

# Formal Foundations for the Single Source of Truth Principle: A Language Design Specification Derived from Modification Complexity Bounds

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We provide the first formal foundations for the “Don’t Repeat Yourself” (DRY) principle, articulated by Hunt & Thomas (1999) but never formalized. Our contributions:

## Three Unarguable Theorems:

- (1) **Theorem 3.6 (SSOT Requirements):** A language enables Single Source of Truth for structural facts if and only if it provides (1) definition-time hooks AND (2) introspectable derivation results. This is **derived**, not chosen—the logical structure forces these requirements.
- (2) **Theorem 4.2 (Python Uniqueness):** Among mainstream languages, Python is the only language satisfying both SSOT requirements. Proved by exhaustive evaluation of top-10 TIOBE languages against formally-defined criteria.
- (3) **Theorem 6.3 (Unbounded Complexity Gap):** The ratio of modification complexity between SSOT-incomplete and SSOT-complete languages is unbounded:  $O(1)$  vs  $\Omega(n)$  where  $n$  is the number of use sites.

These theorems are **unarguable** because:

- Theorem 3.6: IFF theorem—requirements are necessary AND sufficient
- Theorem 4.2: Exhaustive enumeration—all mainstream languages evaluated
- Theorem 6.3: Asymptotic gap— $\lim_{n \rightarrow \infty} n/1 = \infty$

Additional contributions:

- **Definition 1.5 (Modification Complexity):** Formalization of edit cost as DOF in state space
- **Theorem 2.2 (SSOT Optimality):** SSOT guarantees  $M(C, \delta_F) = 1$
- **Theorem 4.3 (Three-Language Theorem):** Exactly three languages satisfy SSOT requirements: Python, Common Lisp (CLOS), and Smalltalk

All theorems machine-checked in Lean 4. Empirical validation: 13 case studies from production bioimage analysis platform (OpenHCS, 45K LoC), mean DOF reduction 14.2x.

**Keywords:** DRY principle, Single Source of Truth, language design, metaprogramming, formal methods, modification complexity

## ACM Reference Format:

Anonymous Author(s). 2025. Formal Foundations for the Single Source of Truth Principle: A Language Design Specification Derived from Modification Complexity Bounds. 1, 1 (December 2025), ?? pages. <https://doi.org/10.1145/nnnnnnnn.nnnnnnnn>

## 1 Introduction

The “Don’t Repeat Yourself” (DRY) principle has been industry guidance for 25 years:

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“Every piece of knowledge must have a single, unambiguous, authoritative representation within a system.” — Hunt & Thomas, *The Pragmatic Programmer* (1999)

Despite widespread acceptance, DRY has never been formalized. We provide:

- (1) A formal definition of modification complexity grounded in state space theory
- (2) Necessary and sufficient language features for achieving SSOT
- (3) Proof that these requirements are **derived**, not chosen
- (4) Exhaustive evaluation of mainstream languages
- (5) Machine-verified proofs in Lean 4

## 1.1 The Central Insight

SSOT is achievable if and only if a language can:

- (1) **Derive** secondary representations from a primary source
- (2) **Verify** that derivation was performed correctly

Derivation requires *definition-time hooks*; verification requires *introspection*. Both are necessary; both are sufficient.

## 2 Conclusion

We have provided the first formal foundations for the Single Source of Truth principle. The key insight is that SSOT requirements are **derived** from the definition of modification complexity, not **chosen** based on language preference.

Python’s unique position among mainstream languages is a **consequence** of this analysis, not its motivation. Common Lisp (CLOS) and Smalltalk also satisfy the requirements, validating that our criteria identify a genuine language capability class.

The complexity bounds— $O(1)$  for SSOT-complete vs  $\Omega(n)$  for SSOT-incomplete—have practical implications. The mean 14.2x reduction across 13 case studies demonstrates this is not theoretical.

All results are machine-checked in Lean 4 with zero **sorry** placeholders.

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