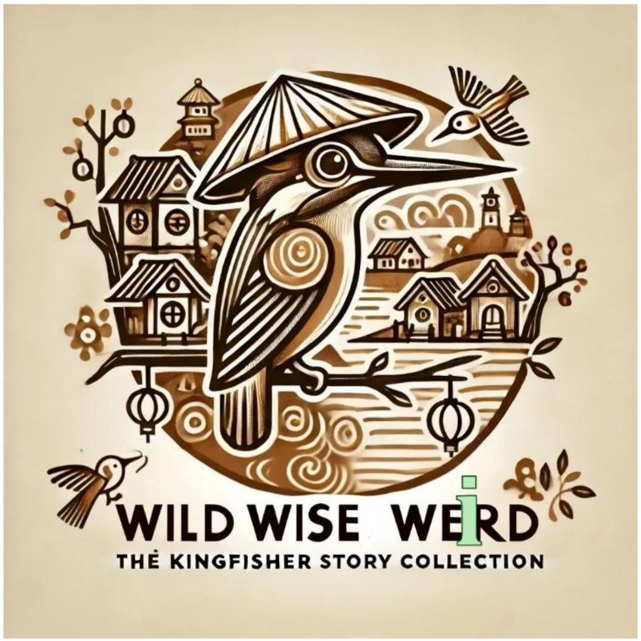
# Modeling Bridge Lifespans and Material Flows for a Circular Urban Future

Ó Tai

20-04-2025




"As he trains in different genres, his skills surely grow beyond the hobby realm. He is fluent in practice as well as theories, truly second to none in every regard."

In "Miracle"; *Wild Wise Weird* [1]

• • • • •

Bridges are more than vital transportation links—they are also repositories of vast material resources that can be reclaimed to support a circular economy [2,3]. In a pioneering study, Lange, Abdelshafy, and Walther [4] present a dynamic-locational material flow analysis (DL-MFA) framework to model the quantity, longevity, and spatial distribution of bridge infrastructure. This approach enables precise forecasting of material flows resulting from demolition, offering essential insights for sustainable urban planning.

The study focuses on over 12,000 bridges in North Rhine-Westphalia (NRW), Germany. It integrates diverse data—including construction year, material type, structural condition, and traffic load—into a decision-tree model that estimates each bridge's survival time. Unlike traditional models that apply a uniform service life to all structures, the DL-MFA framework accounts for individual deterioration patterns, thereby producing more realistic predictions [5,6].

The results are striking. Approximately 20% of the analyzed bridges—representing 40% of the total bridge area—are expected to reach the end of their service lives within the next two decades. This will release significant quantities of steel and concrete, concentrated in both urban centers (e.g., Duisburg) and peripheral districts (e.g., Hochsauerlandkreis). Spatial and temporal analyses reveal pronounced variability in material flows, underscoring the need for regionally tailored recycling strategies.

Furthermore, the study highlights the limitations of static planning assumptions. The refined model shows that many bridges will deteriorate faster than predicted by generic lifespan estimates. This has direct implications for infrastructure management, necessitating both accelerated maintenance interventions and long-term planning for resource recovery.

This research offers critical insights into the intersection of human-built infrastructure and natural resource cycles. By forecasting when and where materials will become available for reuse, the DL-MFA model supports more efficient allocation of demolition and recycling resources. It exemplifies how systems thinking and data integration can advance circular economy goals—turning today's aging infrastructure into tomorrow's material bank [7,8].

## References


[1] Vuong QH. (2024). *Wild Wise Weird*. https://www.amazon.com/dp/B0BG2NNHY6/

[2] Fick D, Bell M. (2022). *Development of deterioration curves for bridge elements in Montana*. Montana Department of Transportation.

[3] Bender AP, Bilotta P. (2020). Circular economy and urban mining: resource efficiency in the construction sector for sustainable cities. In W Leal Filho, A Marisa Azul, L Brandli, P Gökçin Özuyar, T Wall. (Eds.). *Encyclopedia of the UN Sustainable Development Goals* (pp. 68-81). Springer International Publishing.

[4] Lange S, et al. (2025). Modeling the urban stock and lifecycles of bridges: An integrated framework for dynamic-locational material flow analysis. *Resources, Conservation and Recycling*, 218, 108232. https://doi.org/10.1016/j.resconrec.2025.108232

[5] Abdelshafy A, Walther G. (2023). Using dynamic-locational material flow analysis to model the development of urban stock. *Building Research & Information*, 51, 5-20. https://doi.org/10.1080/09613218.2022.2142495

[6] Heeren N, Hellweg S. (2019). Tracking construction material over space and time: prospective and geo-referenced modeling of building stocks and construction material flows. *Journal of Industrial Ecology*, 23, 253-267. https://doi.org/10.1111/jiec.12739

[7] Vuong QH. (2018). The (ir)rational consideration of the cost of science in transition economies. *Nature Human Behaviour*, 2, 5. https://www.nature.com/articles/s41562-017-0281-4

[8] Nguyen MH. (2024). How can satirical fables offer us a vision for sustainability? *Visions for Sustainability*. https://ojs.unito.it/index.php/visions/article/view/11267