Individual Assignment I – Ontological Modeling

-Glass Curtain Wall Facade Systems-

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1. Introduction and Background Research

The purpose of this study is to develop an ontology-based representation of the curtain wall façade system in order to support systematic performance and sustainability analysis. The research domain of this ontology is the curtain wall façade system, a non-load-bearing external envelope commonly used in modern high-rise buildings. A curtain wall integrates glass panels, aluminum frames, silicone sealants, gaskets, anchors, and surface coatings, providing weather protection, daylighting, and architectural continuity. According to the Code of Practice for the Mandatory Building Inspection Scheme [7], curtain walls require periodic inspection due to safety issues such as loose fixings, corroded frames, and degraded sealants.

In humid subtropical climates, typhoon wind pressure, ultraviolet exposure, and high humidity accelerate both chemical and mechanical deterioration. Previous studies [2][3] indicate that curtain wall deterioration is a gradual process influenced by material properties and environmental exposure.

The ontology developed in this study formalizes the curtain wall into three conceptual categories:

1. ***Physical components*** – subdivided into **primary framing** (mullions, transoms, anchors) that transfer loads to the structure, and **secondary sealing and infill subsystems** (glass units, gaskets, sealants) that ensure airtightness and water resistance.

2. ***Material types*** – glass, aluminum, silicone, EPDM, and fluoropolymer coatings, which determine structural strength, durability, and optical performance [1][3].

3. ***Functional roles*** – weather barrier, structural interface, and visual transparency, defining the façade's technical and architectural purpose [7].

The inclusion of these categories follows façade engineering logic: **components** define geometry and assembly, **materials** define behavior and durability, and **functions** define performance objectives.

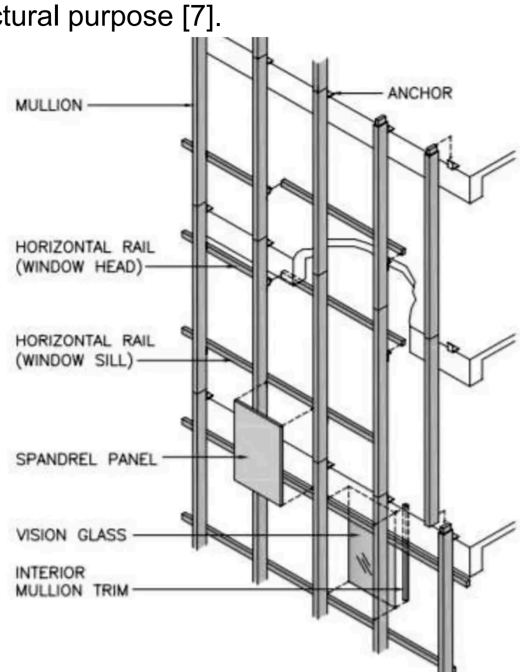


Figure 1. Curtain Wall Structural Composition and Primary Framing Elements

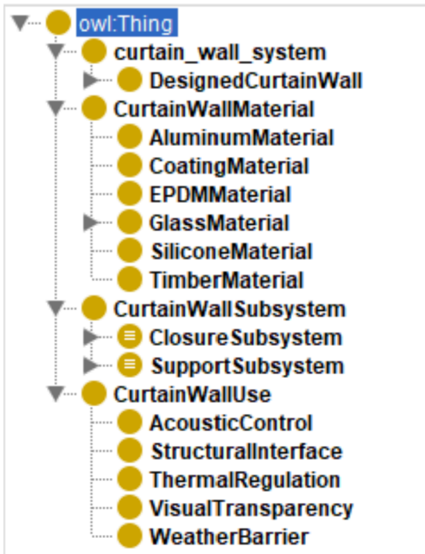
2. Ontology Development Process

2.1 Purpose and Scope

The ontology's main purpose is to represent façade knowledge for **performance comparison** and **sustainability evaluation**.
Its scope includes:
1. System configuration and hierarchical composition
2. Material typology and associated environmental impacts
3. Performance data such as *U-value*, *Sound Transmission Class (STC)*, and *Embodied Carbon.*

2.2 Class Hierarchy Design

The ontology is structured into **five top-level classes**, each reflecting a fundamental dimension of façade design:



Top-Level Class	Description	Example Subclasses
CurtainWallSystem	The overall façade assembly; main container for all subsystems and materials.	DesignedCurtainWall CurtainWallOption1_Single CurtainWallOption2_Double
CurtainWallMaterial	Physical construction materials that define mechanical, optical, and chemical properties.	AluminumMaterial, GlassMaterial, SiliconeMaterial, EPDMMaterial, TimberMaterial, CoatingMaterial
CurtainWallSubsystem	Intermediate layer representing functional assemblies.	ClosureSubsystem, SupportSubsystem
CurtainWallUse	Abstract functions describing façade performance roles.	AcousticControl, StructuralInterface, ThermalRegulation, VisualTransparency, WeatherBarrier

Table2.2-1 Structure of Ontology

2.3 Object Properties

The ontology's semantic relations are defined through a **hierarchical property structure**, as shown below:

Property	Domain → Range	InverseOf
hasSubsystem	CurtainWallSystem → CurtainWallSubsystem	isSubsystemOf
hasClosureSubsystem	CurtainWallSystem → ClosureSubsystem	isClosureSubsystemOf
hasSupportSubsystem	CurtainWallSystem → SupportSubsystem	isSupportSubsystemOf
hasPrimaryElement		
hasMaterial	CurtainWallSystem → CurtainWallMateria	isMaterialOf
hasInfill	CurtainWallSystem → GlassMaterial	isInfillOf
hasUse	CurtainWallSystem → CurtainWallUse	isUseOf

Table 2.2-2 Ontology's Semantic Relations

3. Engineering Applications and Case Study

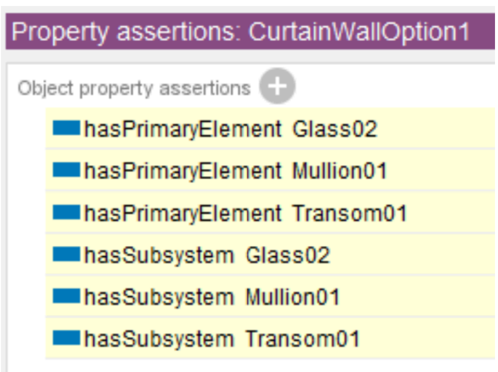
3.1 Overview

To demonstrate the applicability of the curtain wall ontology, three façade configurations were modeled as individuals under the DesignedCurtainWall class.
Each configuration represents a distinct design approach—ranging from basic aluminum-glass construction to advanced low-carbon hybrid systems—allowing comparison in material composition, subsystem hierarchy, and environmental performance.

Ontology Individual	Façade Type	Key Feature	Complexity Level
CurtainWallOption1_Single	Single-glazed curtain wall	Simple aluminum frame with single glass unit	Low
CurtainWallOption2_Double	Double-glazed curtain wall	Larger mullions with double-glazed vision glass	Medium
CurtainWallOption3_LowC	Low-carbon hybrid façade	Timber-supported structure with shading spandrel	High

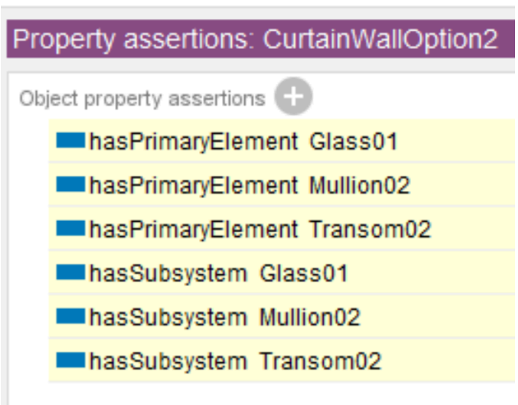
Table 3.1-1 the Generic Curtain Wall Structure and Element

3.2 CurtainWallOption1 – Single Glass Unit System



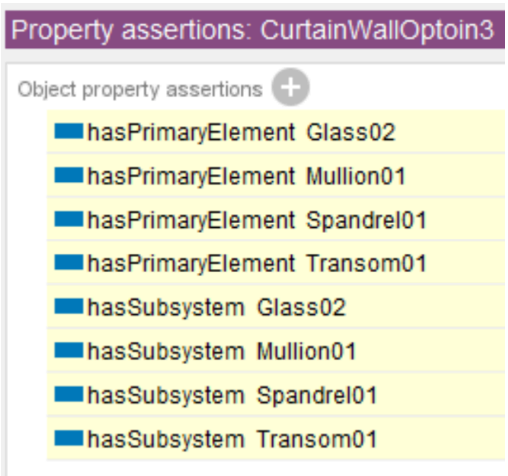
The first configuration models a **single-glazed stick system** composed of *Glass02* and *AluminumMaterial*. Object properties link the system to its essential subsystems through hasPrimaryElement (Mullion01, Transom01) and hasSubsystem (ClosureSubsystem and SupportSubsystem). Functional roles include VisualTransparency and WeatherBarrier, indicating basic daylight and protection capabilities. From a performance perspective, this system represents **a baseline façade** with high transparency (91.5%), moderate sound insulation (STC 32 dB), and limited thermal performance (U = 2.8 W/m²K).

3.3 CurtainWallOption2 – Double Glazed System



The second configuration introduces a **double-glazed façade** with a more robust structural framing (Mullion02, Transom02) and *Glass01* infill. Ontology relations were expanded to include hasInfill some DoubleGlazedUnit and hasUse some ThermalRegulation and so on, representing enhanced insulation functions.The U-value improves to **1.4 W/m²K**, and sound transmission loss increases to **STC 38 dB**, while transparency slightly decreases to **85%**.

3.4 CurtainWallOption3 – Low Carbon Hybrid System



The third configuration models a **low-carbon adaptive curtain wall**, incorporating *TimberMaterial* in the structural frame and *Spandrel01* as a shading subsystem.
This model introduces new relationships such as hasPrimaryElement value Spandrel01 and hasUse some StructuralInterface, bridging visual, thermal, and load functions. It achieves the lowest embodied carbon (**120 kg CO_2e/m^2**) and best thermal efficiency (**U = 1.2 W/m^2K**), due to reduced aluminum use and the integration of timber and shading components.

The ontology successfully supports multi-criteria comparison of curtain wall systems through structured semantic attributes, linking *object properties* with *data properties*.

4. Discussion and Reasoning Results

4.1 Ontology Reasoning and Structural Logic

After defining object properties, a reasoner was applied to validate the consistency of the ontology and automatically classify subclass relationships. The reasoning confirmed a **hierarchical logic** between the *CurtainWallSystem*, *Subsystems*, and *Material classes*.

When reasoning was executed, Protégé successfully inferred subclass relationships among the closure and support systems and validated the existence of composite individuals. This demonstrates that the ontology maintains **logical consistency and semantic traceability**.

4.2 Sustainability and Performance Reasoning

Through the structured data properties assigned to each individual, the ontology can reason about sustainability attributes such as **thermal efficiency**, **sound insulation**, and **embodied carbon intensity**.
When queried through SPARQL or reasoned in Protégé, the system could group façades by material performance. This reasoning layer demonstrates the ontology's capacity to function not just as a taxonomy, but as a **knowledge-based evaluation framework**.

4.4 Conclusion

This study addresses the problem of fragmented and unstructured knowledge in curtain wall façade systems by developing a formal ontology that enables structured reasoning on performance and sustainability. The ontology provides a systematic knowledge framework for comparing façade configurations in terms of materials, subsystems, and environmental impact, and offers a scalable foundation for future integration with BIM and digital twins, supporting automated façade specification checks, rule-based compliance queries, and multi-criteria decision-making on U-value, and embodied carbon.

5. References

[1] K. P. Allana, *Curtain Wall Handbook*, 2017.
[2] E. T. Yalaz, *Curtain Wall Deficiency and Failures: Observations on Multi-Story Buildings in Istanbul*, 2016.
[3] F. B. de Souza, *Polymer Degradation and Stability: Environmental Aging of Building Envelope Components*, 2025.
[4] *Damage Assessment of Curtain Wall Glass*, 2015.
[5] Central Weather Administration (CWA), *Taiwan Climate Statistics Report*.
[6] Environmental Protection Administration (EPA), *Acid Rain and Air Pollution Annual Report*.
[7] Buildings Department, HKSAR, *Code of Practice for the Mandatory Building Inspection Scheme (MBIS)*, 2023.
[8] Arup & Saint-Gobain Glass, *The Carbon Footprint of Façades: The Significance of Glass*, 2023.
[9] Clayton Glass Ltd., *Table of U-Values*, 2022