Development of a Rooftop Helipad Ontology for Civil and Structural Engineers

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1. Introduction

- **Purpose**

  To provide a logically structured knowledge model of rooftop helipads in order to support conceptual design, safety evaluation, and communication between engineers and non-experts.
- **Scope**

  The ontology includes structural aspects like substructure, superstructure, and operational aspects (use, materials, safety parameters) of rooftop helipads but excludes aerodynamic or flight control modeling.
- **Intended Users**

  Civil and structural engineers, architects, and safety consultants. It also includes clients such as hospital administrators and developers as well.
- **Intended Use**
  1. To act as a common knowledge base for engineers.
  2. To define design parameters such as diameter, load, friction.
  3. To help compliance with heliport standards.
  4. To act as an educational resource for students who are interested in rooftop aviation infrastructure.

2. System Overview and Background Research

A rooftop helipad is a **landing and take-off area** located on the roof of a building. According to the International Civil Aviation Organization (ICAO, 2020), heliports consist of a Final Approach and Take-Off area (FATO) and a Touchdown and Lift-Off area (TLOF). The structural design of rooftop helipads must satisfy load, vibration, and safety requirements defined in CAP 1264 – Standards for Helicopter Landing Areas at Hospitals (Civil Aviation Authority [CAA], 2025). Materials may include reinforced concrete or aluminium alloys, designed to limit noise and vibration transmission (NORSOK C-004, 2013).

Two design options were studied:

- **Aluminium Helipad**: A modular system with lightweight deck panels supported by an aluminium frame (Fech Heliports, 2024).
- **Concrete Helipad**: A heavier integral pad cast into the roof slab, providing durability and rigidity (ICAO, 2020).

Environmental interfaces include integration with the building's roof structure, electrical systems (lighting), and flight safety control systems (NORSOK C-004, 2013).

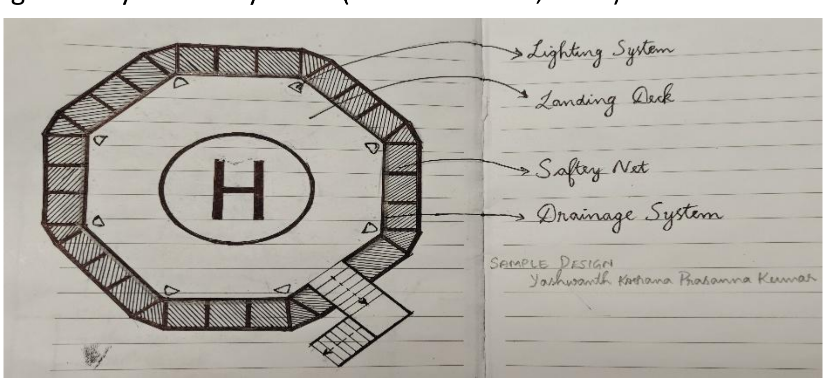

Figure 1: Conceptual diagram of Rooftop Helipad showing main Components

3. Ontology Development

The ontology was implemented in **Protégé 5.6.8** using **OWL 2 DL** reasoning. Its development followed *Noy and McGuinness (2001)* "Ontology Development 101" methodology and the modeling logic introduced in the bridge tutorial (Krötzsch et al., 2012).

3.1 Class Hierarchy and Its Purpose

The class structure was chosen to represent both the physical and operational decomposition of the helipad. Structural elements like SubstructureHelipad and SuperstructureHelipad support mechanical reasoning about load and stiffness, whereas HelipadUse and HelipadMainMaterial allow classification by purpose and composition. The class hierarchy is as shown in Figure 2.

Disjoints: Defined between Helipad, HelipadDomain, HelipadMainMaterial and HelipadUse to prevent classification overlap.

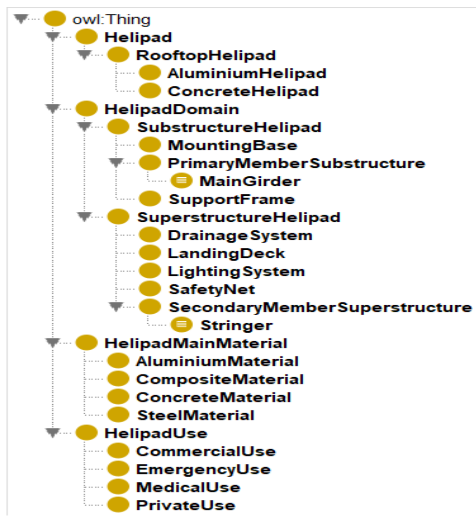

Figure 2: Class hierarchy

3.2 6 Object and Data Properties: Representing Structural and Operational Logic

Object properties were created to represent physical and logical relationships between components, reflecting how design engineers describe real-world assemblies. For example, hasSubstructure and hasSuperstructure correspond to the physical hierarchy of the deck and frame, while data properties capture quantitative design parameters required for regulatory compliance (CAA, 2025; ICAO, 2020).

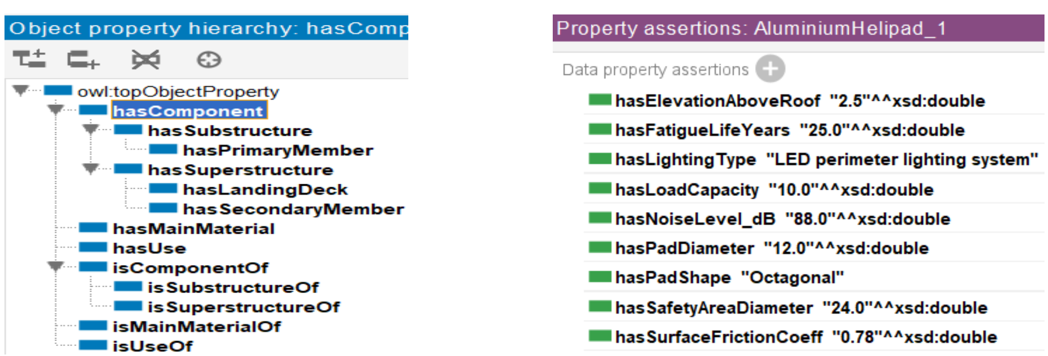

Figure 3: Object and data properties view in Protégé.

3.3 Logic Axioms

The ontology's logic axioms ensure that helipads are automatically classified based on their components and parameters. Using both existential and value restrictions allows engineers to reason about incomplete or specific configurations, similar to parametric modeling workflows.

The ontology's logical structure can be divided into its terminological (TBox), role (RBox), and assertional (ABox) components, following the description logic framework outlined by Krötzsch et al. (2012).

* TBox – Terminological Axioms

Concept / Class	Axiom / Relationship	Description
Helipad ⊑ hasSubstructure some SubstructureHelipad	Existential restriction	Every Helipad has a substructure
Helipad ⊑ hasSuperstructure some SuperstructureHelipad	Existential restriction	Every Helipad has a superstructure
Helipad ⊑ hasMainMaterial some HelipadMainMaterial	Existential restriction	Helipads are made from some material
Helipad ⊑ hasUse some HelipadUse	Existential restriction	Helipads serve a defined purpose
AluminiumHelipad ⊑ Helipad	Subclass	Aluminium Helipad is a type of helipad
ConcreteHelipad ⊑ Helipad	Subclass	Concrete helipad is a type of Helipad
HelipadMainMaterial ⊥ HelipadUse	Disjoint classes	Prevents overlap between material and use

* RBox – Role (Property) Axioms

Property	Inverse / Domain / Range	Description
hasSubstructure	Inverse: isSubstructureOf	Links Helipad to its supporting frame
hasSupestructure	Inverse: isSupestructureOf	Links Helipad to its deck and fittings
hasLandingDeck	Domain: Helipad; Range: LandingDeck	Assigns a deck to each Helipad
hasMainMaterial	Inverse: isMainMaterialOf	Connects Helipad and material
hasUse	Domain: Helipad; Range: HelipadUse	Defines operational use
hasComponent	Transitive Property	For hierarchical structural inclusion

* ABox – Assertional Axioms

Individual	Class Membership	Data Properties / Values
AluminiumHelipad_1	AluminiumHelipad	hasPadDiameter = 12 m, hasLoadCapacity = 10 t, hasNoiseLevel_dB = 88, hasSurfaceFrictionCoeff = 0.78, hasElevationAboveRoof = 2.5 m
ConcreteHelipad_1	ConcreteHelipad	hasPadDiameter = 16 m, hasLoadCapacity = 15 t, hasNoiseLevel_dB = 92, hasSurfaceFrictionCoeff = 0.75, hasElevationAboveRoof = 2.5 m
SupportFrame_1	SubstructureHelipad	No data properties; object-linked to both helipads.
LandingDeck_Alu	SuperstructureHelipad	Assigned to AluminiumHelipad via hasLandingDeck
LandingDeck_Conc	SuperstructureHelipad	Assigned to ConcreteHelipad via hasLandingDeck

3.4 Individuals and Parametrization

Individuals represent boundary design options like minimum and maximum parameter sets. This enables parametric reasoning, where a designer or auditor can query allowable ranges for load capacity or noise limits (Krötzsch et al., 2012). Values were derived from ICAO (2020), CAA (2025), and Fech Heliports (2024) to maintain engineering realism.

Few example data properties:

Property	AluminiumHelipad_1	ConcreteHelipad_1	Unit / Source
hasPadDiameter	12	16	m (ICAO, 2020)
hasSafetyAreaDiameter	24	24	m (ICAO, 2020
hasLoadCapacity	10	15	t (CAA, 2025)
hasElevationAboveRoof	2.5	2.5	m (Fech Heliports, 2024)
hasSurfaceFrictionCoeff	0.78	0.75	– (NORSOK C-004, 2013)
hasNoiseLevel_dB	88	92	dB (CAA, 2025)

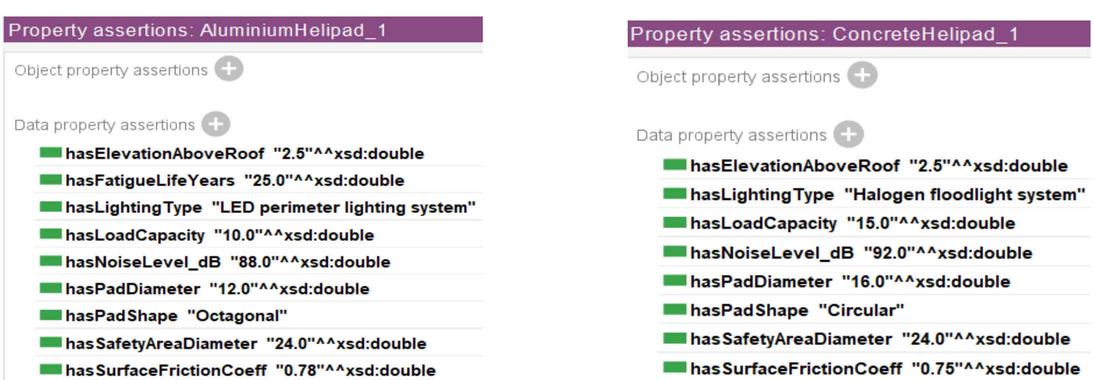

Figure 4: Individuals view in Protégé showing AluminiumHelipad_1 and ConcreteHelipad_1

3.5 Domain and Range

Defining domains and ranges reinforces logical precision, ensuring that relationships (e.g., hasSubstructure) only occur between valid engineering entities. This mirrors how data validation occurs in engineering databases, reducing modeling ambiguity.

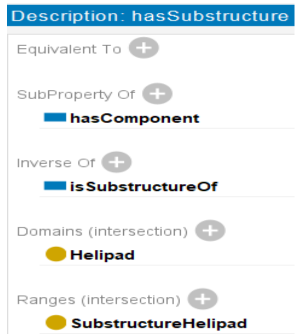

Figure 5: Domain and range panel example.

3.6 Ontology Procedures According to Noy and McGuinness

- **Transitivity:** Each subclass logically relates to its superclass (SubstructureHelipad ⊑ Helipad).
- **Class count:** Each class maintains 2–10 subclasses, per best practice.
- **Naming:** Spaces avoided for interoperability; descriptive terms preferred.
- **Disjointness:** Applied to HelipadUse and HelipadMainMaterial classes.
- **Generalization:** Sibling classes share equal levels of generality.
- **Multiple inheritance:** Avoided to maintain clarity, except when linking shared components (e.g., SupportFrame).
- **Annotations:** Provided for ontology reuse and clarity for future users.

4. Engineering Examples

1) Hospital Helipad Upgrade

Scenario: A city hospital plans to operate a new 10-ton rescue helicopter, but its existing rooftop helipad was designed for lighter aircraft.

Use Case: Using the ontology, engineers quickly identify both helipad configurations capable of supporting ≥10 t load capacity. The ontology highlights related components such as substructure frame and landing deck that would need verification. This structured knowledge allows the team to adapt the pad safely without redesigning the entire rooftop system.

2) High-Rise Retrofit Design

Scenario: A corporate tower developer wants to install a rooftop helipad but must minimize added weight and vibration.

Use Case: Through the ontology, designers compare aluminium and concrete deck options, viewing data such as elevation above roof, friction coefficients, and load limits. This helps them choose the lightweight aluminium system suitable for restricted roof capacity, ensuring both safety and regulatory compliance.

3) Medical-Use Certification

Scenario: A regulatory auditor reviews multiple helipads in the city to confirm those labeled for medical use meet safety-area and lighting standards.

Use Case: The ontology filters helipads tagged as MedicalUse, showing their associated deck dimensions and materials. This enables quick verification of which facilities meet emergency-service requirements before field inspection.

5. Discussion and Improvements

- The ontology was verified using the **Pellet reasoner**, which confirmed full logical consistency. The main difficulty was resolving an initial inconsistency caused by Equivalent To {…} axioms. Replacing these with value restrictions resolved the issue.
- The ontology successfully represents the key physical and functional aspects of rooftop helipads, supporting interoperability between structural design and regulatory documentation.
- **Potential Improvements:**
  The ontology can be expanded to include **dynamic load analysis**, **temperature effects**, or integration with **BIM models** for 3D coordination (Hartmann, 2024).
- Future work could also incorporate **material fatigue behaviour** of aluminium helidecks to support life-cycle design and maintenance evaluation (Pawiroredjo, 2013).

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