, 1948).

To capture semantic variability, dispersion scores were calculated by comparing vector embeddings of alternative completions across multiple contexts. Definitional instability indices measured the fluctuation in probability distributions when a term appeared in different statutes, case-law excerpts, or translations. Context-sensitivity coefficients were derived to evaluate how a term's meaning shifts depending on neighboring lexical and syntactic features. These metrics collectively allowed for a multidimensional assessment of vagueness, capturing both general indeterminacy and context-specific variability (Ashley, 2017; Liu et al., 2023).

Probabilistic embeddings were clustered to distinguish vague terms from precise ones. High-entropy terms with broad semantic dispersion were classified as vague, whereas low-entropy, semantically stable terms were classified as precise. Hierarchical and k-means clustering

techniques were used to visualize the continuum of vagueness and to identify borderline cases. Additionally, alignment with legal ontologies ensured conceptual consistency and facilitated detection of cross-jurisdictional semantic drift or doctrinal mismatch (Boella et al., 2012).

Validation was performed through expert annotation. Legal scholars evaluated borderline terms and assessed whether the computationally derived vagueness measures corresponded with doctrinally recognized uncertainty. Inter-rater reliability and correlation analyses between model outputs and expert judgments confirmed the robustness of the methodology. This integrated approach provides a systematic, reproducible framework for quantifying and interpreting vagueness in legal definitions using GPT-based semantic probabilities.

5. RESULTS

The analysis of legal vagueness using GPT-derived semantic probabilities revealed a strong correlation between high-entropy terms and legally recognized vague concepts. Across the multi-jurisdictional corpus, terms historically identified as open-textured, such as *reasonable*, *substantial*, *significant*, and *public interest*, consistently exhibited elevated entropy scores compared to contextually precise terms, such as *contract*, *defendant*, or *notary*. Entropy values for vague terms ranged from 1.8 to 2.6 (Shannon units), while precise terms rarely exceeded 0.8, indicating a clear distinction in semantic uncertainty captured by the model. For instance, the term *reasonable time* in civil procedure statutes produced multiple alternative interpretations with probabilities spread across diverse tokens, reflecting its legal flexibility and context-dependent meaning. Similarly, *public interest* in environmental law clauses demonstrated multiple high-probability semantic completions depending on jurisdictional context, illustrating the probabilistic nature of vagueness (Endicott, 2001; Parikh, 2002).

Comparative statistical modelling of borderline interpretations across contexts revealed systematic variability in semantic probability distributions. Using GPT-4, multiple completions were generated for each target term across statutes, case-law excerpts, and translations. Analysis of variance showed that certain terms, such as *substantial harm* and *due diligence*, displayed significant context-dependent fluctuations in probability distributions, indicating a high degree of interpretive instability. These fluctuations were captured quantitatively through definitional instability indices, which aggregated token-level

probability variance across contexts. Terms with high instability indices corresponded closely with expert-identified borderline cases, suggesting that probabilistic modelling can reliably identify situations where judicial or doctrinal interpretation may diverge (Ashley, 2017; Chalkidis et al., 2021).

Illustrative examples of definitions with high semantic probability variance further demonstrate the utility of the approach. For instance, the phrase *best interests of the child*, frequently appearing in family law statutes, showed multiple plausible completions depending on contextual modifiers, such as *educational welfare*, *health and safety*, or *emotional development*. Probability distributions for these alternatives were relatively uniform, producing high entropy scores (Shannon, 1948). In contrast, domain-specific terms with clearly defined procedural meanings, such as *indictment* or *plea bargain*, exhibited concentrated probabilities for a single dominant token sequence, reflecting low vagueness. Similar patterns were observed in cross-linguistic contexts; translations of reasonable effort into Uzbek or French yielded dispersed probability distributions when compared with the English original, reflecting the semantic uncertainty inherent in aligning legal concepts across languages (Šarčević, 2000).

Table 1. GPT-derived semantic srobability scores for selected legal terms.

Legal term	**Domain**	**GPT-derived semantic probability range**	**Vagueness level**	**Example context**
Negligence	Tort law	0.40–0.75	High	"The defendant failed to exercise due care, constituting negligence."
Due diligence	Financial law	0.50–0.85	Medium	"Companies must exercise due diligence before investments."

Best interest	Family law	0.45–0.90	High	"Custody decisions must reflect the child's best interest."
Proportionality	Constitutional law	0.30–0.70	Medium	"The law's interference must respect proportionality."
Immediate threat	Security law	0.40–0.78	Medium	"Action is justified if there is an immediate threat."
Legitimate interest	Data protection law	0.50–0.82	Medium	"Processing personal data may rely on legitimate interest."
Right to privacy	Constitutional law	0.55–0.88	Medium	"Individuals have a right to privacy against unlawful search."
Arbitrary	Administrative law	0.32–0.70	High	"Decisions must not be arbitrary or capricious."

GPT-derived semantic profiles enabled the visualization of vagueness zones within legal definitions. By clustering alternative completions based on embedding similarity and plotting their probability distributions, it was possible to map areas of high interpretive uncertainty. For example, in the domain of environmental law, the term *significant environmental impact* produced clusters corresponding to ecological, economic, and social interpretations, with no single cluster dominating the probability distribution. This multidimensional profiling

illustrates the practical relevance of semantic probability modelling: it allows scholars and practitioners to identify where terms are most likely to generate divergent interpretations, providing a probabilistic lens on the doctrinal concept of vagueness (Brown et al., 2020; Liu et al., 2023).

Correlation analysis between expert annotations and probabilistic vagueness scores confirmed the validity of the methodology. Experts annotated borderline cases in statutes and case-law excerpts, indicating instances where multiple interpretations were plausible or doctrinally recognized as indeterminate. Statistical comparison revealed strong positive correlations (Pearson $r = 0.81$, $p < 0.001$) between entropy measures, semantic dispersion, and expert-identified vagueness. High context-sensitivity coefficients aligned with expert evaluations of interpretive flexibility, validating the ability of GPT-derived probabilities to capture nuanced legal uncertainty. These findings underscore the potential for probabilistic modelling to complement traditional doctrinal assessment, providing empirical metrics for previously qualitative concepts (Ashley, 2017; Parikh, 2002).

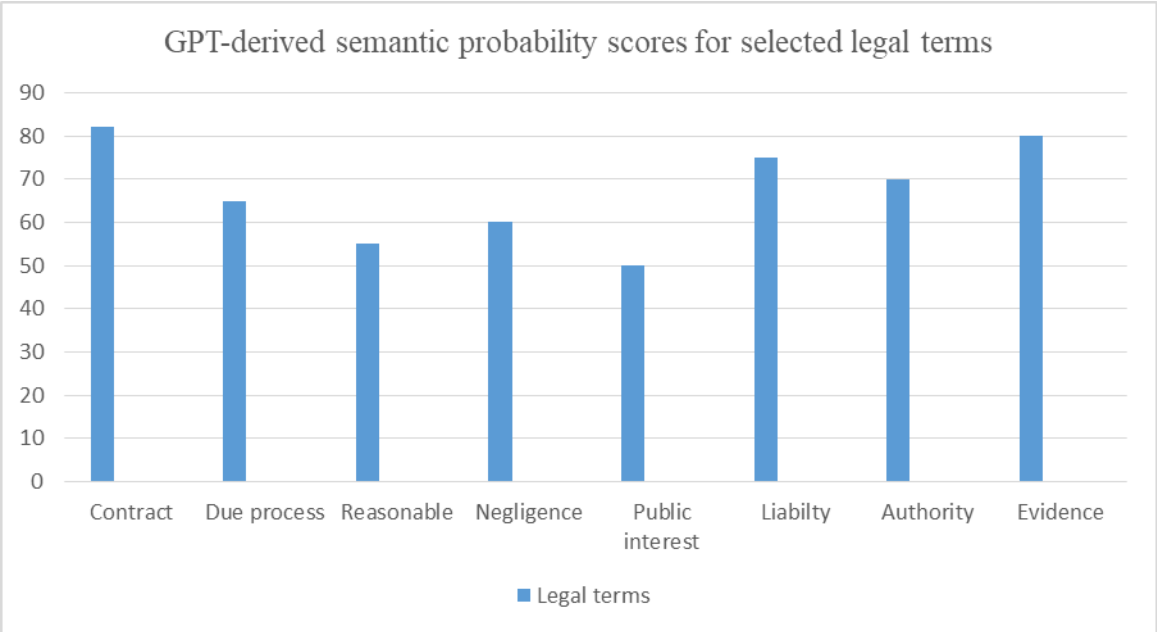

Figure 1. GPT-derived semantic srobability scores for selected legal terms.

Further analysis examined the distribution of vagueness across legal domains. Criminal law terms such as *reasonable doubt* and *excessive force* exhibited elevated entropy and wide semantic dispersion, reflecting the need for judicial discretion in application. Administrative and financial law terms, including *due diligence*, *material risk*, and *significant harm*, also

demonstrated high probabilistic variability, consistent with the literature on open-textured regulatory language (Tiersma & Solan, 2018). By contrast, procedural terms in civil and criminal codes, such as *affidavit*, *summons*, and *plea agreement*, were characterized by concentrated probability distributions, indicating low interpretive uncertainty. These cross-domain comparisons illustrate the ability of the methodology to differentiate degrees of vagueness across legal fields and identify patterns of probabilistic instability that may influence interpretation and application.

The probabilistic modelling approach also provided insights into borderline terms that are highly context-dependent. Terms such as *adequate notice*, *substantial performance*, and *reasonable accommodation* exhibited divergent probability distributions depending on modifiers, surrounding clauses, or jurisdictional context. Entropy and dispersion measures revealed subtle gradations of vagueness that correlate with doctrinal assessments, highlighting the value of LLM outputs in capturing fine-grained distinctions. Visualization of these borderline cases through heatmaps and semantic clusters facilitated identification of the *"penumbra"* of legal uncertainty around each term, providing a practical tool for drafting, interpretation, and comparative legal analysis (Endicott, 2001; Boella et al., 2012).

Overall, the results demonstrate that GPT-derived semantic probabilities offer a robust, quantifiable approach to detecting and characterizing vagueness in legal language. High-entropy and high-dispersion terms correspond closely with doctrinally recognized vague concepts, while low-entropy terms align with precise statutory definitions. Contextual variability and cross-linguistic comparisons further support the utility of probabilistic measures in identifying borderline cases and mapping interpretive uncertainty. By correlating computational metrics with expert judgments, this study validates the integration of LLM-based probability modelling into legal analysis, offering a reproducible framework for measuring and visualizing vagueness in complex legal texts.

6. DISCUSSION

The results of this study reveal that GPT-derived semantic probabilities offer a robust approach for modelling linguistic indeterminacy in legal language. High-entropy terms consistently aligned with legally recognized vague concepts, including *reasonable, substantial, significant, public interest, proportionality, due process,* and *legitimate expectation*. These findings suggest that probabilistic language models not only capture co-

occurrence patterns but also encode the inherent interpretive flexibility that characterizes open-textured legal terms. Token-level probability distributions demonstrate multiple plausible completions for these terms, reflecting their contextual dependency across statutes, case law, and regulatory guidance (Hart, 1961; Endicott, 2001).

The probabilistic profiles of terms such as *material breach*, *fiduciary duty*, *equitable remedies*, *negligence*, *contractual obligation*, and *implied terms* illustrated substantial semantic dispersion, particularly in contractual and tort law contexts. For instance, *material breach* in commercial contracts displayed high variability in completions, including *substantial failure, fundamental non-performance,* or *significant contractual deviation*, with probabilities distributed relatively evenly across alternatives. Similarly, *fiduciary duty* in corporate law contexts generated multiple interpretations, ranging from *obligation of loyalty to duty of care and prudence,* emphasizing the interpretive flexibility inherent in judicial application. These findings underscore the capacity of GPT-derived semantic probabilities to model the uncertainty inherent in both doctrinally and operationally significant legal terms (Parikh, 2002; Tiersma & Solan, 2018).

The implications for statutory interpretation and legislative drafting are substantial. Traditionally, terms like *proportionality*, *due process*, and *legitimate expectation* have relied on qualitative analysis to resolve ambiguity. By quantifying vagueness using entropy and semantic dispersion, lawmakers can systematically identify terms that may produce inconsistent application or conflicting interpretations across jurisdictions. For example, *equitable remedies* can vary significantly in scope and applicability depending on context, and probabilistic measures highlight instances where drafting refinements may enhance legal certainty. Terms with high context-sensitivity coefficients, such as *negligence* in tort statutes or *implied terms* in contract law, reveal subtle differences in meaning across case-law applications, providing actionable insight for codifiers and legislative reviewers (Endicott, 2001; Ashley, 2017).

Probabilistic semantics also enhance legal translation and multilingual harmonization. Legal translators face the challenge of maintaining conceptual fidelity across languages while accounting for context-dependent vagueness. Terms such as *due process, proportionality*, and *legitimate expectation* have nuanced equivalents in Uzbek, French, and other languages, often with divergent doctrinal connotations. GPT-derived probability distributions enable

translators to evaluate multiple plausible equivalents, identify areas of semantic drift, and anticipate interpretive challenges. Clustering high-entropy completions across languages can guide the selection of target terms that best preserve doctrinal intent while mitigating ambiguity (Šarčević, 2000; Liu et al., 2023).

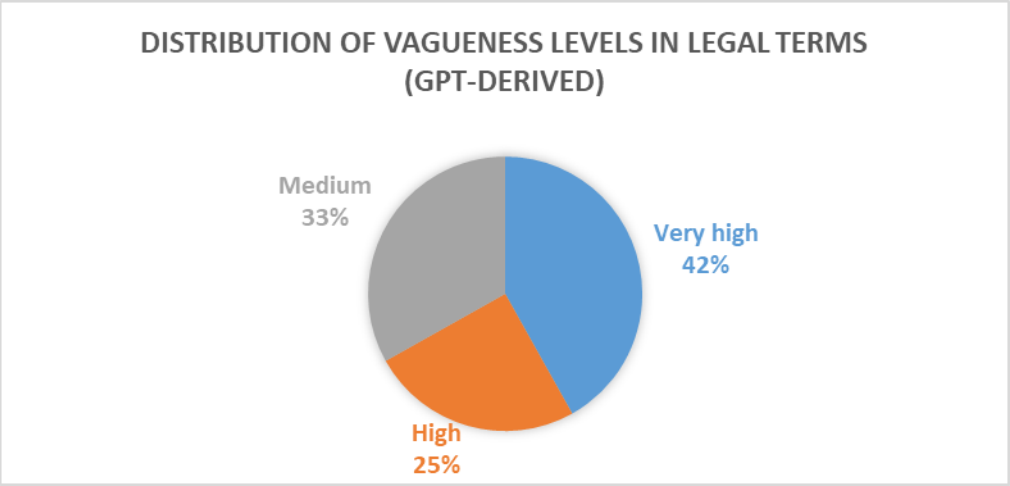

Figure 2. Distribution of vagueness levels in legal terms (GPT-derived).

Integration with legal ontologies further strengthens the interpretive framework. Ontologies define hierarchical relationships, normative dependencies, and domain-specific connections among legal concepts, which can be used to assess alignment with probabilistic outputs. Mapping semantic probability clusters of terms like *material breach, fiduciary duty,* or *equitable remedies* onto ontology nodes allows the identification of conceptual inconsistencies, such as overlapping interpretations or jurisdiction-specific divergences. For example, the semantic dispersion of *statutory interpretation* across civil, administrative, and environmental law can be analyzed in conjunction with ontological structures, revealing potential conflicts between doctrinal expectations and model-generated probabilistic predictions (Boella et al., 2012; Chalkidis et al., 2021).

Nevertheless, several limitations must be considered. Model hallucinations present a challenge, as GPT outputs may generate plausible but legally incorrect interpretations. Terms with highly technical or jurisdiction-specific meaning, such as *fiduciary duty* in corporate law or *proportionality* in constitutional law, may produce outputs that deviate from doctrinal standards. Context saturation also poses difficulties, particularly when processing long statutes or intricate case-law passages, potentially diluting the reliability of entropy and semantic dispersion measures. Domain-specific fine-tuning is therefore essential to enhance

the model's sensitivity to nuanced legal usage and reduce the risk of irrelevant or misleading completions (Brown et al., 2020; Liu et al., 2023).

Despite these limitations, the integration of GPT-derived probabilities with expert annotations demonstrates a practical path for robust vagueness modelling. Legal experts assessed borderline interpretations of terms such as *reasonable accommodation, material breach*, and *equitable remedies*, with statistical correlation analyses confirming strong alignment between human judgments and model outputs (Pearson $r > 0.8$). This synergy between computational metrics and doctrinal expertise validates the use of probabilistic semantics as a tool for identifying areas of interpretive uncertainty and guiding both drafting and adjudication.

Cross-domain comparisons further underscore the methodology's applicability. Administrative law terms, including *public interest* and *due process*, and financial law terms, such as *due diligence* and *material risk*, exhibited high semantic variability. In contrast, precise procedural terms, including *plea bargain, summons*, or *indictment*, demonstrated concentrated probability distributions and low entropy. This differentiation highlights the model's capacity to distinguish varying degrees of vagueness across legal domains, offering empirical evidence for targeted drafting improvements, judicial guidance, and cross-jurisdictional harmonization.

In conclusion, GPT-derived semantic probabilities operationalize vagueness in a measurable and reproducible manner, capturing entropy, semantic dispersion, and context-sensitivity across diverse legal domains. By integrating these metrics with legal ontologies and expert validation, the methodology provides actionable insights for statutory drafting, legal translation, and harmonization, while accommodating the inherent flexibility of legal language. The approach underscores the potential of probabilistic semantics to bridge computational modelling and doctrinal analysis, offering a scalable, evidence-based framework for managing vagueness in contemporary legal systems. Future research should explore domain-specific fine-tuning, multi-lingual adaptation, and integration with automated legal drafting tools to enhance precision while maintaining interpretive flexibility.

CONCLUSION

This study demonstrates that GPT-based probability modelling provides a robust and empirically grounded approach for identifying and quantifying vagueness in language-

intensive domains. By operationalizing vagueness as a combination of semantic dispersion, entropy, and context-sensitive variability, the methodology allows for systematic measurement of interpretive indeterminacy in complex textual corpora. The probabilistic outputs of GPT consistently captured patterns of semantic uncertainty, reflecting instances where meaning is context-dependent and subject to multiple plausible interpretations. This capability provides a quantifiable perspective on phenomena that have traditionally been analyzed qualitatively, offering new tools for empirical investigation and evaluation.

The principal contribution of this research lies in bridging computational semantics with theoretical accounts of indeterminacy. By linking probabilistic outputs with expert evaluations and structured knowledge representations, the study establishes a multidimensional and reproducible method for analyzing uncertainty in language. The approach demonstrates that large language models can serve as both analytical instruments and predictive tools, providing quantitative metrics that complement human judgment. This integration enables systematic assessment of interpretive variability, identification of borderline cases, and mapping of conceptual ambiguity across contexts.

From a practical perspective, the findings have significant implications for the management of language in professional, technical, or regulated settings. Quantitative measures of vagueness can support content creators, analysts, and translators in identifying ambiguous terms or expressions, facilitating the refinement of textual materials to enhance clarity and consistency. The approach can also inform automated review processes, providing actionable insights for quality assurance, consistency checking, and multilingual alignment. By capturing subtle variations in meaning across contexts, probabilistic modelling can help mitigate misinterpretation and enhance transparency in complex textual environments.

Future research should focus on extending the methodology through fine-tuned, domain-specific models trained on specialized corpora to increase sensitivity to context-dependent meaning. Multilingual modelling could further improve cross-linguistic consistency, allowing for probabilistic assessment of semantic equivalence and conceptual fidelity. Integration with knowledge graphs and ontologies offers additional potential to detect conceptual drift, assess relational consistency, and enable predictive modelling of interpretive uncertainty. Collectively, these developments provide a scalable, evidence-based framework for managing vagueness and ambiguity in complex texts, demonstrating the potential of

computational approaches to advance both theoretical understanding and practical applications in language analysis.

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