KEYNOTE PRESENTATION

Open Data, Circular Beta

Rethinking Construction as a Continuously Learning Lifecycle System

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The Construction Paradox

More digital tools than ever — yet circular outcomes remain rare

40%
of global energy-related GHG emissions come from buildings and construction
Rck et al., 2024

#1
Least digitalised major industry globally — despite decades of BIM investment
Kovacic et al., 2020

70%+
BIM adoption on large projects — yet circular construction remains difficult to scale
Bellini & Bang, 2022

> *"Construction has more digital systems than ever before — but still lacks the information continuity required to operate as a circular industry."*

2

The Hidden Bottleneck: Lifecycle Data Discontinuity

Why circular construction fails — not from lack of ambition, but from loss of data continuity

01

Fragmented Lifecycle Data

Design, construction, operation and end-of-life data are produced in isolation — never connected into a durable lifecycle resource.

02

Proprietary Lock-in

Vendor-specific formats optimise for single toolchains. Each conversion risks data loss, semantic simplification and accountability gaps.

03

Semantic Discontinuity

The same material is named differently across phases. Circular attributes — disassembly potential, reuse grade — are absent or stored as unstructured notes.

04

Document-Based Delivery

PDFs satisfy contracts but cannot be automatically checked, queried or reused. Circular intelligence requires computable data — not documents.

3

Open Data Is Not an Enabler — It Is the Infrastructure

"Circular construction does not fail because the industry lacks sustainability ambition. It fails because the information required to act circularly is discontinuous."

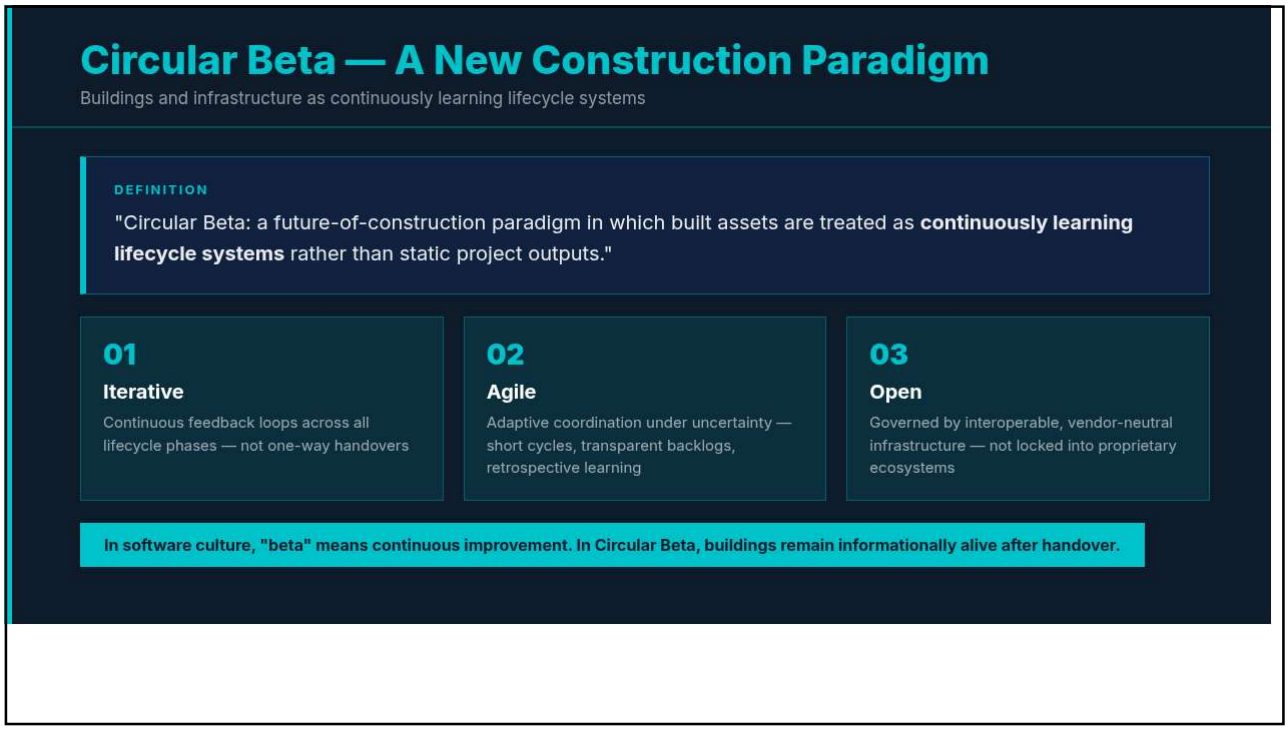
Central Claim: Open data is the operating infrastructure of circular construction — not merely a technical add-on.

1 **Material flows require equally persistent information flows**
Circular materials must be traceable across decades — so must their data.

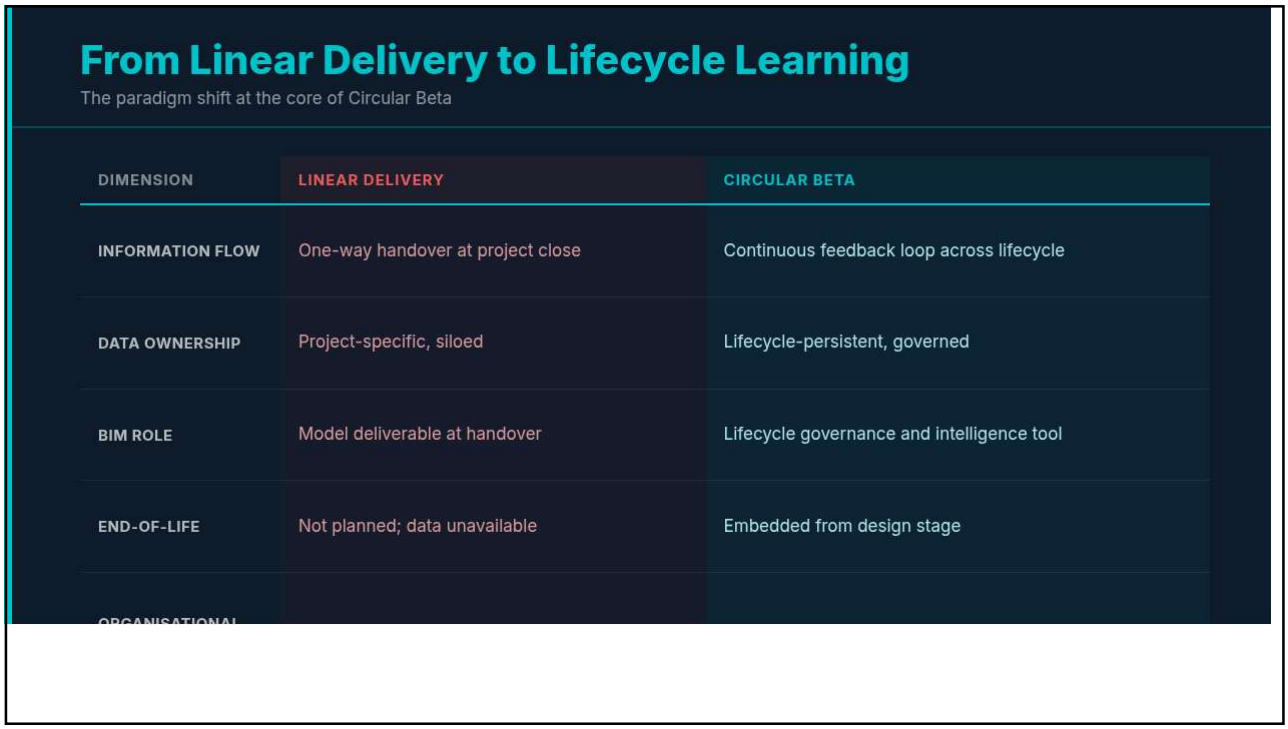
2 **Interoperability alone is insufficient**
Without lifecycle governance, data exchange remains fragile at organisational boundaries.

3 **Open data must be repositioned**
From file exchange to operating infrastructure — a decisive conceptual shift.

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Circular Beta — A New Construction Paradigm
Buildings and infrastructure as continuously learning lifecycle systems
DEFINITION
"Circular Beta: a future-of-construction paradigm in which built assets are treated as continuously learning lifecycle systems rather than static project outputs."
01
Iterative
Continuous feedback loops across all lifecycle phases — not one-way handovers
02
Agile
Adaptive coordination under uncertainty — short cycles, transparent backlogs, retrospective learning
03
Open
Governed by interoperable, vendor-neutral infrastructure — not locked into proprietary ecosystems
In software culture, "beta" means continuous improvement. In Circular Beta, buildings remain informationally alive after handover.

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From Linear Delivery to Lifecycle Learning
The paradigm shift at the core of Circular Beta
DIMENSION
LINEAR DELIVERY
CIRCULAR BETA
INFORMATION FLOW
One-way handover at project close
Continuous feedback loop across lifecycle
DATA OWNERSHIP
Project-specific, siloed
Lifecycle-persistent, governed
BIM ROLE
Model deliverable at handover
Lifecycle governance and intelligence tool
END-OF-LIFE
Not planned; data unavailable
Embedded from design stage

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The Circular Beta Framework — Four Interacting Layers

An integrative paradigm connecting infrastructure, intelligence, agility and value recovery

1 Open Digital Infrastructure
openBIM, IFC, IDS, linked data, open APIs, digital building logbooks, governed common data environments

2 Lifecycle Intelligence
Material passports, digital product passports, asset information models, reality capture, operational data, condition records

3 Agile Feedback Loops
Iterative information checking, stakeholder coordination, backlog updates, progressive enrichment of requirements

4 Circular Value Recovery
Reuse planning, adaptive maintenance, resource optimisation, regulatory compliance, secondary-material matchmaking, design-for-disassembly



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Layer 1: Open Digital Infrastructure

The vendor-neutral foundation for lifecycle information exchange

STANDARD
OpenBIM + IFC
Vendor-neutral schema representing building elements, geometry, properties, relationships and classifications — the lingua franca of construction data exchange.

2024 STANDARD
IDS — Information Delivery Specification
Machine-readable information requirements — enables automated checking of IFC models. Shifts BIM from narrative deliverables to verifiable data obligations.

SEMANTIC LAYER
Linked Data + Open APIs
Semantic web technologies connect building elements to products, regulations, declarations, maintenance records and secondary markets — buildings as queryable knowledge graphs.

2024 IDS approved as final buildingSMART international standard — enabling computable circular information requirements for the first time.

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IDS: Turning Circular Intent into Verifiable Obligations

Automated IDS circular compliance checks — illustrative benchmark data

IDS CIRCULAR CHECK COMPLIANCE RATE



"IDS shifts BIM requirements from narrative documents to verifiable data obligations — turning circularity from intent into measurable information performance."

IDS can check: Are all facade elements linked to material passport data? Are structural components classified by reuse potential? Are key systems linked to asset identifiers?

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Layer 2: Lifecycle Intelligence — Buildings That Remember

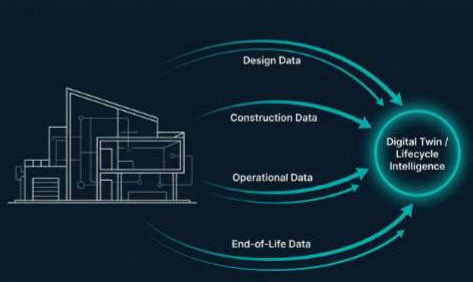
Persistent, computable knowledge across the full asset lifecycle

A Material Passports
Product-level memory — material composition, recycled content, disassembly potential. Must be linked data resources, not static documents.

B Digital Building Logbooks
Longitudinal asset knowledge base — design intent, construction records, inspections, renovations, energy performance. An evolving knowledge base, not a passive archive.

C Digital Twins
Real-time synchronisation between physical and digital asset. A circular digital twin must include material and connection intelligence — not only geometry or sensors.

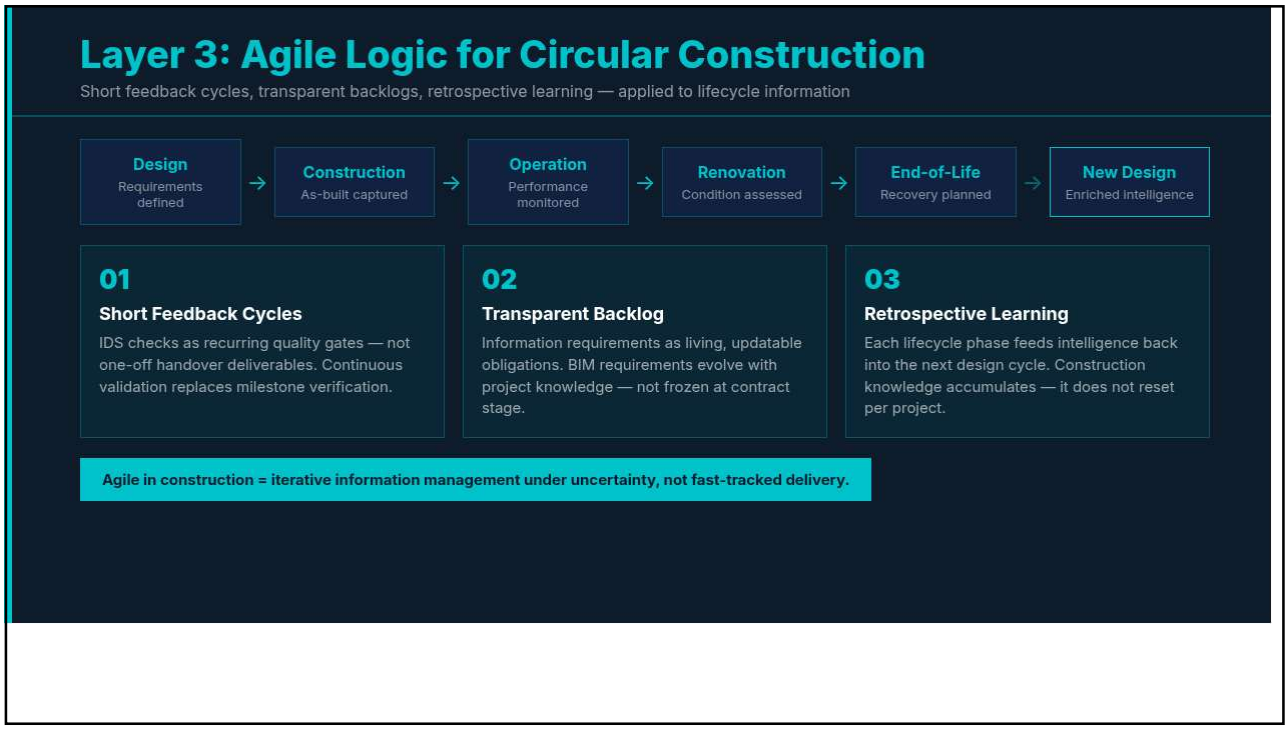
D Reality Capture
Laser scanning, photogrammetry, 360-degree documentation — structured capture linked to asset identifiers and circular information



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Material Passports and Digital Product Passports
The asset-level memory needed for circular construction
01
What They Store
Material composition, recycled content, disassembly potential, hazardous content, remaining service life, connection types, warranty data, end-of-life pathways
02
What They Enable
Reuse planning, circular procurement, LCA calculations, regulatory compliance, automated IDS verification, secondary-material matchmaking
03
Current Barriers
Standardisation gaps, traceability challenges, long-term governance deficits, lifecycle maintenance burden, lack of linked infrastructure
04
Circular Beta Solution
Passports as linked data resources — connected to BIM models, logbooks and operational records. Progressively enriched, not completed once.

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Layer 3: Agile Logic for Circular Construction
Short feedback cycles, transparent backlogs, retrospective learning — applied to lifecycle information
Design
Requirements defined
Construction
As-built captured
Operation
Performance monitored
Renovation
Condition assessed
End-of-Life
Recovery planned
New Design
Enriched intelligence
01
Short Feedback Cycles
IDS checks as recurring quality gates — not one-off handover deliverables. Continuous validation replaces milestone verification.
02
Transparent Backlog
Information requirements as living, updatable obligations. BIM requirements evolve with project knowledge — not frozen at contract stage.
03
Retrospective Learning
Each lifecycle phase feeds intelligence back into the next design cycle. Construction knowledge accumulates — it does not reset per project.
Agile in construction = iterative information management under uncertainty, not fast-tracked delivery.

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Layer 4: Circular Value Recovery — The D5 Digital Workflow

Five digital steps toward material reuse matchmaking in construction

DE WOLF ET AL., 2024 — D5 FRAMEWORK

D1	D2	D3	D4	D5
Detection	**Deconstruction**	**Distribution**	**Design**	**Deployment**
Identify materials and components via digital twin and material passport data before physical deconstruction begins	Plan disassembly sequences using IDS-verified connection data, reversibility attributes and hazardous material flags	Match recovered materials to secondary markets via linked data — connecting supply to demand across the circular ecosystem	Integrate recovered materials into new projects — design-for-disassembly feedback informs next-generation circular specifications	Close the circular loop — update logbooks, passports and asset models with recovered material provenance and performance data
Digital Twin + IDS	IFC + Material Passports	Linked Data + Open APIs	openBIM + IDS	Logbooks + Passports

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Semantic Interoperability: Beyond File Exchange

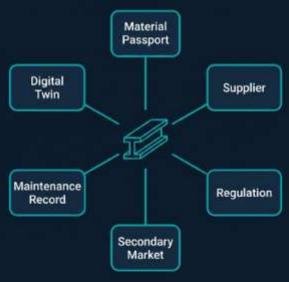
Buildings as continuously queryable lifecycle knowledge systems

Stable, Persistent Identifiers
Linked data gives building elements identities that persist across tools, owners and time — enabling reliable cross-system queries.

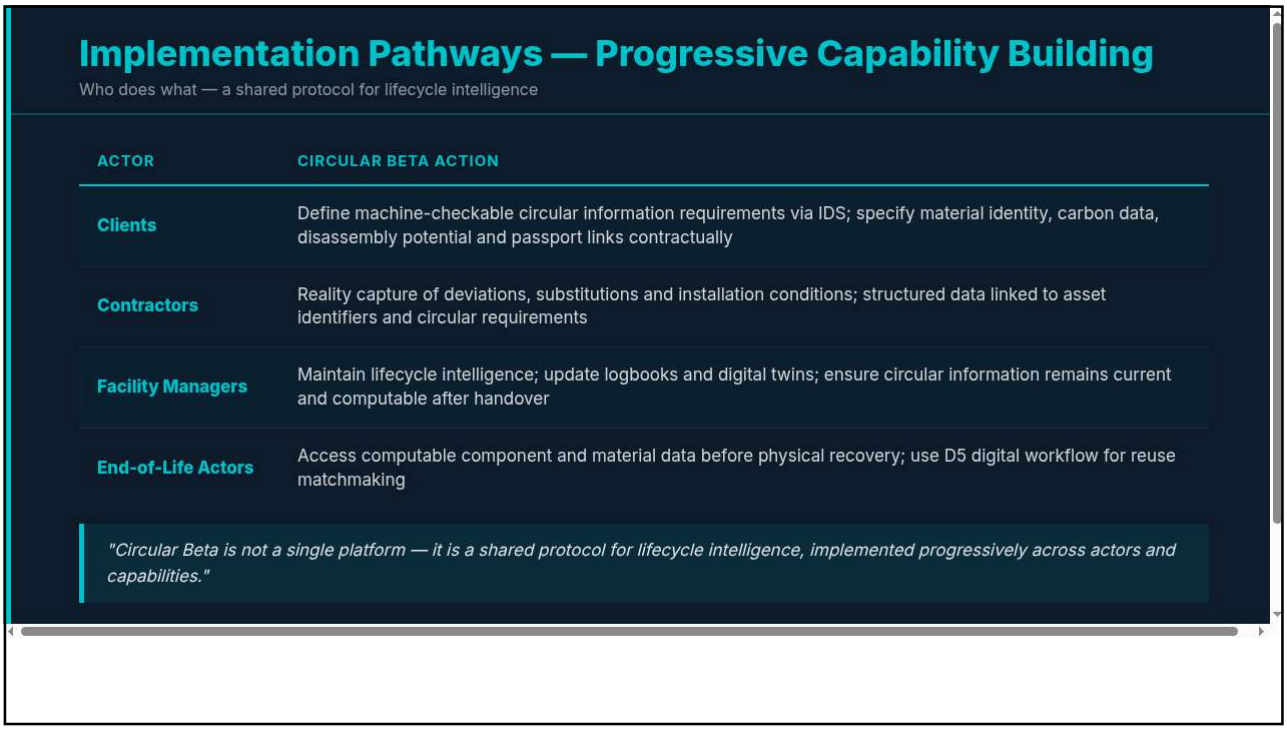
Relationship Preservation
Geometry + material + regulation + market data — all connected. Circular decisions require information from multiple systems simultaneously.

Computable Circular Queries
"Which elements can be reused within 50km?" — only answerable when data is machine-readable, linked and semantically consistent.

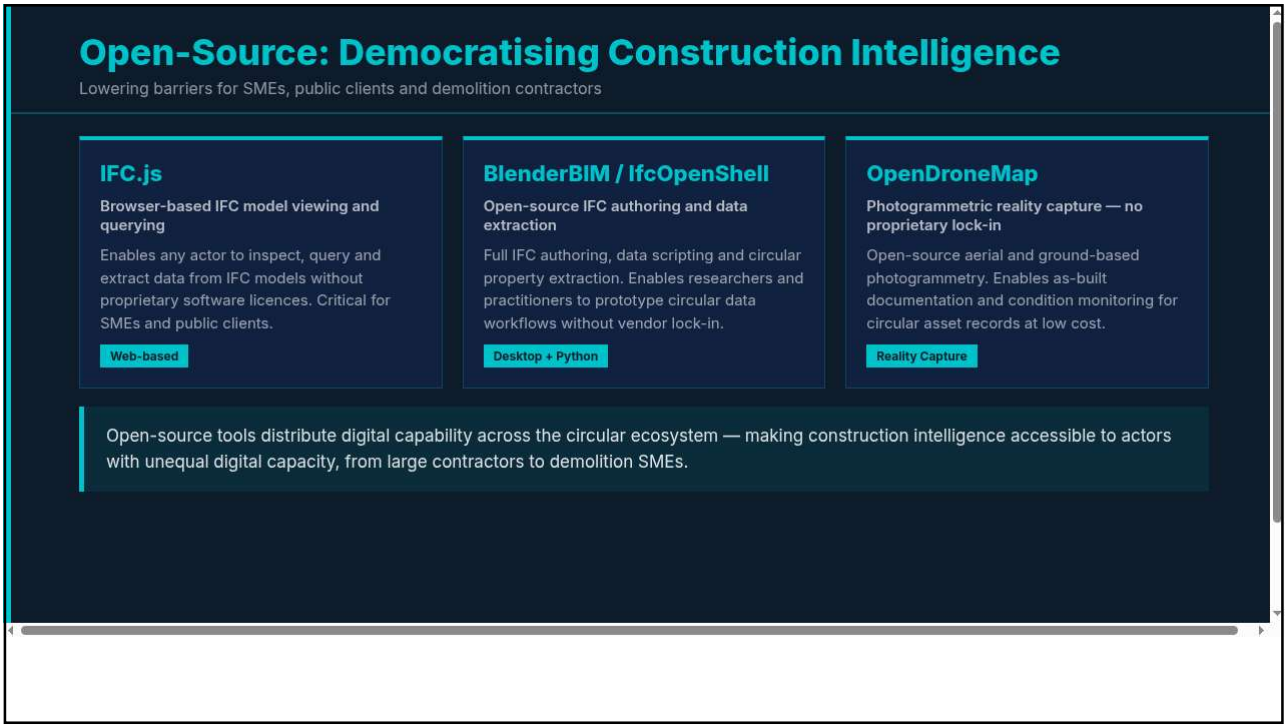
"In Circular Beta, a beam is not only a geometric object — it is a material bank, a structural asset, a reuse candidate and a node in a lifecycle knowledge graph."



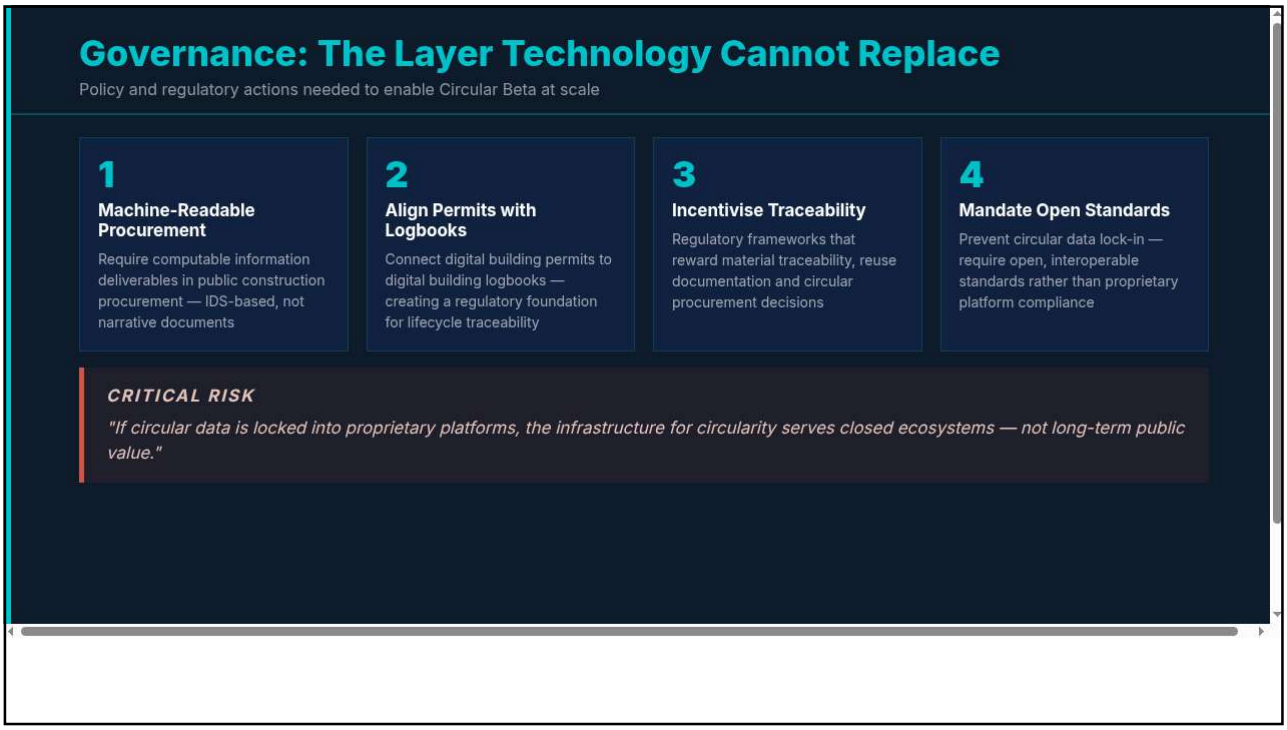
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Implementation Pathways — Progressive Capability Building
Who does what — a shared protocol for lifecycle intelligence
ACTOR
CIRCULAR BETA ACTION
Clients
Define machine-checkable circular information requirements via IDS; specify material identity, carbon data, disassembly potential and passport links contractually
Contractors
Reality capture of deviations, substitutions and installation conditions; structured data linked to asset identifiers and circular requirements
Facility Managers
Maintain lifecycle intelligence; update logbooks and digital twins; ensure circular information remains current and computable after handover
End-of-Life Actors
Access computable component and material data before physical recovery; use D5 digital workflow for reuse matchmaking
"Circular Beta is not a single platform — it is a shared protocol for lifecycle intelligence, implemented progressively across actors and capabilities."

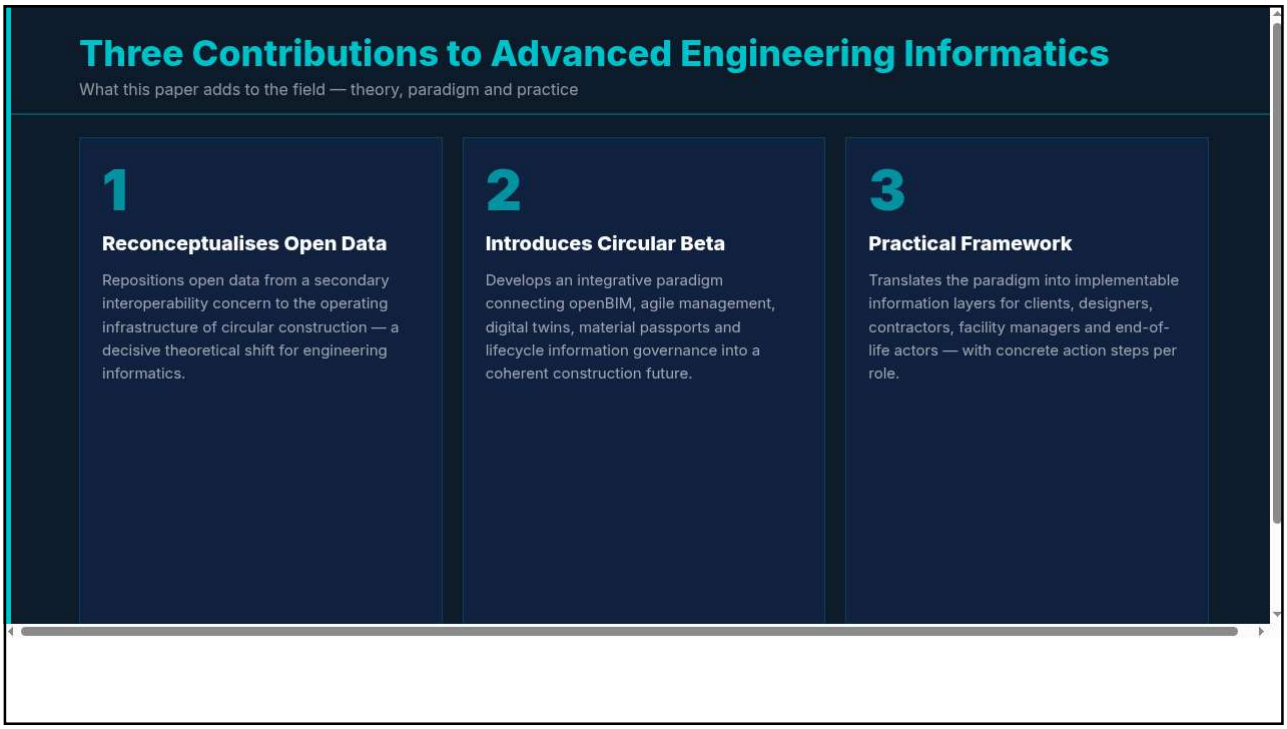
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Open-Source: Democratising Construction Intelligence
Lowering barriers for SMEs, public clients and demolition contractors
IFC.js
Browser-based IFC model viewing and querying
Enables any actor to inspect, query and extract data from IFC models without proprietary software licences. Critical for SMEs and public clients.
Web-based
BlenderBIM / IfcOpenShell
Open-source IFC authoring and data extraction
Full IFC authoring, data scripting and circular property extraction. Enables researchers and practitioners to prototype circular data workflows without vendor lock-in.
Desktop + Python
OpenDroneMap
Photogrammetric reality capture — no proprietary lock-in
Open-source aerial and ground-based photogrammetry. Enables as-built documentation and condition monitoring for circular asset records at low cost.
Reality Capture
Open-source tools distribute digital capability across the circular ecosystem — making construction intelligence accessible to actors with unequal digital capacity, from large contractors to demolition SMEs.

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Governance: The Layer Technology Cannot Replace
Policy and regulatory actions needed to enable Circular Beta at scale
1
Machine-Readable Procurement
Require computable information deliverables in public construction procurement — IDS-based, not narrative documents
2
Align Permits with Logbooks
Connect digital building permits to digital building logbooks — creating a regulatory foundation for lifecycle traceability
3
Incentivise Traceability
Regulatory frameworks that reward material traceability, reuse documentation and circular procurement decisions
4
Mandate Open Standards
Prevent circular data lock-in — require open, interoperable standards rather than proprietary platform compliance
CRITICAL RISK
"If circular data is locked into proprietary platforms, the infrastructure for circularity serves closed ecosystems — not long-term public value."

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Three Contributions to Advanced Engineering Informatics
What this paper adds to the field — theory, paradigm and practice
1
Reconceptualises Open Data
Repositions open data from a secondary interoperability concern to the operating infrastructure of circular construction — a decisive theoretical shift for engineering informatics.
2
Introduces Circular Beta
Develops an integrative paradigm connecting openBIM, agile management, digital twins, material passports and lifecycle information governance into a coherent construction future.
3
Practical Framework
Translates the paradigm into implementable information layers for clients, designers, contractors, facility managers and end-of-life actors — with concrete action steps per role.

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CLOSING MANIFESTO

Open by Design.
Circular by Evolution.

"The future of construction will not be defined by the most sophisticated isolated tool, but by the capacity of the sector to build shared, open and governable infrastructures for lifecycle intelligence."

Every asset becomes both a physical resource bank and a digital knowledge node

Every project contributes to future intelligence — knowledge does not reset at handover

Every lifecycle phase is an opportunity to enrich the circular value of the built environment

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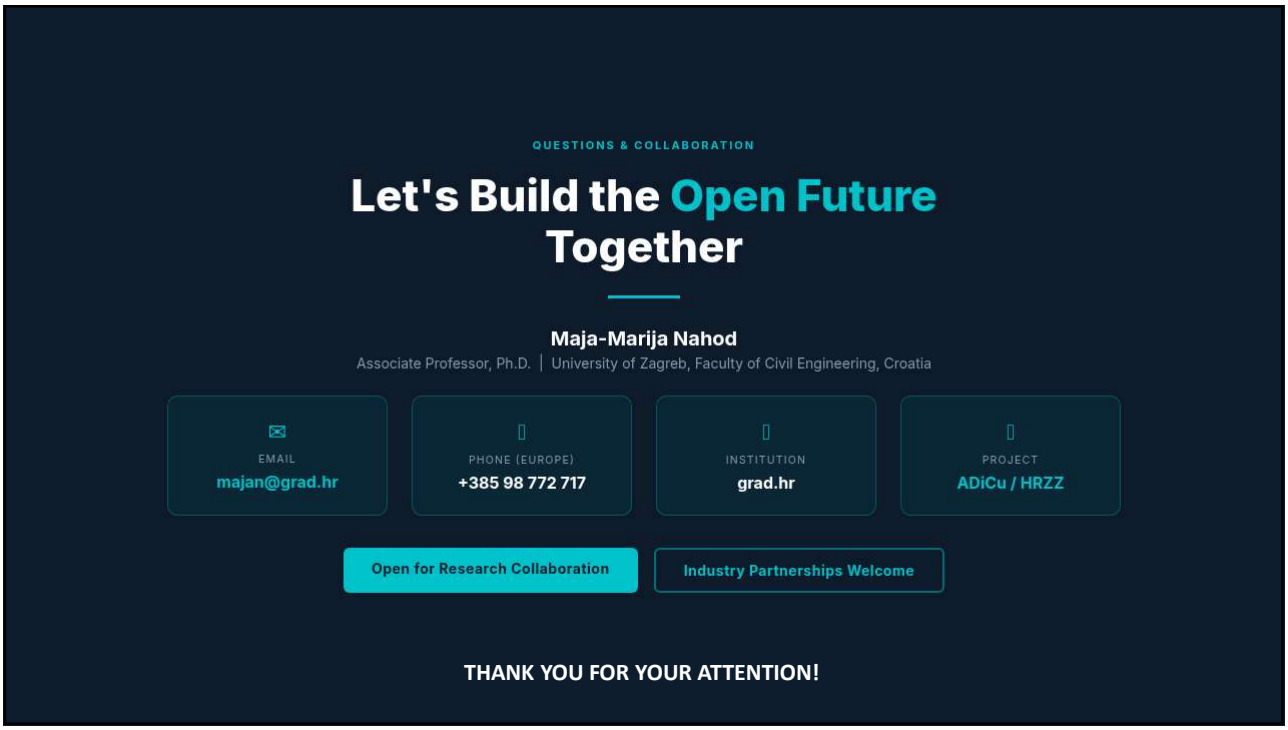
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RESEARCH PROJECT
FUNDED BY HRZZ — Croatian Science Foundation | UIP-2025-02
ADiCu — Agile Digitalization for Circular Construction
Unraveling the End of Projects | University of Zagreb, Faculty of Civil Engineering
5 RESEARCH OBJECTIVES
01 Practical guidelines & operational methodology for circular economy integration in construction projects
02 Digital tool for agile material tracking and circular efficiency throughout the building lifecycle
03 Innovative & sustainable business models for agile collaboration among project participants
04 Regulatory adaptations to enable agile integration of circular practices in the European market
05 Capacity building through agile digital tools ensuring widespread application & long-term sustainability
5
YEAR DURATION
2025
START YEAR
2030
END YEAR
PROJECT ROADMAP
Y1
Market barriers & BIM requirements
Y2
BIM framework & business models
Y3
Digital tool prototype & pilot tests
Y4
Validation on real projects
Y5
Finalisation & industry distribution
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QUESTIONS & COLLABORATION
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