

A Formal Ontology for Civic Accountable Entities (CAE)

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Abstract

We present a formal ontology of Civic Accountable Entities (CAE), defining the kinds of entities that participate in civic accountability relationships. CAE partitions entities into six disjoint kinds: Actors (A), Sites/Assets (S), Instruments (I), Events (E), Jurisdictions (J), and Observations (O), according to their role in obligations, authority relationships, and accountability-bearing exchanges, rather than by domain, sector, or function.

The ontology is explicitly obligation-driven: entities are included only insofar as they participate in accountability relationships, and apparent role changes are modeled through relationships rather than reclassification. Roles, classifications, and sectoral labels are treated as attributes or relations rather than entity kinds, ensuring disjointness

and preventing ontological overlap. Laws and regulations are modeled as enduring Instruments that ground concrete Events without requiring exhaustive modeling of legal texts.

The six kinds are designed to be stable over time and sufficient to represent long-term public investments, regulatory regimes, financial flows, and outcome measurements across domains including procurement, health, environment, education, and infrastructure. CAE provides the ontological foundation for the Civic Exchange Protocol (CEP), which models how entities exchange value and authority, and for Contextual Evidence and Explanations (CEE), which attaches structured explanations to civic decisions. By separating what exists from how it moves and how decisions are explained, CAE enables interoperable, auditable, and longitudinal analysis of public systems while remaining neutral with respect to policy positions or causal claims.

Keywords: Formal ontology, civic accountability, knowledge representation, applied ontology, public data interoperability, accountability relationships.

1 Introduction and Motivation

Civic systems are governed by complex interactions among laws, institutions, infrastructure, financial flows, and measured outcomes. Data describing these systems is typically fragmented across domains such as procurement, public health, environmental regulation, education, and infrastructure. While each domain is often supported by mature data systems, the structural relationships that connect authority, obligation, action, and long-term outcomes are rarely represented in a unified or interoperable form [Bowker and Star \[2000\]](#), [Edwards \[2011\]](#).

This fragmentation presents a fundamental obstacle to accountability and longitudinal analysis. Short-term metrics are frequently privileged over long-term public value, and outcomes that accrue over decades—such as population health, infrastructure resilience, or environmental quality—are difficult to relate back to the legal, institutional, and financial decisions

that shape them [Edwards \[2011\]](#), [Kahn et al. \[2002\]](#). As a result, public investments with high upfront costs and diffuse benefits are systematically undervalued, even when their historical impact is well established.

Many existing approaches focus either on transactional data (such as payments or contracts), legal texts (such as statutes and regulations), or outcome measures (such as health or economic indicators). Few provide a principled way to connect these elements without collapsing distinct concepts into a single layer or embedding interpretive assumptions directly into data models [Bowker and Star \[2000\]](#).

This paper introduces the Civic Accountable Entities (CAE) ontology as a foundational response to this challenge. CAE defines a formal ontology of entities that participate in obligations, authority, and accountability within civic systems. Rather than modeling domains or sectors directly, CAE identifies a small set of disjoint entity kinds that are stable across time and context and sufficient to represent the structural relationships underlying civic accountability.

The design of CAE emphasizes ontological clarity over descriptive completeness. Entities are partitioned into disjoint kinds with explicit identity criteria; roles, classifications, and sectoral labels are modeled as attributes or relationships rather than as entity kinds. This discipline prevents ontological overlap and supports formal reasoning about obligations, authority, and evidence.

CAE draws on foundational work in formal ontology, particularly the emphasis on rigorous categorization found in BFO [Arp et al. \[2015\]](#) and DOLCE [Masolo et al. \[2004\]](#), while making commitments tailored to civic accountability: entities are included in CAE only insofar as they participate in accountability-bearing relationships, and the ontology is designed to remain stable as domains, policies, and tooling evolve. [Section 2](#) discusses these relationships in detail.

CAE provides the ontological foundation for the Civic Exchange Protocol (CEP), which models how entities exchange value and authority, and for

Contextual Evidence and Explanations (CEE), which attaches structured explanations to civic decisions. By separating what exists from how it moves and how decisions are explained, CAE enables interoperable, auditable, and longitudinal analysis of public systems while remaining neutral with respect to policy positions or causal claims.

The remainder of this paper is organized as follows: Section 2 situates CAE within related work in formal ontology; Section 3 outlines the design principles and scope of CAE; Section 4 defines the six disjoint entity kinds; Section 5 discusses relationships and structural constraints; Section 6 evaluates CAE via competency questions; Section 7 discusses laws, regulations, and accountability chains; Section 8 discusses outcomes, observations, and public value; Section 9 includes discussion and future work; and Section 10 provides a conclusion.

2 Related Work

CAE is informed by foundational work in formal ontology while making distinct commitments suited to civic accountability. This section positions CAE relative to upper ontologies, ontological methodology, and relevant domain standards.

2.1 Upper Ontologies

The Basic Formal Ontology (BFO) [Arp et al. \[2015\]](#) provides a realist upper ontology grounded in scientific practice. BFO distinguishes continuants (entities that persist through time) from occurrents (entities that unfold in time), a distinction reflected in CAE’s separation of enduring entities (Actors, Sites/Assets, Instruments, Jurisdictions) from time-indexed entities (Events, Observations). However, BFO adopts a realist stance in which entities are included by virtue of mind-independent existence. CAE takes a more operational approach: entities are included insofar as they participate

in accountability-bearing relationships, independent of broader metaphysical commitments.

DOLCE (Descriptive Ontology for Linguistic and Cognitive Engineering) [Marsolo et al. \[2004\]](#) adopts a descriptive orientation, modeling categories as they are conceptualized rather than as they exist independently. CAE shares this pragmatic stance but is substantially more constrained: where DOLCE provides a general-purpose upper ontology with rich taxonomic structure, CAE defines exactly six entity kinds with no subkind hierarchy at the ontological level. This minimalism is deliberate; taxonomic and sectoral distinctions are deferred to vocabularies and attributes.

2.2 Ontological Methodology

The design of CAE reflects methodological principles from OntoClean [Guarino and Welty \[2002\]](#), [Guarino et al. \[2009\]](#). OntoClean emphasizes rigorous identity criteria and the distinction between rigid properties (essential to an entity’s identity) and anti-rigid properties (borne contingently). CAE’s commitment to disjoint entity kinds reflects the OntoClean requirement that taxonomic structures respect identity: an entity’s kind is rigid and invariant, while roles such as regulator, funder, or recipient are modeled as anti-rigid relational properties.

This treatment prevents the ontological confusion that arises when roles are reified as entity types, a common source of inconsistency in information systems [Guarino et al. \[2009\]](#).

2.3 Provenance and Evidence

The W3C PROV-O ontology [Lebo et al. \[2013\]](#) provides a widely adopted model for representing provenance of entities, activities, and agents. CAE’s Events bear resemblance to PROV-O’s Activity class, and Observations relate to PROV-O’s Entity as a record of state. However, CAE makes distinc-

tions not explicit in PROV-O. Events in CAE are time-indexed occurrences asserted under the authority of Instruments; they are not merely activities but accountability-bearing assertions. Observations are measurements or indicators with associated provenance, distinct from the Events they may describe.

Instruments, as enduring normative constructs that create or constrain obligations, have no direct counterpart in PROV-O, which models provenance rather than authority. CAE’s Instrument kind is closer to deontic and legal ontology concepts discussed below.

2.4 Legal and Institutional Ontologies

Modeling legal and institutional structures has been addressed by several ontology efforts. LKIF-Core [Hoekstra et al. \[2007\]](#) provides an ontology for legal knowledge, including norms, roles, and legal documents. CAE’s Instruments overlap conceptually with LKIF’s normative concepts but are more abstractly defined: an Instrument in CAE is any enduring construct that grounds obligations, whether a statute, contract, permit, or formally adopted program.

The Financial Industry Business Ontology (FIBO) [Bennett \[2013\]](#) models contracts, parties, and obligations in the financial domain. CAE shares FIBO’s concern with obligations and parties but is domain-neutral; where FIBO provides rich financial semantics, CAE provides minimal cross-domain structure intended to support interoperability across procurement, health, environment, education, and other civic domains.

2.5 Information Artifacts

The Information Artifact Ontology (IAO) [Ceusters \[2012\]](#), developed as an extension to BFO, models information-bearing entities such as documents, data items, and specifications. CAE’s Instruments might be analyzed as

information artifacts in the IAO sense—they are often realized as documents (contracts, statutes, permits) that carry normative content. However, CAE treats Instruments as a primitive kind defined by their functional role (grounding obligations and authority) rather than by their material realization. A single Instrument may be realized in multiple documents or amendments over time; CAE abstracts over this multiplicity.

2.6 Positioning CAE

CAE is neither an upper ontology nor a domain ontology in the traditional sense. It occupies a middle position: a small, stable set of entity kinds designed to support interoperability across civic domains without imposing the full apparatus of a foundational ontology or the specificity of a sectoral model.

Readers familiar with foundational ontologies may recognize parallels between CAE’s enduring entities and time-indexed entities and distinctions such as *continuant/occurrent* (BFO) or *endurant/perdurant* (DOLCE). These references are provided for orientation; CAE does not inherit, extend, or depend on any upper ontology.

The six CAE kinds are intended to be necessary and sufficient to represent the structural relationships (obligations, authority, action, measurement) that underlie civic accountability. Richer semantics, domain vocabularies, and explanatory structures are expected to be layered above CAE rather than incorporated into it.

While the foundational ontologies and standards reviewed above provide essential grounding, none directly addresses cross-domain civic accountability: a minimal, stable partition of entity kinds sufficient to represent obligations, authority, action, and measurement without imposing domain-specific semantics or comprehensive legal modeling. CAE is designed to fill this gap.

3 Design Principles and Scope

In light of the foundational and methodological work reviewed above, CAE adopts a small number of explicit design principles intended to ensure clarity, stability, and extensibility.

CAE is a domain-constrained reference ontology designed for accountability analysis, rather than a foundational or upper ontology.

3.1 Accountability-Driven Inclusion

CAE models entities only insofar as they participate in accountability-bearing relationships. An entity is introduced when it bears obligations, exercises authority, participates in regulated actions, or is the subject of measurement and evaluation. CAE does not attempt to enumerate all organizations, facilities, laws, or social phenomena exhaustively.

This accountability-driven inclusion rule prevents ontological bloat and ensures that the ontology remains focused on structures that matter for civic accountability [Bowker and Star \[2000\]](#).

3.2 Disjoint Entity Kinds

CAE defines a strict partition of entities into disjoint kinds. Each entity is assigned exactly one kind, and entity kinds do not overlap. This disjointness follows established ontological methodology for maintaining clear identity conditions and avoiding category overlap following OntoClean methodology [Guarino and Welty \[2002\]](#). It is a foundational constraint: it prevents ambiguity and supports formal reasoning over accountability-bearing relationships.

Changes in function, responsibility, or context are represented through relationships rather than reclassification. An entity does not change kind

over time, even as its role within civic systems evolves.

For compact reference, the six entity kinds are occasionally denoted by single-letter symbols (A, S, I, E, J, O). These symbols are introduced here for concise notation and are used sparingly in this paper.

3.3 Roles as Relationships

CAE does not model roles, sectors, or functions as entity kinds. Concepts such as regulator, funder, operator, recipient, or subject of regulation are represented as patterns of relationships among entities. This approach avoids proliferation of role-specific entity types and ensures that entity identity remains stable across contexts.

This design aligns with established ontological treatments of roles as anti-rigid properties that an entity may gain or lose without affecting its identity [Guarino \[1998\]](#), [Masolo et al. \[2004\]](#).

3.4 Selective Modeling

Entities, particularly laws and regulations, are included selectively based on their operational relevance. Normative or regulatory instruments are introduced only when they ground concrete events or observations. This selective modeling strategy supports scalable implementation and avoids premature commitment to comprehensive legal or administrative catalogs.

3.5 Neutrality and Separation of Concerns

CAE is intentionally neutral with respect to causal inference, evaluative judgment, and policy interpretation. The ontology encodes structural relationships that make accountability and outcomes inspectable, but it does not assert that particular instruments cause particular outcomes or that specific outcomes are desirable [Pearl \[2009\]](#).

Interpretation, explanation, and evidentiary reasoning are deferred to analytic layers built upon CAE. This separation of concerns supports transparency, reproducibility, and pluralistic analysis.

3.6 Durability and Extensibility

CAE is designed to remain stable over long time horizons. The entity kinds and structural constraints are intended to be invariant even as institutions, measurement practices, and data sources evolve [Edwards \[2011\]](#). Extension occurs through the addition of entities and relationships, not through modification of the underlying ontology.

This design supports incremental adoption and cross-domain interoperability without requiring coordinated changes across systems.

4 Ontological Partition of Accountable Entities

This section defines the core ontological commitment of the Civic Accountable Entities (CAE) framework. CAE introduces a strict partition of accountable entities into six disjoint kinds: Actors (A), Sites/Assets (S), Instruments (I), Events (E), Jurisdictions (J), and Observations (O). Each entity instantiated within CAE is assigned exactly one kind. Entity kinds are invariant over time: entities do not change kind, and apparent role changes are represented through relationships rather than reclassification.

The partition is designed to support formal reasoning about obligations, authority, and evidence while preventing ontological overlap. Inclusion of an entity in CAE is driven by participation in obligations, authority relationships, or accountability-bearing exchanges, rather than by descriptive completeness or sectoral classification.

4.1 Actors (A)

Actors are entities capable of bearing rights, obligations, or responsibilities within civic systems. An Actor may initiate, receive, authorize, or be held accountable for actions governed by Instruments and manifested through Events. Actors are the only entity kind that may serve as parties to obligations.

Examples include governments, public agencies, private businesses, nonprofit organizations, universities, research institutes, and other organizational bodies that participate in civic accountability relationships. Public or private status, sector, mission, and organizational role are treated as attributes or relationships, not as entity kinds.

An Actor is introduced into CAE only when it participates in an accountability relationship, such as receiving funds, issuing authority, operating regulated Sites, or being subject to reporting or enforcement. CAE does not attempt to enumerate organizations exhaustively; it models Actors only insofar as they are implicated in obligations, authority, or accountability-bearing exchanges.

See Section 4.5 for clarification on Actors and Jurisdictions with shared labels.

4.2 Sites/Assets (S)

Sites/Assets are physical or operational entities that are acted upon but do not themselves bear obligations. They provide the spatial, infrastructural, or material substrate upon which civic activity occurs. Sites/Assets may be owned, operated, regulated, inspected, or measured, but they are not parties to Instruments.

Examples include facilities, buildings, campuses, power plants, laboratories, stores, transportation infrastructure, and other physical or operational installations. Geographic location is an intrinsic property of Sites/Assets and

provides a natural point of attachment to Jurisdictions.

Treating Sites/Assets as a distinct entity kind ensures a clear separation between accountable actors and the physical or operational entities through which obligations are exercised or impacts are realized.

4.3 Instruments (I)

Instruments are *enduring* constructs: they persist over time and are not tied to a single occurrence or timestamp, even though they may be enacted, amended, applied, or terminated by Events.

Instruments create, modify, delegate, or constrain rights, obligations, or authority. Instruments mediate relationships between Actors and govern the conditions under which Events may occur.

An Instrument provides the normative or regulatory basis for why an action, decision, or outcome takes the form it does, independent of the specific Event that realizes it. By distinguishing Instruments from Events, CAE separates the existence of obligations or authority from their execution, fulfillment, or violation.

CAE distinguishes common functional roles of Instruments without introducing additional entity kinds.

Examples include formal agreements (such as contracts and memoranda of understanding), statutes and laws, rules and regulations, and programmatic constructs such as grants, permits, licenses, formally constituted programs, or formally adopted procedural regimes. These examples are illustrative rather than exhaustive; all Instruments share the defining property of grounding obligations or authority that can give rise to accountable Events.

Formally constituted programs and procedural regimes include only those that are explicitly adopted by an authoritative body and impose binding conditions on participation, evaluation, or compliance.

In CAE, a grant program or award framework is modeled as an Instrument, while the disbursement of grant funds is modeled as an Event.

CAE deliberately excludes artifacts that do not themselves create or constrain obligations. Operational tools, analytical software, formatting utilities, quality assurance tools, or internal workflows are not treated as Instruments unless they are explicitly incorporated into a binding normative, regulatory, or contractual structure. This constraint preserves the stability of the ontology and prevents implementation-specific mechanisms from being mistaken for sources of civic authority.

Instruments are included in CAE only when they give rise to concrete Events or Observations. This design avoids exhaustive modeling of legal or administrative texts while preserving the accountability structure required for tracing downstream exchanges and evidentiary relationships.

4.4 Events (E)

Events are time-indexed occurrences that are recorded or asserted within the scope of one or more Instruments. An Event records that something happened at a particular time and place and may involve one or more Actors, Sites, or Jurisdictions. Events constitute the primary evidence of activity within civic systems.

Examples include payments, inspections, filings, emissions submissions, audits, enforcement actions, and other discrete occurrences, including the execution, violation, or fulfillment of obligations.

Events are not enduring objects; their identity is inseparable from their temporal occurrence and provenance.

By separating Events from Instruments, CAE distinguishes between the existence of obligations and the activities that occur under, in response to, or in violation of those obligations. This separation is essential for representing compliance, non-compliance, performance, and accountability over time.

4.5 Jurisdictions (J)

Jurisdictions are entities that scope authority, applicability, and governance. They define where Instruments apply, where Events may occur, and how Observations are interpreted. Jurisdictions are not Actors; they do not initiate actions or bear obligations.

Examples include nations, states, provinces, municipalities, regulatory regions, air basins, and watersheds. Jurisdictions may be nested or overlapping, and such structure is represented explicitly through relationships.

Treating Jurisdictions as a distinct entity kind allows CAE to model legal, regulatory, and environmental scope without conflating authority with agency or action.

Actors and Jurisdictions as Distinct Entities. In CAE, political or administrative names (e.g., California, City of Chicago) may refer to multiple distinct entities that occupy different ontological roles. When such an entity acts, e.g. by entering contracts, issuing permits, making payments, or bearing obligations, it is modeled as an *Actor*. When the same named entity defines legal scope, authority, or applicability, it is modeled as a *Jurisdiction*. These are distinct entities with separate identities, even when they share a common label or geographic extent.

This separation ensures disjointness between Actors and Jurisdictions and prevents role-based reclassification. An Actor may operate within, be constrained by, or exercise authority over a Jurisdiction, but it does not become a Jurisdiction by acting, nor does a Jurisdiction become an Actor by scoping authority.

4.6 Observations (O)

Observations are measurements or indicators describing the state, performance, or outcomes associated with Actors, Sites, Instruments, Events, or

Jurisdictions. Observations do not create obligations and do not represent actions; they assert measured or derived facts with associated provenance.

Examples include health outcomes, emissions intensity metrics, educational attainment measures, coverage metrics, and other longitudinal or comparative indicators. Observations may be aggregated, statistical, or model-based and are typically associated with populations or regions through attributes and relationships.

Introducing Observations as a first-class entity kind enables CAE to represent long-term public value and outcomes without collapsing measurement into Events or Instruments. This separation supports comparison across time and jurisdictions while remaining neutral with respect to causal interpretation.

4.7 Ontological Stability and Non-Goals

CAE is intentionally minimal and non-exhaustive. It does not aim to provide sector taxonomies, domain-specific subclasses, or comprehensive classifications of civic activity. The six entity kinds defined are intended to be necessary and sufficient to ground accountability, exchange, and evidence across domains, independent of sector, policy area, or implementation technology. Future extensions are expected to occur through vocabularies, schemas, and domain-specific layers built atop CAE, rather than through modification or proliferation of the ontological kinds themselves. Stability of the CAE partition over time is a design goal: changes in practice, tooling, or policy should be representable through new entities and relationships, not through alteration of the underlying ontology.

By enforcing disjointness among entity kinds, CAE prevents category confusion and ensures clarity in modeling accountability relationships. This clarity is essential for formal reasoning about obligations, authority, and evidence within civic systems.

5 Relationships and Structural Constraints

Having defined the disjoint kinds of civic accountable entities, we now specify the allowed relationships between them and the structural constraints that govern their valid configuration. CAE does not enumerate all possible relationships; instead, it constrains the space of valid relationships so that accountability, authority, and evidence can be expressed without ontological ambiguity.

Relationships in CAE are typed, directional, and kind-constrained. They serve as the primary carriers of semantic meaning, while entity kinds remain invariant over time. Roles, classifications, and contextual interpretations are expressed through relationships and attributes rather than through reclassification of entities.

5.1 Kind-Constrained Relationships

Each relationship in CAE specifies admissible source and target kinds. These constraints prevent category errors such as treating physical Sites as obligation-bearing parties or conflating Events with enduring authority.

Representative examples include:

- *enacts* : Actor \rightarrow Instrument
- *implements* : Instrument \rightarrow Instrument
- *issues* : Actor \rightarrow Instrument
- *party-to* : Actor \rightarrow Instrument
- *occurs-under* : Event \rightarrow Instrument
- *involves* : Event \rightarrow Actor
- *acts-on* : Event \rightarrow Site
- *located-in* : Site \rightarrow Jurisdiction
- *applies-in* : Instrument \rightarrow Jurisdiction
- *measures* : Observation \rightarrow (Actor | Site | Jurisdiction)

These constraints ensure that accountability flows through relationships rather than being implicit in entity types.

5.2 Authority and Obligation Flow

CAE encodes authority and obligation as relational structure rather than as intrinsic properties of entities. Authority originates with normative or regulatory Instruments enacted or issued by Actors and flows through relationships to constrain Events and generate Observations.

For example, a statute (Instrument) enacted by a legislature (Actor) delegates authority to an agency (Actor), which issues permits (Instruments) governing the operation of facilities (Sites). Emissions reports (Events) occur under these permits, and health outcomes (Observations) are measured within relevant Jurisdictions.

This directional flow preserves a clear distinction between the existence of authority, its execution, and its observed consequences.

5.3 Temporal Structure and Provenance

Time is represented explicitly only through Events and Observations. Actors, Sites, Instruments, and Jurisdictions are enduring entities whose identity is not defined by temporal occurrence, although they may participate in time-indexed relationships.

Every Event and Observation is associated with provenance information specifying its source, time, and evidentiary context. CAE itself does not prescribe a provenance model; rather, it ensures that provenance can be attached without conflicting with entity kinds or relationship constraints.

This separation supports longitudinal analysis while avoiding the reification of temporal states as distinct entities.

5.4 Role Representation

Roles are not modeled as entity kinds within CAE. Instead, roles emerge from patterns of relationships. An Actor may simultaneously occupy multiple roles, such as regulator, funder, operator, or recipient, depending on its relational position with respect to Instruments and Events.

For example, a university may act as a grant recipient, a facility operator, and a reporting entity without requiring reclassification. This approach avoids role-based overlap and ensures that entity identity remains stable even as context changes.

5.5 Structural Invariants

CAE enforces several structural invariants:

- Each entity belongs to exactly one entity kind.
- Entity kinds do not change over time.
- Authority and obligation are expressed only through relationships.
- Events and Observations are the only time-indexed entities.
- No relationship may violate declared kind constraints.

These invariants ensure that CAE remains internally consistent and supports formal reasoning about accountability relationships.

6 Evaluation via Competency Questions

This section evaluates the adequacy of the CAE ontology using explicit competency questions grounded in real civic data. The goal is not exhaustive validation, but to demonstrate that the ontological distinctions introduced by CAE enable representations that are difficult or ambiguous under common alternative models.

6.1 Explicit Competency Questions

The following competency questions guided the design of CAE and are used here to assess its expressive adequacy:

- **CQ1:** Can the ontology distinguish enduring sources of authority from the time-indexed events that realize or execute that authority?
- **CQ2:** Can a single civic entity participate simultaneously in multiple accountability roles (e.g., regulator, operator, recipient) without reclassification or type mutation?
- **CQ3:** Can outcomes and public value be represented as observable entities without asserting causal claims or embedding evaluative judgments in the ontology?
- **CQ4:** Can accountability chains be traced across jurisdictions and over time without redefining entity identity?
- **CQ5:** Can delegation of authority be represented explicitly through instruments, rather than implicitly through role-based entity types?

These questions are answered through a worked mapping of a real public grant record and a comparative discussion with an established provenance model.

6.2 Dataset Mapping: USAspending Grant Example

To illustrate these competency questions, we consider a representative grant record published via USAspending.gov. The example is intentionally minimal and descriptive; it is not intended as a comprehensive schema mapping.

A typical grant record involves the following elements:

- **Actors (A):** a federal awarding agency and a recipient organization
- **Instruments (I):** an enduring grant program and a specific grant award
- **Events (E):** obligation and payment events occurring at specific times

- **Jurisdictions (J):** federal and state jurisdictions governing applicability
- **Observations (O):** optional outcome indicators (e.g., program-level performance metrics)

In CAE, the grant program is modeled as an enduring *Instrument* that grounds authority and eligibility conditions. The grant award and subsequent payments are modeled as *Events* occurring under that instrument. The recipient organization remains a single *Actor* throughout, even as it occupies the roles of applicant, awardee, and reporting entity.

This representation directly addresses CQ1, CQ2, and CQ4 by separating authority from execution, preserving entity identity, and allowing longitudinal analysis across jurisdictions.

6.3 Comparative Limitation of Provenance-Oriented Models

In widely used provenance ontologies such as PROV-O, both grant programs and grant awards are typically represented as `prov:Entity`, while payments are represented as `prov:Activity`. While sufficient for recording provenance, this structure does not enforce a distinction between enduring normative constructs and time-indexed realizations.

As a result, expressing the difference between a standing source of authority (e.g., a grant program) and the events that execute or fulfill that authority requires additional modeling conventions external to the ontology. Similarly, role distinctions (e.g., regulator versus operator) must be handled informally or through application-specific typing.

6.4 CAE Representation of the Same Scenario

CAE addresses these limitations through its disjoint partition of entity kinds. In the same grant scenario:

- The grant program is modeled as an *Instrument* (enduring authority).
- The award and payments are modeled as *Events* (time-indexed occurrences).
- The recipient organization remains a single *Actor*, with roles emerging from relationship patterns rather than reclassification.

No subclassing, role entities, or ad hoc conventions are required. Authority, execution, and observation are separated structurally rather than procedurally.

6.5 Discussion of Results

These examples demonstrate that CAE’s disjoint partition enables ontological distinctions that are not enforced in provenance-oriented or transaction-centric models. In particular, CAE supports explicit representation of authority, delegation, execution, and outcomes while remaining neutral with respect to causal interpretation or policy evaluation.

The evaluation indicates that CAE satisfies the stated competency questions and provides a stable ontological foundation for downstream exchange semantics and explanatory frameworks, without requiring their inclusion in the present paper.

7 Laws, Regulations, and Accountability Chains

This section describes how laws and regulations are represented within the CAE ontology and how they participate in accountability chains without requiring exhaustive modeling of legal texts. CAE treats statutes and regulations as Instruments that ground authority, obligations, and enforcement while remaining structurally suited to accountability analysis.

The objective is not to encode legal doctrine, but to preserve the accountability structure through which public authority produces concrete actions

and observable outcomes.

7.1 Normative and Regulatory Instruments

Within CAE, laws and regulations are modeled uniformly as Instruments. A statute, act, or treaty is treated as a normative instrument: an enduring construct that establishes authority, delegates power, or defines obligations at a high level. Regulations, rules, and administrative codes are treated as regulatory instruments: instruments that operationalize normative instruments by specifying procedures, thresholds, or reporting requirements.

Both normative and regulatory instruments share the defining property of grounding accountability relationships. They differ only in scope and level of abstraction, not in ontological kind. This approach avoids proliferating entity types while preserving the hierarchical structure of legal authority.

7.2 Delegation and Implementation Chains

Accountability chains emerge through explicit relationships between instruments and actors. A normative instrument may delegate authority to one or more Actors, which in turn issue regulatory or programmatic instruments. These downstream instruments constrain Events and give rise to Observations.

For example, a statute enacted by a legislature delegates authority to an agency. The agency issues regulations implementing the statute, which authorize permits governing the operation of facilities. Compliance reports, inspections, and violations occur as Events under these permits, and population-level impacts are captured as Observations.

Representing delegation and implementation explicitly allows CAE to trace how authority flows from abstract law to concrete outcomes without conflating normative intent with execution.

7.3 Selective Inclusion and Modeling

CAE does not require comprehensive inclusion of all laws or regulations. Normative and regulatory instruments are introduced only when they ground accountability-bearing Events or Observations. This selective inclusion strategy prevents ontological bloat and supports scalable implementation.

For instance, a health statute need not be modeled until insurance programs, payments, enforcement actions, or outcome measurements associated with that statute are introduced. The presence of an instrument in CAE is therefore driven by its operational relevance rather than by its legal prominence.

This design ensures that CAE remains extensible and performant while preserving the structural relationships necessary for accountability analysis.

7.4 Jurisdictional Scope and Applicability

Every normative or regulatory instrument applies within one or more Jurisdictions. Jurisdictional scope is represented explicitly through relationships rather than being implied by instrument identity. This allows instruments with overlapping or nested applicability to coexist without ambiguity.

Explicit jurisdictional modeling supports comparative analysis across regions and time, enabling the study of how differing legal regimes relate to variations in events and observations. It also permits instruments to evolve or be superseded without altering the identity of affected entities.

7.5 Accountability Chains and Observability

An accountability chain is defined as a connected subgraph linking normative or regulatory instruments to concrete events and observations through delegation, issuance, participation, and measurement relationships. Such chains make explicit how public authority is exercised and how its consequences are observed.

CAE does not assert causal claims within these chains. Instead, it provides a structural representation that allows causal hypotheses to be articulated, tested, or debated using evidence and explanations attached at analytic layers above CAE. This separation of structure from inference ensures neutrality while enabling rigorous analysis.

7.6 Implications for Longitudinal Analysis

By modeling laws and regulations as enduring instruments within accountability chains, CAE supports longitudinal analysis of public interventions. Changes in legal regimes, regulatory thresholds, or enforcement practices can be represented as modifications or additions to instruments and relationships rather than as redefinitions of entities.

This approach enables comparative study of long-term public investments and policy choices, such as infrastructure development, public health interventions, or environmental regulation, while preserving continuity of entity identity across time.

8 Outcomes, Observations, and Public Value

This section addresses how CAE represents outcomes and public value through Observations, enabling longitudinal and comparative analysis of civic systems without embedding normative judgments or causal assertions in the ontology itself. CAE treats outcomes as observable properties of actors, sites, or jurisdictions over time, grounded in accountability chains but analytically distinct from actions and obligations.

By separating structure from interpretation, CAE enables outcomes to be examined as inspectable evidence rather than as implicit conclusions.

8.1 Observations as First-Class Entities

Observations are first-class entities within CAE, distinct from Events and Instruments. An Observation represents a measurement, indicator, or statistical assertion describing the state, performance, or outcome associated with one or more accountable entities. Observations do not create obligations, authorize actions, or record occurrences; they assert measured or derived facts with explicit provenance.

Examples include public health metrics, infrastructure coverage rates, emissions intensity measures, food access indicators, educational attainment statistics, and economic or environmental indices. Observations may be derived from surveys, administrative data, sensors, or analytic models, and may be reported at varying levels of aggregation.

Treating Observations as a distinct entity kind prevents the conflation of measurement with action and ensures that outcome data can evolve independently of the instruments or events that give rise to it.

8.2 Attachment and Scope of Observations

Observations may be associated with Actors, Sites, Jurisdictions, or defined populations through typed relationships. For example, a health outcome observation may be associated with a jurisdiction and a demographic group, while an emissions intensity observation may be associated with a site or facility.

Temporal scope is an intrinsic property of Observations, enabling representation of trends, baselines, and changes over time. Spatial and jurisdictional scope are represented explicitly, allowing comparable observations to coexist across regions with differing legal or institutional contexts.

This explicit attachment enables comparative analysis without requiring redefinition of entity identity or reclassification of entity kinds.

8.3 From Accountability Chains to Outcome Analysis

Observations are connected to accountability chains through relationships to Events, Instruments, and Jurisdictions. These connections make explicit which instruments and actions are relevant to a given outcome without asserting that any particular instrument caused the observed result.

For example, public health outcomes may be associated with vaccination programs, regulatory regimes, and funding events through shared jurisdictions and temporal overlap. Infrastructure access observations may be linked to investment programs, construction events, and regulatory requirements governing service provision.

By representing these connections structurally, CAE enables analysts to examine patterns, correlations, and hypotheses while preserving neutrality with respect to causation.

8.4 Public Value and Long-Term Investments

Many of the most consequential civic investments involve high upfront costs and long-term, diffuse benefits. Examples include public health interventions, communications infrastructure, transportation systems, education, and basic scientific research. Such investments often resist evaluation under short-term accounting frameworks.

CAE supports representation of public value by allowing Observations to capture longitudinal outcomes such as population health, access to services, economic mobility, environmental quality, and quality of life. These outcomes can be examined alongside the instruments and events that structure investment and governance, enabling analysis that extends beyond immediate financial return.

This capability is essential for examining effectiveness and efficiency of public spending without reducing value to short-term metrics alone.

8.5 Neutrality and Interpretive Separation

CAE deliberately avoids encoding evaluative judgments or causal conclusions in the ontology. Whether an outcome is considered desirable, effective, or efficient is a matter of interpretation, policy choice, or analysis external to the ontological layer.

By providing a structured representation of entities, relationships, and observations, CAE enables such interpretations to be made explicit, contested, and revised. This separation of representation from judgment supports transparency, reproducibility, and pluralistic analysis.

8.6 Implications for Comparative and Global Analysis

The explicit representation of Observations, Jurisdictions, and accountability chains enables comparative analysis across regions, institutions, and time. Differences in legal regimes, investment strategies, or governance structures can be examined alongside corresponding variations in outcomes without requiring domain-specific ontological extensions.

This design supports global comparison of public interventions, infrastructure development, and social outcomes, making long-term effects inspectable even in the presence of incomplete or heterogeneous data sources.

9 Discussion and Limitations

CAE is intentionally conservative in its ontological commitments. It does not attempt to enumerate all possible civic entities, nor does it claim completeness with respect to real-world institutional complexity. Entities are introduced only insofar as they participate in accountability-bearing relationships, and many socially significant phenomena remain outside the scope of the ontology.

The framework does not encode causal claims, evaluative judgments, or policy

prescriptions. While CAE enables structural comparison and longitudinal analysis, interpretation of outcomes and attribution of causality are deferred to analytic layers built upon the ontology. This design choice prioritizes neutrality and reusability over prescriptive modeling.

CAE also depends on the quality and availability of upstream data sources. Incomplete, inconsistent, or biased data may limit the conclusions that can be drawn from analyses grounded in the ontology. However, by making structural relationships explicit, CAE enables such limitations to be surfaced rather than hidden.

Finally, while CAE is designed to be stable over time, real-world institutions, laws, and measurement practices evolve. The ontology accommodates such evolution through the addition or modification of entities and relationships without requiring reclassification or type mutation. This approach supports incremental extension while preserving semantic continuity.

The adequacy of CAE is evaluated using competency questions grounded in real civic datasets rather than axiomatic completeness.

10 Conclusion

This paper has introduced CAE, a formal ontology of civic accountable entities designed to represent the structural relationships underlying civic accountability. By defining a strict, disjoint partition of entity kinds and constraining admissible relationships, CAE establishes a stable foundation for modeling obligations, authority, actions, and outcomes.

The ontology emphasizes accountability as the organizing principle, enabling representation of long-term public investments, regulatory regimes, financial flows, and measured outcomes without collapsing structure into interpretation. By separating ontological commitment from domain-specific vocabularies and analytic methods, CAE supports interoperability, auditability, and longitudinal analysis across jurisdictions and time.

CAE is designed to be extensible, neutral, and durable. It supports downstream frameworks for modeling exchanges and attaching structured explanations to civic decisions, without requiring modification of the ontological kinds defined here. The six entity kinds and their structural constraints provide a basis for making civic systems and their outcomes inspectable, comparable, and accountable.

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Appendix A. Worked Examples

A.1 Instrument Examples¹

Scope note (non-normative): The labels used in this subsection (e.g., “normative,” “programmatic,” “procedural”) are descriptive only. They do not introduce formal subclasses, types, or constraints on Instruments within CAE. All entities listed here remain members of the single Instrument kind defined in Section 4.3.

These examples illustrate common kinds of authoritative documents and the general instrumental function they represent.

A normative Instrument may be a high-level authoritative document that establishes obligations, rights, or responsibilities. Examples may include:

- A federal statute enacted by Congress (e.g., the Clean Water Act).
- A state regulation promulgated by an environmental agency (e.g., air quality standards).
- A municipal ordinance adopted by a city council (e.g., zoning regulations).
- An international treaty ratified by national governments (e.g., Paris Agreement on climate change).
- A constitutional provision establishing fundamental rights or governance structures.

A programmatic Instrument may be an Instrument explicitly established by an authority that creates standing obligations or eligibility conditions. These exist independently of any single payment, award, or inspection, and continue to ground accountability over time. Examples may include:

- A federal grant program established by statute or agency rule (e.g.,

¹These examples are illustrative and do not define a controlled vocabulary or formal typology of Instruments.

a transportation infrastructure grant program with defined eligibility, reporting, and audit requirements).

- A state procurement program that defines allowable vendors, contracting thresholds, and compliance obligations.
- A public benefits program (housing assistance, health coverage, educational aid) with formally defined enrollment rules and verification requirements.
- A research funding program operated by a public agency with binding reporting, data-sharing, or compliance conditions.
- A regulatory compliance program (e.g., emissions reporting, safety certification) that structures recurring obligations across many Events.

A formally adopted procedural regime may be a procedural Instrument that is binding because it is adopted. These constrain how decisions or actions must be carried out, not just what is allowed.

Examples may include:

- A procurement evaluation procedure formally adopted by an agency (e.g., a scoring rubric mandated by policy or regulation).
- A compliance review process required by regulation (e.g., mandatory inspection sequences or escalation rules).
- A grant review workflow codified in agency policy that determines eligibility, ranking, and award decisions.
- A data reporting protocol mandated by regulation (e.g., required schemas, submission cycles, validation steps).
- A formally adopted analytical methodology when explicitly named in statute, rule, or contract (e.g., a required risk-scoring method used for eligibility or enforcement).

Many Instruments combine multiple functional aspects. For example, a statute may authorize a program, mandate procedures, and define reporting obligations. CAE does not require assigning an Instrument to a single

functional pattern; the examples above highlight dominant characteristics only. Formal typologies of Instruments are outside the scope of this paper.

This appendix also provides concrete examples illustrating how CAE’s six entity kinds and relationship constraints apply across different civic domains. The goal is to demonstrate that the ontology is sufficient for modeling diverse accountability scenarios without domain-specific extensions.

The following examples use real-world entities purely for illustrative purposes. No evaluative, legal, or causal claims are implied beyond the structural relationships shown.

A.2 Chicago Procurement: Following Federal Funds to Local Contractors

Scenario: The Federal Highway Administration (FHWA) provides funding to the Illinois Department of Transportation (IDOT), which contracts with a construction company to repair Chicago infrastructure.

CAE Representation:

Actors (A):

- FHWA (federal agency)
- IDOT (state agency)
- ABC Construction Company (contractor)
- City of Chicago (local government)

Instruments (I):

- Federal Highway Act (normative Instrument)
- IDOT-FHWA Grant Agreement (programmatic Instrument)
- Construction Contract (programmatic Instrument)

Events (E):

- Payment from FHWA to IDOT (\$2.5M, 2024-03-15)
- Payment from IDOT to ABC Construction (\$2.4M, 2024-04-01)
- Project completion inspection (2024-11-20)

Sites (S):

- Bridge on Interstate 90 (infrastructure site)

Jurisdictions (J):

- United States (federal scope)
- Illinois (state scope)
- Chicago (municipal scope)

Observations (O):

- Bridge safety rating (2025-01-10: "Good")
- Project completion rate (100%)

Key Relationships:

- *enacts*: Congress → Federal Highway Act
- *implements*: IDOT-FHWA Grant → Federal Highway Act
- *party-to*: FHWA → IDOT-FHWA Grant
- *party-to*: IDOT → IDOT-FHWA Grant
- *occurs-under*: Payment Event → IDOT-FHWA Grant
- *acts-on*: Inspection Event → I-90 Bridge
- *located-in*: I-90 Bridge → Chicago
- *measures*: Safety Rating → I-90 Bridge

Note: This example demonstrates selective inclusion. Many other federal programs, state agencies, and contractors exist but are not modeled unless they participate in accountability-bearing relationships relevant to this exchange.

A.3 Public Health Program: Statute to Population Outcomes

Scenario: The Affordable Care Act (ACA) authorizes the Department of Health and Human Services (HHS) to expand Medicaid. States adopt the expansion, health insurance coverage changes over time, with longitudinal changes observed in population health indicators.

CAE Representation:

Actors (A):

- U.S. Congress
- HHS (federal agency)
- California Department of Health Care Services (state agency)
- Kaiser Permanente (health insurer)

Instruments (I):

- Affordable Care Act (normative Instrument)
- Medicaid Expansion Regulation (regulatory Instrument)
- California Medicaid Plan (programmatic Instrument)

Events (E):

- California adopts Medicaid expansion (2014-01-01)
- Enrollment event (2014-03-15, 500,000 new enrollees)
- Claims payments (ongoing, monthly)

Jurisdictions (J):

- United States
- California

Observations (O):

- Uninsured rate (2013: 17%, 2020: 7%)
- Preventable hospitalizations (2013: 45 per 1000, 2020: 32 per 1000)

- Life expectancy (measured at county level, longitudinal)

Temporal Structure: Events occur at specific times (2014-01-01, 2014-03-15), while Observations track outcomes over years (2013-2020). The ACA (Instrument) remains an enduring entity throughout this period.

Accountability Chain: Observations are connected to the ACA through shared Jurisdictions and temporal overlap, enabling analysis of health outcomes before and after expansion. CAE does not assert that the ACA caused the improvements, but it makes the structural connections explicit for hypothesis testing.

A.4 Environmental Regulation: Permits and Emissions

Scenario: The Clean Air Act authorizes the EPA to regulate emissions. A state environmental agency issues a permit to a power plant. The plant submits emissions reports, and air quality is monitored.

CAE Representation:

Actors (A):

- EPA (federal regulator)
- Ohio EPA (state regulator)
- FirstEnergy (power plant operator)

Instruments (I):

- Clean Air Act (normative Instrument)
- Title V Operating Permit (regulatory Instrument)

Events (E):

- Permit issuance (2020-06-01)
- Quarterly emissions report (2024-10-01)
- Compliance inspection (2024-11-15)

Sites (S):

- W.H. Sammis Power Plant (coal facility)

Jurisdictions (J):

- United States
- Ohio
- Stratton Air Basin (regulatory region)

Observations (O):

- $O_{\text{SO}_2}^{\text{intensity}}(2024\text{Q3}) = 0.12 \text{ lb/MMBtu}$
- $O_{\text{PM}_{2.5}}^{\text{ambient}} = 8.5 \text{ }\mu\text{g/m}^3$

Jurisdictional Nesting: The Stratton Air Basin (environmental jurisdiction) overlaps with Ohio (political jurisdiction). Both are represented as distinct Jurisdictions with explicit *contains* relationships.

Actor-Site Distinction: FirstEnergy (Actor) operates the Sammis Plant (Site). The permit constrains the Site’s operations, while FirstEnergy bears the legal obligation to comply.

A.5 Infrastructure Investment: Long-Term Public Value

Scenario: A state issues bonds to fund rural broadband infrastructure. Private ISPs are awarded contracts to build fiber networks. Over time, internet access and economic indicators improve.

CAE Representation:

Actors (A):

- Minnesota Department of Employment and Economic Development (state agency)
- Arvig Communications (ISP contractor)

- Local counties (grant recipients)

Instruments (I):

- Minnesota Broadband Development Act (normative Instrument)
- Bond authorization (programmatic Instrument)
- Construction grant (programmatic Instrument)

Events (E):

- Bond issuance (2018-03-01, \$100M)
- Grant award (2018-06-01, \$5M to Arvig)
- Network completion (2020-12-01)

Sites (S):

- Fiber optic network (rural Minnesota)

Jurisdictions (J):

- Minnesota
- Clay County, Norman County (rural counties)

Observations (O):

- Broadband access rate (2018: 45%, 2023: 92%)
- Median household income (2018: \$52K, 2023: \$58K)
- Remote work adoption (2019: 8%, 2023: 24%)

Longitudinal Analysis: Observations span 5+ years, tracking outcomes well beyond the initial investment Events. This structure supports analysis of public value that accrues over decades, not just immediate financial returns.

Diffuse Benefits: Unlike direct procurement (Example B.1), infrastructure benefits are diffuse and population-level. Observations capture these outcomes explicitly rather than inferring them from transaction Events.

A.6 Role Multiplicity: University as Multi-Role Actor

Scenario: A university receives federal research grants, operates regulated laboratories, employs faculty researchers, and reports compliance data.

CAE Representation:

Single Actor (A):

- University of Minnesota

Multiple Relationship Patterns:

- *party-to*: University → NSF Grant (role: grant recipient)
- *operates*: University → Biosafety Lab (role: facility operator)
- *employs*: University → Researcher (role: employer)
- *subject-of*: Compliance Inspection → University (role: regulated entity)

Role as Relationship Pattern: The university is a single Actor. Its roles (recipient, operator, employer, regulated entity) emerge from its relational position with respect to Instruments, Sites, and Events. No reclassification is needed when roles change.

Appendix B. Diagrammatic Intuition

This appendix provides informal diagrams for the entity kinds, relationships, and accountability chains introduced in the main text. The goal is to support intuition rather than to introduce new formal content.

B.1 Entity Kinds and Disjointness

Figure 1 depicts the six entity kinds as disjoint sets.

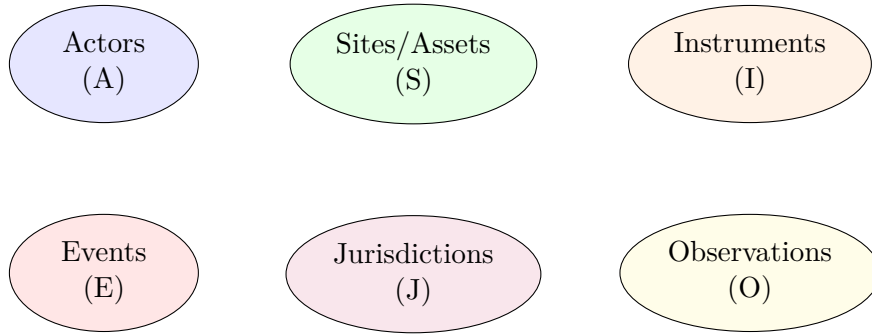


Figure 1: The six disjoint entity kinds in CAE. Each entity belongs to exactly one kind, and kinds do not overlap.

B.2 Accountability Chain: Statute to Outcomes

Figure 2 visualizes an accountability chain from a federal statute through regulatory implementation to observed outcomes.

B.3 Relationship Constraints by Entity Kind

Figure 3 shows representative relationship types and the entity kinds they connect.

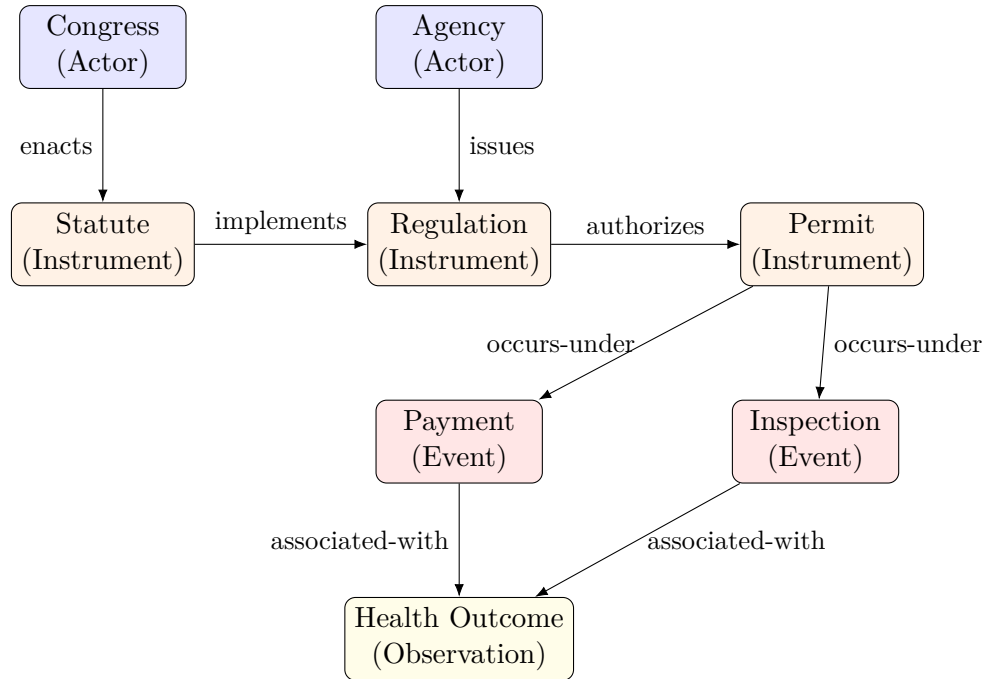


Figure 2: An accountability chain from normative instrument (statute) through regulatory implementation to observed outcomes. Authority flows downward, while Observations connect back to Events and Instruments.

B.4 Role Emergence from Relationship Patterns

Figure 4 illustrates how a university (single Actor) occupies multiple roles through different relationship patterns.

B.5 Temporal Structure: Enduring vs Time-Indexed Entities

Figure 5 contrasts enduring entities (Actors, Instruments, Sites, Jurisdictions) with time-indexed entities (Events, Observations).

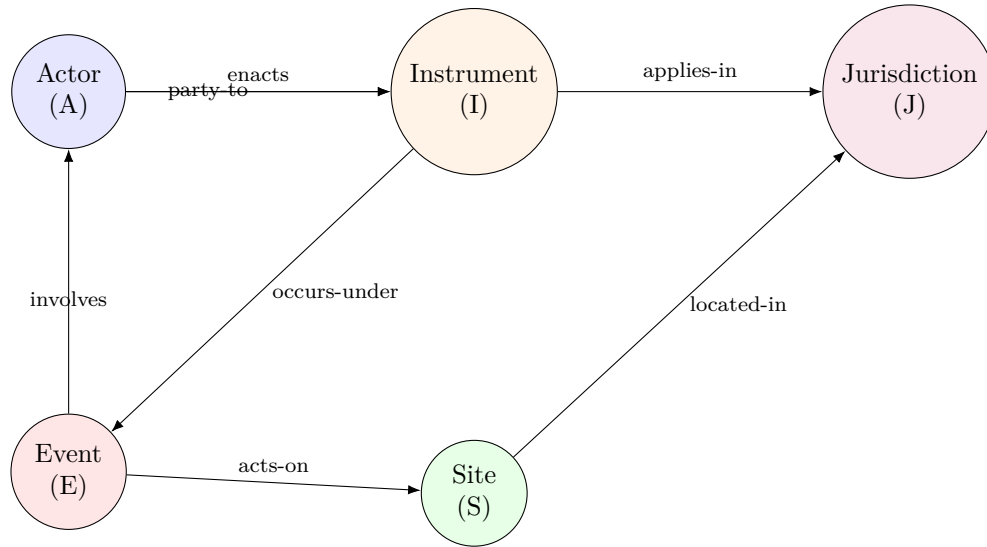


Figure 3: Representative relationship types constrained by source and target entity kinds. For example, *enacts* requires Actor \rightarrow Instrument.

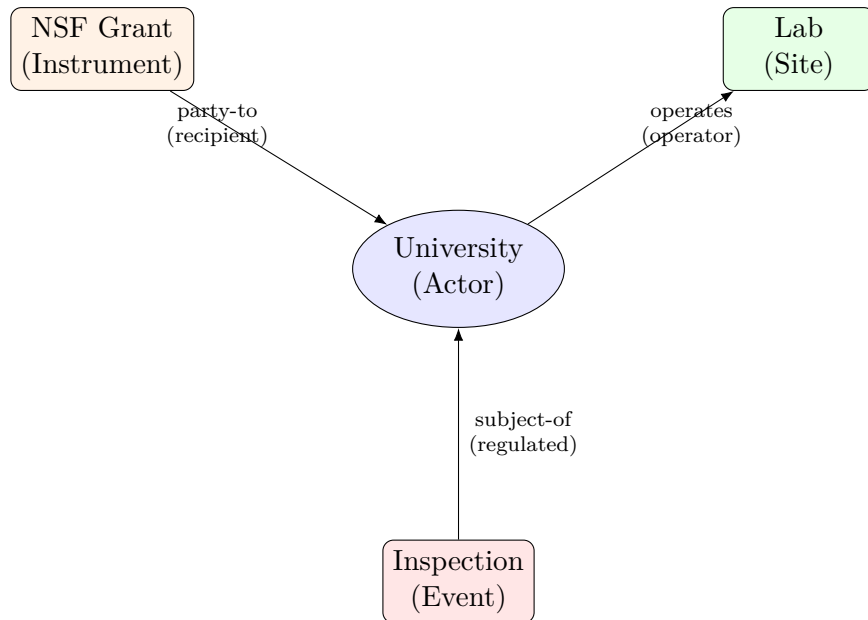


Figure 4: A single Actor (university) occupies multiple roles (recipient, operator, regulated entity) through different relationship patterns. Roles emerge from structure, not from entity kind.

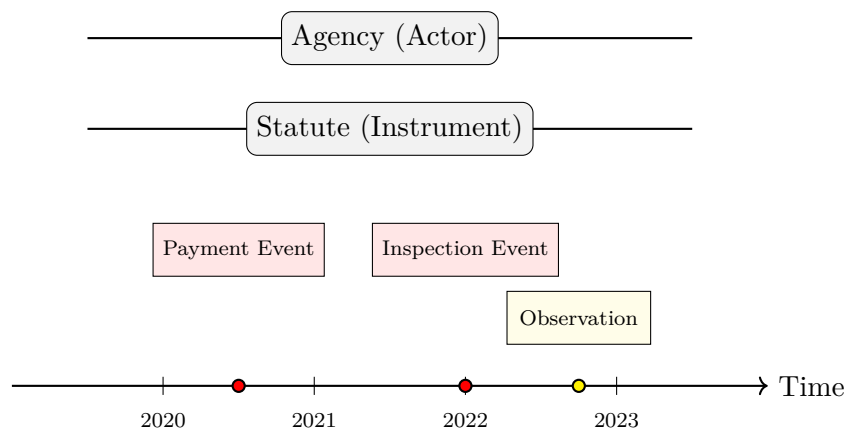


Figure 5: Temporal structure in CAE. Actors and Instruments are enduring entities that persist over time. Events and Observations are time-indexed occurrences.

Appendix C. Glossary of Terms

This appendix provides concise definitions of key terms used throughout the paper.

Entity Kinds

Actor (A): An entity capable of bearing rights, obligations, or responsibilities within civic systems when acting as an accountable party. Examples include governments, public agencies, businesses, nonprofits, and universities.

Site/Asset (S): A physical or operational entity that is acted upon but does not bear obligations. Examples include facilities, buildings, infrastructure, and power plants.

Instrument (I): An enduring construct that creates, modifies, or constrains rights, obligations, or authority. Examples include statutes, regulations, contracts, grants, permits, and licenses.

Event (E): A time-indexed occurrence asserted under the authority of an Instrument. Examples include payments, inspections, filings, violations, and audits.

Jurisdiction (J): An entity that scopes authority, applicability, and governance, defining where Instruments apply and where Events occur. Examples include nations, states, municipalities, and regulatory regions.

Observation (O): A measurement or indicator describing state, performance, or outcomes. Observations do not create obligations or authorize actions. Examples include health outcomes, coverage rates, emissions intensity measures, and educational attainment indicators.

Design Concepts

Accountability Analysis: The examination of relationships, obligations, and authority structures within civic systems in order to make responsibility and oversight inspectable.

Accountability-bearing Relationship: A relationship that establishes or reflects accountability obligations between entities, such as delegation of authority, participation in an Event, or the measurement of outcomes.

Applied Ontology: The use of ontological methods and principles to structure, clarify, and analyze real-world domains for practical purposes.

Competency Questions: Questions that an ontology should be able to answer, used to guide its development and to evaluate its adequacy for the intended domain.

Completeness: The extent to which an ontology captures the concepts and relationships required for its stated purpose, without implying exhaustive coverage of all possible phenomena.

Disjointness: The property that entity kinds do not overlap; each entity belongs to exactly one kind.

Domain Ontology: An ontology that captures concepts and relationships specific to a particular application domain. CAE is not a domain ontology.

Domain-Constrained Reference Ontology: An ontology that provides a stable, reusable set of entity kinds and relationships tailored to a particular domain, without committing to sector-specific taxonomies. CAE is a domain-constrained reference ontology.

Enduring Entity: An entity that persists through time while maintaining its identity, even as its properties or relationships change.

Entity Kind: A fundamental category of entities within the ontology, defined by distinct identity criteria and invariant over time.

Longitudinal Change: Variation or trends in data, conditions, or outcomes observed over extended periods of time.

Knowledge Representation: The formal specification of entities, relationships, and structures within a domain to support interoperability and structured analysis.

Ontology: A formal representation of entities within a domain and the relationships that hold between them.

Ontology Drift: The gradual divergence of an ontology’s scope, structure, or commitments from its original design intent.

Selective Modeling: The inclusion of entities based on operational relevance rather than exhaustive enumeration, introducing entities only when they participate in accountability-bearing relationships.

Semantics: The interpretation of structures and relationships defined by an ontology, without implying evaluative or causal claims at the ontological level.

Soundness: The property that an ontology’s definitions and constraints are internally consistent and aligned with their intended interpretations.

Subclassing: The creation of a hierarchy of classes or categories within an ontology, where more specific classes inherit properties and relationships from more general ones. CEA avoids subclassing within its six entity kinds.

Time-Indexed Entity: An entity whose identity or assertions are associated with specific points or intervals in time.

Upper Ontology: A domain-independent ontology intended to provide general categories applicable across many domains. CAE is not an upper ontology.

Instrument Roles (Descriptive)

Normative role (descriptive): A functional role in which an Instrument establishes authority or defines obligations. Examples include statutes, acts, and treaties.

Regulatory role (descriptive): A functional role in which an Instrument specifies procedures, thresholds, or requirements. Examples include regulations, rules, and administrative codes.

Methodological Context

CAE is a formal ontology in the knowledge representation tradition: a specification of what kinds of entities exist in the civic accountability domain, what properties they have, and what relationships hold between them. The six entity kinds form a strict partition: each entity belongs to exactly one kind, and kinds do not overlap. This structure supports rigorous, neutral reasoning about obligations, authority, and evidence without embedding causal or evaluative assumptions.

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