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Imperfection Modelling in Fault-Tolerant System Design

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INTRODUCTION & AIM

Traditional fault-tolerant engineering often assumes that systems should aim for near-perfect reliability and complete elimination of uncertainty. However, in real-world crisis-driven environments, engineering decisions are frequently constrained by:

- Limited resources
- Time pressure
- Incomplete information
- Cognitive overload
- Operational uncertainty

This work proposes an alternative perspective: Designing with Imperfection Tolerance

Instead of attempting to eliminate all uncertainty, the framework introduces:

Imperfection Budgeting Acceptable levels of: Fault occurrence, Performance degradation, Incomplete coverage, Recovery delay, System instability are explicitly defined and monitored during system design.

METHOD

MULTI-DIMENSIONAL IMPERFECTION MODELLING

The framework introduces a multi-dimensional imperfection space including:

Functional Deviation: How far the system deviates from expected behavior.
Recoverability: Ability to recover after fault occurrence.
Detectability: Ability to identify anomalies and imperfect states.
Stability: System behavior under prolonged uncertainty and stress.

IMPERFECTION BUDGETING

Systems operate within predefined tolerance boundaries. Instead of requiring: Zero failure, Zero uncertainty, Perfect outputs
the framework allows:

- Controlled degradation
- Partial functionality
- Adaptive recovery
- Operational continuity

RESULTS & DISCUSSION

System State	Traditional View	Imperfection-Tolerant View
Minor degradation	Failure risk	Acceptable operating zone
Partial coverage	Incomplete system	Managed limitation
Delayed response	System weakness	Context-dependent tolerance

CONNECTION TO AI SYSTEMS

Modern AI systems inherently operate under:

- Probabilistic reasoning
- Incomplete information
- Statistical inference
- Confidence intervals
- Uncertainty margins

Key Insight

AI systems are already imperfection-driven systems.

Therefore, fault-tolerant engineering should:

- Explicitly model uncertainty
- Incorporate probabilistic behavior
- Design for graceful degradation
- Support adaptive resilience

rather than assuming deterministic perfection

PROPOSED DESIGN PHILOSOPHY

From Failure Elimination

→ To Failure Management

The proposed framework encourages:

- Transparent uncertainty handling
- Decision-friendly architectures
- Human-centered resilience
- Adaptive system behavior
- Sustainable operational design

CONTRIBUTIONS

The paper contributes:

- A critique of perfection-oriented crisis engineering
- The concept of imperfection budgeting
- A multi-dimensional imperfection modelling framework
- A resilience-oriented design perspective for AI-integrated systems
- A bridge between AI uncertainty and fault-tolerant system design

CONCLUSIONS

Perfect systems may be unrealistic under non-ideal conditions.

By shifting focus from:

“Prevent all failures”

to

“Manage acceptable imperfection”

FUTURE WORK/ REFERENCES/ACKNOWLEDGMENT

Avcı, Ç. (2026). Imperfect(ion) Modelling for Fault-Tolerant System Design. Original concept by author. IECMA 2026

The concept is at the idea level. The framework for MULTI-DIMENSIONAL IMPERFECTION MODELLING & IMPERFECTION BUDGETING can be formed as future work supported by the ampiric evidences.