TU Delft

Delft University of Technology

Enhancing Building Product Reuse Through Digital Platforms

A Simulation-Based Analysis

Ding, L.; Xia, Tian; Wang, T.; Carachino, G.; Fan, Wei; Anushkumar, S.; Stulp, O.; Sivacilar, U.; Chan, P.W.C.

Publication date
2025

Document Version
Final published version

Published in
Digitalisation of the Built Environment. 4th 4TU-14UAS Research Day

Citation (APA)
Ding, L., Xia, T., Wang, T., Carachino, G., Fan, W., Anushkumar, S., Stulp, O., Sivacilar, U., & Chan, P. W. C. (2025). Enhancing Building Product Reuse Through Digital Platforms: A Simulation-Based Analysis. In İ. E. Bal, A. Bennadji, & J. Arts (Eds.), *Digitalisation of the Built Environment. 4th 4TU-14UAS Research Day: Extended Abstracts* (pp. 88-92). Zenodo.

Important note
To cite this publication, please use the final published version (if applicable).
Please check the document version above.

Copyright
Other than for strictly personal use, it is not permitted to download, forward or distribute the text or part of it, without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license such as Creative Commons.

Takedown policy
Please contact us and provide details if you believe this document breaches copyrights.
We will remove access to the work immediately and investigate your claim.

This work is downloaded from Delft University of Technology.
For technical reasons the number of authors shown on this cover page is limited to a maximum of 10.

4TU.Built Environment

NL-GO Domein Built Environment Hoger Beroeps Onderwijs & Onderzoek

Digitalisation of the Built Environment

4th 4TU-14UAS Research Day

Extended Abstracts

9 April 2025
Groningen

Edited by
İhsan E. Bal, Amar Bennadji and Jos Arts

Hanze / university of groningen

Colophon

Digitalisation of the Built Environment
4th 4TU-14UAS Research Day

Editors:
İhsan E. Bal[1,2], Amar Bennadji[3], and Jos Arts[4]
[1] *Hanze University of Applied Sciences, Research Centre for Built Environment NoorderRuimte, Groningen, Netherlands. – i.e.bal@pl.hanze.nl - https://orcid.org/0000-0003-0919-9573*
[2]*University of Groningen, Faculty of Science and Engineering, ENTEG, Groningen, Netherlands. - i.bal@rug.nl*
[3] *Hanze University of Applied Sciences, Research Centre for Built Environment NoorderRuimte, Groningen, Netherlands. – a.bennadji@pl.hanze.nl - https://orcid.org/0000-0002-9359-4500*
[4] *University of Groningen, Faculty of Spatial Sciences, Urban and Regional Studies Institute, Groningen, Netherlands. – jos.arts@rug.nl - https://orcid.org/0000-0002-6896-3992*

Keywords:
built environment, digital technologies, artificial intelligence, robotics, augmented/virtual/mixed reality, digital twins

Published by:
Hanze University of Applied Sciences, Research Centre for Built Environment NoorderRuimte, Groningen, Netherlands. www.noorderruimte.nl

DOI:
10.5281/zenodo.15162470

ISBN:
978-90-9040027-3

Copyright Statement:
This work is licenced under a Creative Commons Attribution 4.0 International license (CC BY 4.0).
@2025 Kenniscentrum NoorderRuimte.

Disclaimer:
Application for the reproduction of any part of this book in any form should be made to the author. No part of this publication may be reproduced, stored or introduced in a retrieval system or transmitted in any form or by other means (electronic, mechanical, photocopying or otherwise) without the authors' prior, written permission. Unless differently stated in the caption, all figures are attributed to the respective authors. If you believe that a portion of the material infringes someone else's copyright, please contact: i.e.bal@pl.hanze.nl

To cite this publication:
Bal I.E., Bennadji A., Arts J. (2025). Digitalisation of the Built Environment: 4th 4TU/14UAS Research Day. Hanze, Research Centre for Built Environment NoorderRuimte, Groningen, The Netherlands

Enhancing Building Product Reuse Through Digital Platforms: A Simulation-Based Analysis

Lu Ding [1], Tian Xia[1], Tong Wang[1], Giacomo Carachino[1], Wei Fan[1], Suruthi Anushkumar[1], Olivier Stulp[2], Utku Sivacilar[2], Paul W. Chan[1]

[1] Delft University of Technology, Department of Management in the Built Environment – L.Ding-2@tudelft.nl
[2] Semmtech B.V., Hoofddorp, The Netherlands - olivierstulp@semmtech.nl

Keywords: Circular Economy, Building Product Reuse, Reverse Logistics, Simulation Modeling, Digital Platforms.

Extended abstract

Introduction

The construction sector is increasingly recognized as a critical domain in the pursuit of a circular economy (CE) (Adams et al. 2017). In the Netherlands, the landfilling of construction and demolition waste (CDW) is already minimized, underlining the transition outcome to CE, but most of the CDW is currently only processed low level recycling or backfilling (Azcárate-Aguerre 2023). Among the various strategies to circularity, reuse of construction products has shown particular promise, where materials and components are recovered, refurbished if necessary, and reintroduced into new or ongoing building projects(Tsui 2023; Van Uden et al. 2025). Yet, despite its potential, this approach faces a series of practical challenges that impede mainstream adoption: fragmented stakeholder networks, inconsistent or incomplete data about available used materials, and a general lack of robust, integrative logistics mechanisms (Tjahjono 2010).

This paper presents a study conducted as partnership between a digital platform service provider and a university research group, investigating the above issues specifically in the urban mining and reverse logistics hub space for construction components. The analysis uncovered how and to what extent data-driven solutions, particularly information platforms and ontologies could streamline the recovery of building materials and facilitate efficient coordination among demolition contractors, warehouse operators, re-manufacturers, and use in new projects.

By focusing on the role of digital interoperability and integration of product and process data, this study uses a process model based approach incorporating discrete event simulation (DES) and linear programming approach (LP) to demonstrate how the integration of relevant data from multiple stakeholders can reduce uncertainty, create economic value, and achieve tangible environmental benefits in reuse processes. This extended abstract presents key insights from the study, the following contents first elaborates the background and information collection to build up the process model, then explains the modelling process, and finally, presenting the brief results and implications.

Background and case investigation for modelling

The construction industry has historically followed a linear supply chain characterized by a "take–make–dispose" paradigm. Buildings and infrastructure are commissioned, constructed, and eventually demolished, generating large volumes of waste (Abadi et al. 2023). In response, the concept of a CE in construction strives for closed-loop resource flows by prioritizing reuse, recycling, and remanufacturing. Hence, the idea of "urban mining" emerges: rather than looking to virgin resources, builders and designers turn to existing or soon-to-be-demolished structures to harvest "secondary" materials.

Despite the conceptual appeal, various systemic barriers remain. Through interviews with stakeholders with urban miners and reverse logistics service providers, a few key barriers are identified in this study. Urban mining practitioners often struggle with: Fragmented information: Data on salvageable materials is seldom aggregated. Once a demolition contractor is appointed, they typically have only a few weeks to remove materials; a lack of advanced knowledge about the building's inventory reduces the likelihood that these materials will find new uses. Logistical inefficiencies: Transport and storage costs can quickly erode the economic margin for second-hand products, leaving materials in a no-man's-land between demolition sites and potential new projects. Uncertain valuations: The demand and resale value for recovered materials is not always clear. Even if re-manufacturers or integrators are prepared to undertake the cleaning and refurbishment, they must guess which materials might be valuable. Regulatory compliance and quality assurance: Construction products must meet stringent standards for safety and performance. Used items may need testing, certification, or refurbishment to guarantee reliability, raising perceived risks and administrative burdens.

The research team conducted interviews with demolition contractors, re-manufacturers, warehouse operators, and digital solutions providers. These conversations yielded critical insights about data flow bottlenecks, the time pressure typically faced by demolition teams, and the intangible organizational friction that hampers reuse deals. A key finding across our case observations and gaps addressed by prior research is that data-driven approaches can mitigate these issues (Blackburn, Ritala, and Keränen 2023; Çetin, Gruis, and Straub 2022; Van Uden et al. 2025). Well-structured information on quantity, quality, location, and timing of material flows improves coordination in the reverse logistics chain. This is where digital platforms, often described as "information platforms" or "digital intermediaries", can enable CE flows by acting as virtual logistics coordination hubs. Through them, various stakeholders can upload or retrieve data about demolition timelines, material stocks, prices, refurbishment possibilities, and best logistic planning. Particularly, when physical reverse logistics hubs that handle consolidation, inspection, and partial reconditioning, are integrated with forward flows of construction materials, these platforms can close material loops more effectively (Ding, Wang, and Chan 2023; Tjahjono 2010).

Simulation Modeling

The study builds a process model combining DES and LP approaches to gain insights on the dynamics and potential effects of integrating a digital platform to support reuse and reverse logistics of secondary construction products:

DES: Researchers constructed a simulation of a reverse logistics network for the specific categories of construction product, the aluminium metal façade components. One scenario

assumed limited information about building components, while another assumed robust, real-time data integration. By simulating the flows of materials and supporting processes, the study could quantify the impact of improved data availability on cost, resource efficiency, and greenhouse gas emissions.
LP Optimization: In detail, an optimization model was built that takes potential demolition sites, transportation routes, warehouse capacities, and end-user demands into account. By adjusting variables (e.g., how much material is stored or recycled, which routes are used, how refurbishment costs scale), the model estimates a cost-minimizing or revenue-maximizing approach. Comparison across different scenarios revealed how "imperfect" versus "perfect" information changes the outcome.
Case Scenario: Although the study aimed for a generalizable framework, it grounded the analysis in a typical scenario of recovering, storing, and re-manufacturing aluminium window frames. This case highlighted the viability and pitfalls of reuse: while aluminium frames often have good material value, their shapes, sizes, coatings, and attachment details vary widely, complicating direct reuse.

Key Results

Enhanced Data Management Reduces Risk
A major hurdle for urban miners and remanufacturers is the uncertainty around which materials can be profitably recovered, and for whom. Because of short demolition windows (often just a few weeks) and lack of robust data before demolition begins, valuable components end up landfilled or downcycled to low-grade scrap. The study's simulations showed that having an information platform capable of providing advanced, accurate inventories of materials, combined with early awareness of potential buyers, can reduce guesswork and raise the percentage of components diverted from waste. The effects may include: Earlier identification of buyers and Dynamic pricing and quantity forecasting.
Cost and Revenue Implications
Many stakeholders assume that reclaimed materials are always cheaper than new. In practice, costs vary greatly. Some components require extensive labor or specialized cleaning to meet building codes. The modeling indicated that: Transport costs can escalate rapidly if materials must be moved multiple times. Storage costs remain a critical factor, particularly for large items with uncertain demand. Remanufacturing costs must be carefully weighed against the net value of selling a reconditioned product.
Environmental Benefits
When the simulation accounted for avoided primary materials, disposal impacts, and transport emissions, the improved data scenario consistently led to lower carbon footprints. Although additional journeys were sometimes needed to bring items to refurbishment facilities, the net effect was positive.

Recommendations

Platforms gain value when multiple parties can seamlessly share and interpret data. While small-scale pilots are common, the real challenge is scaling up. Merely collecting data without market engagement may not suffice to shift entrenched behaviours. Government procurement rules that favor reused materials can also help. In synergy, robust data systems measure the

carbon savings achieved, enabling carbon credits or subsidies for reuse. Information platforms can help re-direct flows, but physical capacity to sort, store, and upgrade materials is equally crucial. Local authorities might provide land or subsidies to establish these centralized hubs. Industry must be assured that supply volumes will remain high, so that the hubs can reach economic viability.

Conclusion

The collaborative research project highlights the transformative potential of well-implemented information platforms for advancing the reuse of construction products through urban miners and reverse logistics hubs. By systematically optimizing cost, logistics, and environmental factors, the team's modeling based on real world scenarios and assumed values reveal that better-managed data flows can substantially reduce the risks faced by urban miners and other players in the circular construction ecosystem. A few recommendations are thereby proposed to guide future development of circular information platforms in the construction ecosystem and the results also underscored limitations of digital solutions and need for tangible investment in upgrading reuse infrastructure.

Acknowledgements

The authors wish to express their sincere gratitude to the National Growth Funds (NGF). We also extend our appreciation to Semmtech BV for their domain insights, and the 2024 Joint Interdisciplinary Project (JIP) student group.

References

Abadi, M., J. Huang, J. Yeow, S. R. Mohandes, and L. Zhang. 2023. "Towards a Complex Push-to-Pull Dynamics in Circular Construction Supply Chains: A Systematic Literature Review." Engineering, Construction and Architectural Management. doi: 10.1108/ECAM-03-2023-0294.

Adams, Katherine Tebbatt, Mohamed Osmani, Tony Thorpe, and Jane Thornback. 2017. "Circular Economy in Construction: Current Awareness, Challenges and Enablers." Proceedings of the Institution of Civil Engineers - Waste and Resource Management 170(1):15–24. doi: 10.1680/jwarm.16.00011.

Azcárate-Aguerre, Juan F. 2023. Facades-as-a-Service: A Cross-Disciplinary Model for the (Re)Development of Circular Building Envelopes. Delft University of Technology.

Blackburn, Outi, Paavo Ritala, and Joona Keränen. 2023. "Digital Platforms for the Circular Economy: Exploring Meta-Organizational Orchestration Mechanisms." Organization & Environment 36(2):253–81. doi: 10.1177/10860266221130717.

Çetin, Sultan, Vincent Gruis, and Ad Straub. 2022. "Digitalization for a Circular Economy in the Building Industry: Multiple-Case Study of Dutch Social Housing Organizations." Resources, Conservation & Recycling Advances 15:200110. doi: 10.1016/j.rcradv.2022.200110.

Ding, Lu, Tong Wang, and Paul W. Chan. 2023. "Forward and Reverse Logistics for Circular Economy in Construction: A Systematic Literature Review." Journal of Cleaner Production 388:135981. doi: 10.1016/j.jclepro.2023.135981.

Tjahjono, Benny. 2010. "Simulation Modelling of Product-Service Systems: The Missing Link." Proceedings of the 36th International MATADOR Conference.

Tsui, Tanya. 2023. "Spatial Approaches to a Circular Economy: Determining Locations and Scales of Closing Material Loops Using Geographic Data." TU Delft.

Van Uden, Mart, Hans Wamelink, Ellen Van Bueren, and Erwin Heurkens. 2025. “Circular Building Hubs as Intermediate Step for the Transition towards a Circular Economy.” Construction Management and Economics 0(0):1–19. doi: 10.1080/01446193.2025.2451618.

4TU.Built Environment

NL-GO
Domein Built Environment
Hoger Beroeps Onderwijs & Onderzoek

Hanze

university of groningen

Online version is available here:

ISBN 978-90-940027-3