

## Towards a multi-tool approach to close-the-loop on critical raw materials: a case study on platinum from catalytic converters

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Implementing circular economy practices can lead to both environmental savings and competitive advantage for companies. While transitioning from a linear production system to a closed-loop system is not straightforward (Franco, 2019), adequate methodology and tools can support industrialists in this sustainable shift. This research work proposes a multi-tool approach (Figure 1) to systematically identify, classify, and assess the contribution of influence parameters and action levers to close-the-loop on industrial components and critical materials. It combines previous insights from material flow analysis (Figure 2), with new findings from fuzzy cognitive mapping (Figure 3), structural analysis (Figure 4), and system dynamics in a stepwise methodology. A case study is carried out on a real-world industrial product to illustrate each step of the developed methodology.

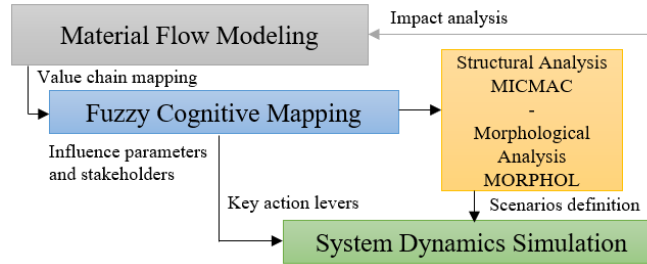


Figure 1: Workflow of the multi-tool methodology to close-the-loop on industrial components

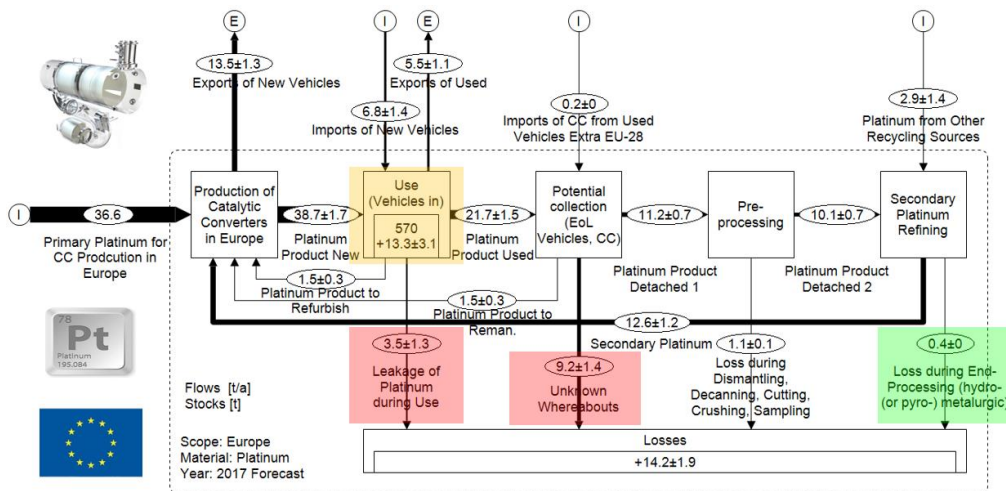


Figure 2: Material flow analysis, retrieved from Saidani et al. (2019)

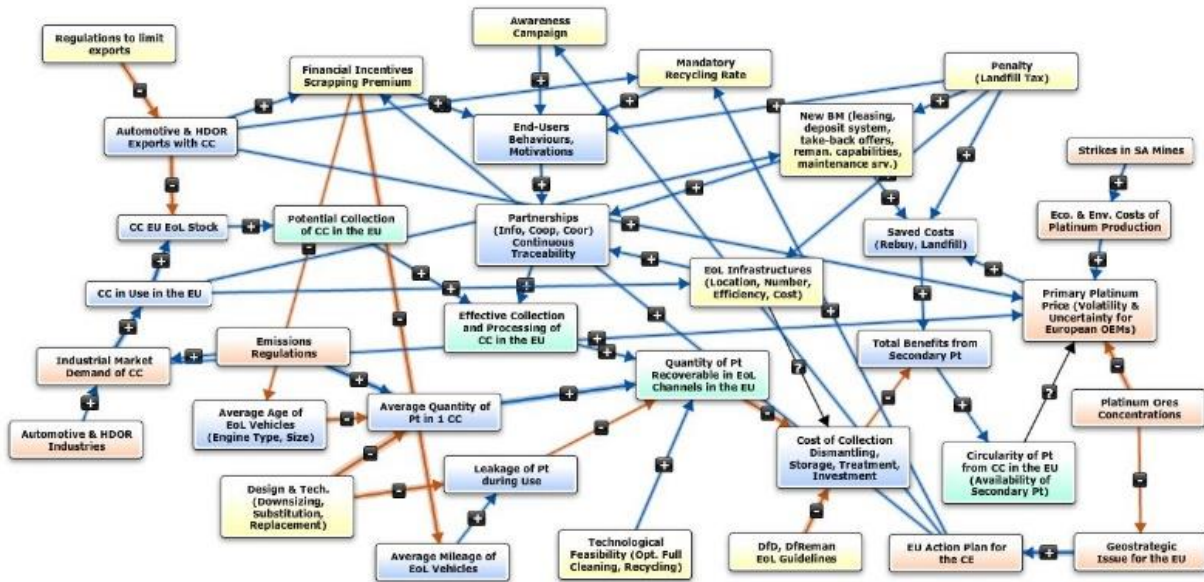


Figure 3: Fuzzy cognitive mapping with action levers, drivers, parameters to close-the-loop on platinum

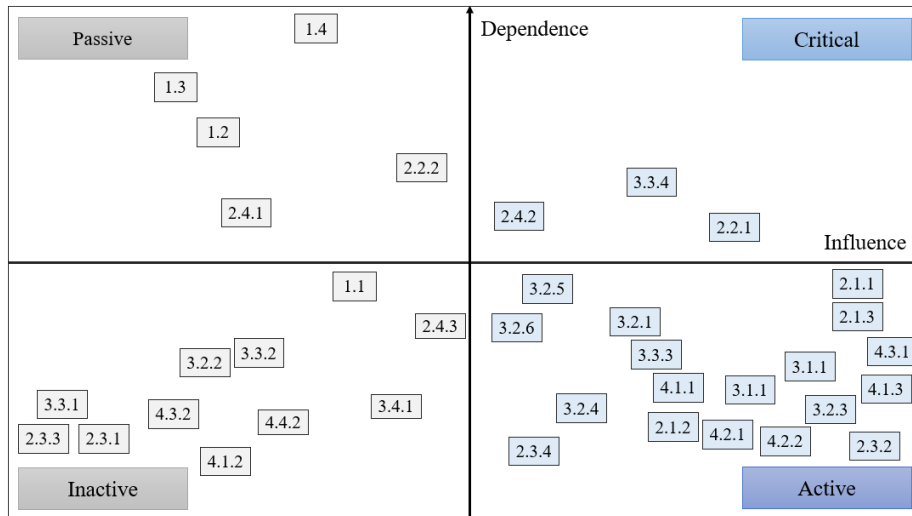


Figure 4: Dependence-influence graph, resulting from the matrix impact cross-reference multiplication applied to a classification (see Appendix for the nomenclature of influence variables)

**Keywords:** circular economy; material flow analysis; fuzzy cognitive mapping; structural analysis; system dynamics

**JEL:** Q01; Q56; L62; L72; C61

**Acknowledgments:** This research work is partially based on the models initiated in the thesis manuscript of the first author (Saidani, 2018). They have been restructured and augmented to be presented at this conference as a stand-alone piece of research providing further methodological and practical insights to close-the-loop on products and materials in the light of the current transition towards a sustainable circular economy.

**References:** Franco, M.A. (2019). A system dynamics approach to product design and business model strategies for the circular economy. *Journal of Cleaner Production*, 241, 118327.

Saidani, M., Kendall, A., Yannou, B., Leroy, Y., Cluzel, F. (2019). Closing the loop on platinum from catalytic converters: Contributions from material flow analysis and circularity indicators. *Journal of Industrial Ecology*, 23(5), 1143-1158.

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**Appendix: List of factors potentially influencing the circularity of platinum in catalytic converters**

Categories	#	Name
<b>Improvement areas</b>	1.1	Potential collection of catalytic converters in the European Union (EU)
	1.2	Effective end-of-life collection and processing of catalytic converters in the EU
	1.3	Quantity of platinum recoverable in catalytic converters end-of-life streams in the EU
	1.4	Circularity of platinum from catalytic converters in the EU
<b>Intermediate influence parameters</b>	2.1.1	Automotive, plus heavy-duty and off-road vehicles exports with catalytic converters
	2.1.2	Catalytic converters in use in the EU
	2.1.3	End-of-life stock of catalytic converters in the EU
	2.2.1	End-users behaviours, including constraints (regulatory) and motivations
	2.2.2	Partnerships for better traceability
	2.3.1	Average age of end-of-life vehicles in the EU
	2.3.2	Average quantity of platinum coated in a catalytic converter
	2.3.3	Average mileage of end-of-life vehicles in the EU
	2.3.4	Leakage of platinum during use
	2.4.1	Costs of collection, dismantling, storage, and end-of-life treatment (refining)
	2.4.2	Value of secondary platinum
	2.4.3	Saved costs (e.g., from rebuy, or landfill tax)
	<b>Action levers – "What if?" variables</b>	3.1.1
3.2.1		Financial incentives (e.g., scrapping premium)
3.2.2		Awareness campaign
3.2.3		Mandatory recycling/reuse rate
3.2.4		Economic penalty (e.g., landfill tax)
3.2.5a		Availability of maintenance and/or upgradability services
3.2.5b		Deposit-refund (or take-back) scheme
3.2.5c		Rental or leasing offers
3.2.6a		Geo-tracking online (telematics) platform for localisation
3.2.6b		Information-sharing system between users and end-of-life stakeholders
3.3.1		Innovative design and/or technology (downsizing, substitution)
3.3.2		Enhanced technological feasibility (recycling, refining process, full cleaning)
3.3.3		Design for circularity (e.g., modular-design, easy-disassembly)
3.3.4	End-of-life infrastructures (for collection, dismantling, processing, refining)	
3.4.1	Financial support for manufacturers and/or end-of-life actors (e.g., taxes reduction)	
<b>Drivers (tier 1)</b>	4.1.1	Industrial (automotive industry) market demand for catalytic converters
	4.2.1	EU Action Plan for the circular economy
	4.3.1	Uncertainty around platinum price (volatility for original equipment manufacturers)
	4.4.1	Geostrategic issue for the EU (platinum dependency)
<b>Drivers (tier 2)</b>	4.1.2	Emissions regulations (e.g., on NOx, CO, particles)
	4.1.3	Sales in the new vehicles
	4.2.2	Environmental and economic costs of platinum extraction/production
	4.3.2	Strikes in platinum ore mines in South Africa
	4.4.2	Platinum ores depletion (i.e., decrease in concentration)