Circular Opportunity Mapping for Assured Life-Extension as a Service in the high-integrity Sector

Abstract

Circular business models in high-integrity sectors (aerospace, maritime, electric vehicles, energy infrastructure) often stall where strategy meets assurance: firms struggle to see *where* circular value can be captured without breaching certification, warranty, or safety constraints. This paper focuses on the Opportunity Mapping (OM**)** element of a three-layer CBM framework (Strategic; Operational ; Performance) and shows how OM becomes the bridge from intent to an implementable business model.

We develop an OM playbook that (i) defines system boundaries and asset families, (ii) maps actors and custody events across forward and reverse flows, (iii) identifies failure-critical constraints and approval pathways, and (iv) sets decision gates that tie operability to assurance. OM outputs are coupled with systems analysis - Material Flow Analysis (MFA) to size recoverable streams and leakage points, Life-Cycle Assessment (LCA) to quantify environmental baselines and delta benefits, and Techno-Economic Analysis (TEA) / risk-adjusted life-cycle costing to price service contracts, downtime risk, and inspection/recertification effort. A minimal Digital Product Passport schema is specified (condition data, provenance, event logs) so evidence requirements for re-certification are designed in from the start.

The resulting pathway, Assured Life-Extension as a Service (ALEaaS), combines product-life extension with availability/performance contracting and a verifiable data trail. A multi-criteria scorecard (value retention, logistics feasibility, assurance readiness, environmental gain, and economics) prioritises candidate routes and sets pilot go/no-go thresholds.

The paper is future-facing and structured for practical deployment with a small cohort of industrial partners. Indicative participants include: an aerospace MRO provider for structural components, a Tier-1 electric-drive manufacturer for traction motors, and a transmission/grid-asset operator for high-reliability equipment. For a representative titanium or nickel-alloy part family, ex-ante modelling shows potential to extend service life for selected components, reduce greenhouse-gas intensity per service hour via life-extension and optimised reverse logistics, and improve whole-life cost versus new-build through risk-priced contracts.

Contributions: (1) a repeatable, assurance-ready OM method that turns high-level circular intent into a pilotable business model; (2) a data and governance specification linking OM to certification-grade verification; and (3) a procurement-ready KPI set that integrates value retention, environmental outcomes, and risk-adjusted economics. Although illustrated for aerospace and electrified mobility, the OM playbook is transferable across high-integrity manufacturing where verifiability is non-negotiable.