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Circular Supply Chains: Improving Inventory Decisions

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Problem of practice

The circular economy has evolved from an aspirational slogan of 'reduce-reuse-recycle' to a driver of value. While supply chain managers and heads of sustainability initiatives have begun using techniques such as 'closing the loop' through recycling and 'slowing the loop' by extending product life, a key execution gap remains. Conventional supply chain moves in one direction: procure → make → sell. However, circular business models introduce complexity due to the reverse flow, the return journey of the products sold: sell → use → return/collect → refurbish → resell. This complexity stems from the uncertainty in the timing, quantity, and quality of returns, which overwhelms human decision-making. Recent research by Sergey Naumov, Saurabh Bansal, and V. Daniel R. Guide reveals that even experienced managers succumb to 'Supply Line Neglect'.[1] If managers neglect the complexity of this reverse flow due to behavioural bias that causes them to overlook inventory already moving through reverse channels and over-order new stock to avoid perceived shortages, it could result in operating costs rising 300% to 700% above optimal benchmarks. The good news is that the research also uncovers strategies to mitigate this threat. For instance, decouple the uncertainty of the quality of returned products from the logistics planning. We unpack this strategy and other approaches to help de-risk a company's sustainability logistics

[1] The article 'Managerial Efficiency and Reverse-Flow Complexity in a Circular Economy' by Sergey Naumov, Saurabh Bansal, and V. Daniel R. Guide, featured in Volume 71, Issue 8 of the *Journal of Operations Management*, shows behavioural nudges can help managers navigate complex return flows and make better inventory decisions, preserving the efficiency benefits of circular supply chains

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Managerial blind spot

The 'execution gap' in circular models is reducing adoption: global circularity penetration dropped from 9.1% in 2018 to 6.9% in 2025.[2] This decline represents a considerable opportunity cost. In the consumer packaged goods sector alone, the use of circular techniques is expected to unlock US$35–115 billion in additional operating profit by 2030.[3]

One important reason for the decline in deployment is that firms often underestimate the operational complexity of 'closing the loop' due to variability in the timing, quality, and quantity uncertainty of returns. The hurdle is primarily cognitive (see **Figure 1**). Humans are evolutionarily wired for linear cause-and-effect, not for the delayed feedback loops of a circular system. Consequently, managers, unable to 'see' the returning stock, often panic-order new inventory to cover 'phantom' shortages, resulting in inventory imbalances. This cognitive disconnect creates unnecessary inventory accumulation, higher working capital and drives operating costs 3-7 times higher than necessary.

Why does this blind spot persist?

In circular systems, complexity pushes managers toward mental shortcuts. Three biases show up repeatedly:

- **Supply-line neglect:** Teams focus on what's in the warehouse and products returning through repair, refurbishment or remanufacturing, often because return data sits dispersed across different systems.[4]
- **Recency and salience bias:** A recent stockout or demand spike dominates attention and triggers over-ordering while giving insufficient weight to historical return pattern.
- **Complexity aversion:** As uncertainty rises, managers simplify decisions to demand and available stock, ignoring return quality and repair lead times.

Together, these biases make the system feel more volatile than it is and amplify costly overreactions.

In the Indian smartphone market, companies like Samsung India face uncertainty in the return period, as trade-in devices can take weeks to move from rural collection points to urban hubs.[5] Financially, this 'time-value-of-waste' degradation means that a device delayed by 30 days can lose up to 15% of its resale value, locking up millions in non-productive working capital.[6]

In the e-waste sector, Attero Recycling faces variability in the quantity of returns due to the seasonal and unregulated nature of e-waste inflows.[7] When quantities fluctuate unpredictably, the plant runs below capacity, wasting expensive equipment and fixed overheads. According to research, operating a high-tech

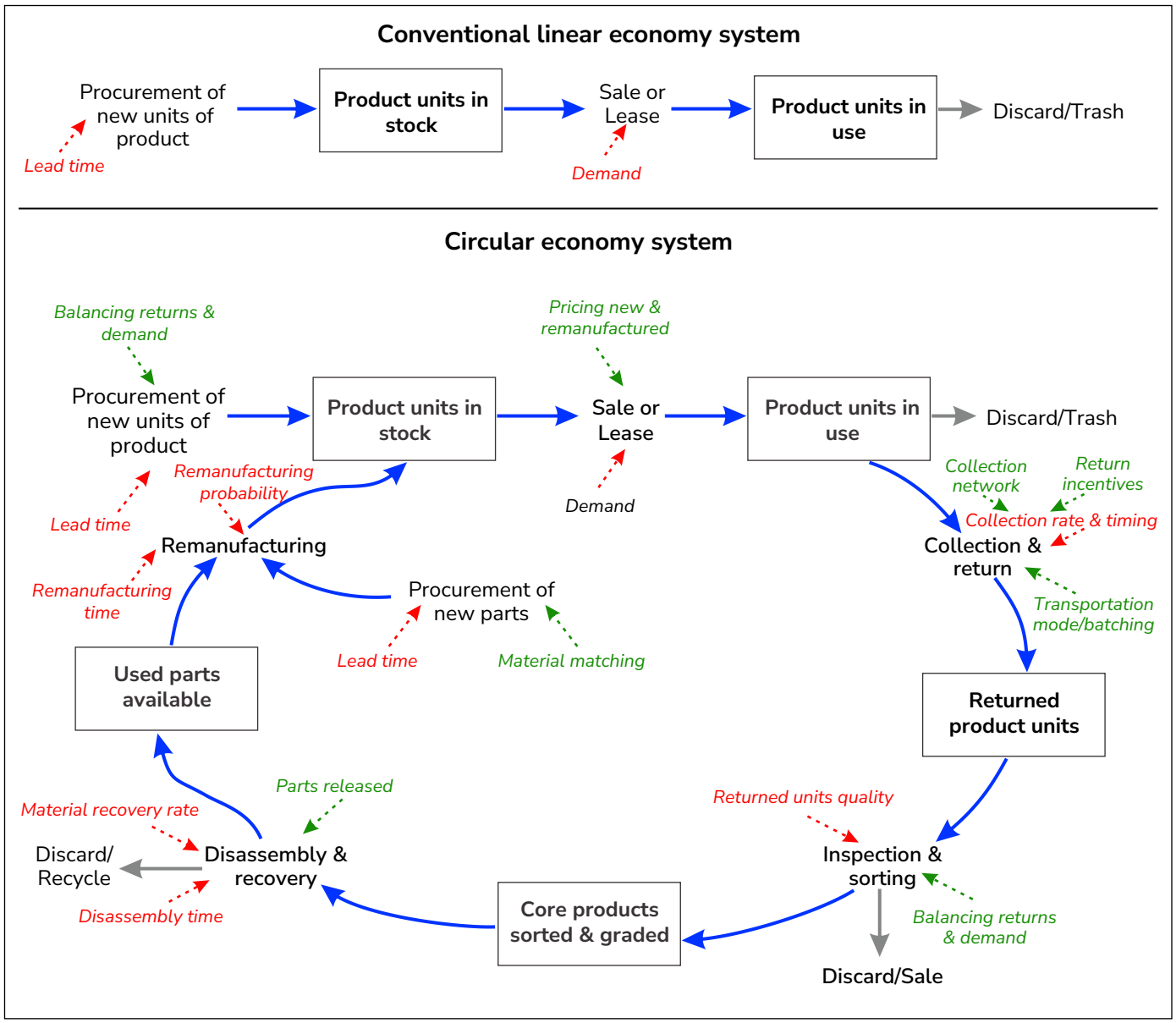


refinery at 40% capacity due to low inflows can increase processing costs per kg by 2.5x, turning a potential profit into a fixed-cost deficit. Recent reporting also notes Attero's plan to double revenue to Rs 2,000 crores in fiscal 2026.[8]

In the automotive aftermarket, Tata Motors (ProLife) faces quality variability when engines returned for remanufacturing are found to be too damaged to repair.[9] A high rate of variability of these returning engines — say a 30% rejection — could force the business to procure more expensive, 'new' components to fulfil service contracts. In turn, this shrinks the expected 40% remanufacturing margin down to a mere 5-10%.

Figure 1 visualises this structural shift. The diagram explicitly maps the intersection between sources of uncertainty (marked in Red) and managerial decisions (marked in Green), highlighting exactly where the 'cognitive fog' of delayed returns disrupts the standard planning process.

Figure 1: Conventional linear supply chains and closed-loop systems with returns



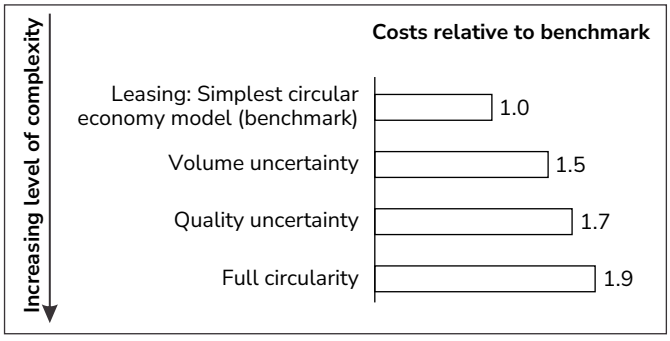
Red text + red dashed arrows: sources of uncertainty, Green text + green dashed arrows: managerial decision, Text in the box: stocks

Source: Created by authors based on Naumov, Sergey, Saurabh Bansal, and V. Daniel R. Guide Jr. "Managerial Efficiency and Reverse-Flow Complexity in a Circular Economy." Journal of Operations Management (2025). https://doi.org/10.1002/joom.70010



In their research, Naumov, Bansal, and Guide found that as reverse-flow uncertainty increased in terms of timing, quantity, and quality, performance deteriorated dramatically. Of the three uncertainty types, quality uncertainty proved most damaging – when managers were unsure which returned products could be reused, they over-ordered new stock. Timing and quantity uncertainty mattered too, but to a lesser extent. **Figure 2** summarises the research findings, showing how managerial inefficiency rises sharply as reverse-flow complexity increases, particularly under quality uncertainty.

Figure 2: Costs versus complexity of reverse-flow-An escalating relationship



The leasing model is the benchmark and is shown as 1.00. A value of 1.5 means costs are about 50% higher than the benchmark; 1.7 means about 70% higher; and 1.9 means about 90% higher.

Source: Created by authors based on Naumov, Sergey, Saurabh Bansal, and V. Daniel R. Guide Jr. "Managerial Efficiency and Reverse-Flow Complexity in a Circular Economy." Journal of Operations Management (2025). https://doi.org/10.1002/joom.70010

Building strategic capability

For CEOs and senior leaders, managing circularity is as much about mindset as it is about systems. The ability to interpret delayed feedback and make measured, data-informed choices is emerging as a key managerial skill. Naumov and team recommend that organisations consciously design bias-resistant processes and decision tools to convert circular initiatives into consistent performance. At the same time, those who ignore the behavioural dimension risk losing efficiency gains. The research proposes four strategies to bridge the execution gap, which are discussed below.

1. Simplify & decouple

Before deploying advanced analytics, stabilise the system by decoupling 'sorting' from 'planning'. This is best achieved through Partner-Led Grading. Partners here refer to specialised Reverse Logistics Providers and certified recyclers (like Li-Cycle in the battery sector).[10] These partners handle the uncertainty of the quality of their messy returns. This shields the inventory manager from the operational noise of sorting thousands of degraded units, effectively converting a complex circular problem into a simpler linear one.

2. Make the invisible visible

To combat cognitive biases like supply line neglect, decision dashboards should be used to display current stock alongside forecasted return volumes, broken down by quality, and refurbishment lead times. When return pipelines become visible and credible, managers

start incorporating them into their replenishment decisions.

3. Bias-resistant process design

Embed safeguards into systems rather than rely on individual vigilance. Automated alerts can flag excessive orders when large returns are expected. Default order parameters can include return forecasts unless manually overridden, turning rational behaviour into routine practice.

4. Build cognitive resilience

Training managers to think dynamically is essential. Simulation-based learning, like 'digital twins'* or simplified 'Beer Game'+ experiments, lets leaders experience the impact of delay and feedback first-hand. Such exercises build intuition about circular systems more effectively than slide decks ever could.

Roadmap for action

Different industries face distinct patterns of reverse-flow complexity, yet all exhibit the same behavioural traps.

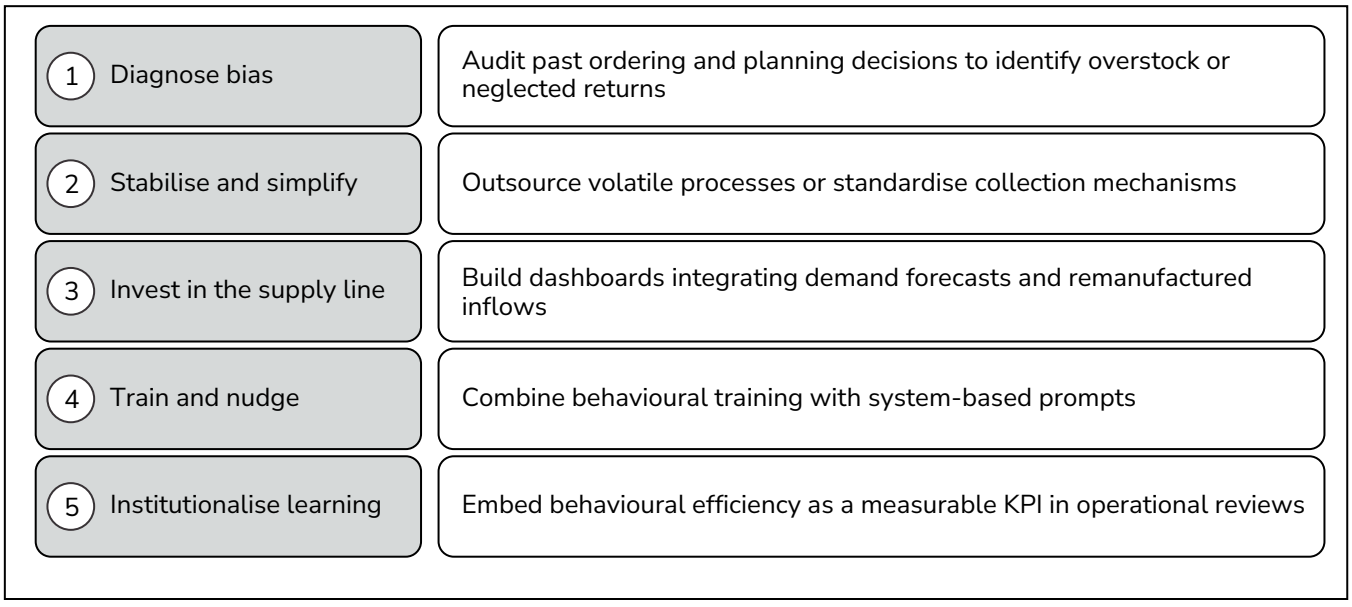
Automotive manufacturers, Renault Group's 'Refactory' in France illustrates the power of physical decoupling.[11] By isolating the unpredictable refurbishment workflow from linear assembly lines, they industrialise the grading process to turn variable used cars into standardised assets. This physical decoupling allows them to offer parts to customers 30% cheaper than the new ones while using 80% less energy. This facility is a cornerstone of Renault's 'The Future Is NEUTRAL' subsidiary, which generated nearly €1 billion in turnover in 2023 and targets a 10% operating margin by 2030.[12]

Caterpillar, manufacturer of construction and mining equipment, uses a financial approach to address quality uncertainty.[13] Their global 'Core Deposit' system imposes strict penalties for poor-quality returns. This effectively forces customers to filter out 'Quality Uncertainty' upstream. This system protects a services business that contributes significantly to Caterpillar's US$ 24 billion annual services revenue (2024), providing 'like-new' components at 40–60% of the cost of new parts.

In the Indian automotive sector, companies like Tata Motors and Mahindra manage uncertainty in engine and gearbox remanufacturing.[14,15] Partner-led grading and predictive maintenance data have reduced variability in return quality. Tata Motors' ProLife business has successfully remanufactured over 250,000 components, offering customers a 30-40% price advantage over new parts while significantly boosting brand loyalty.

In electronics, Samsung India and Attero Recycling use automated diagnostics to classify devices as reusable, repairable or scrap, enhancing planning accuracy.[16] Attero has achieved a 98% recovery rate of precious metals from lithium-ion batteries—significantly higher than the industry average. A practical roadmap emerges from these experiences, as shown in **Figure 3**.

Figure 3: Roadmap for building behavioural efficiency in circular economy planning decisions



Source: Created by authors based on Naumov, Sergey, Saurabh Bansal, and V. Daniel R. Guide Jr. "Managerial Efficiency and Reverse-Flow Complexity in a Circular Economy." Journal of Operations Management (2025). https://doi.org/10.1002/joom.70010

Implementing strategies

While leaders often ask for a fixed price tag for circular transformation, the investment required is not uniform; it depends on the organisation's specific complexity profile.

- ***Volume vs value*:** High-volume, low-value flows (e.g. plastics recycling) often require significant capital investment in automated sorting infrastructure to manage scale. Conversely, for high-value, low-volume flows (e.g. industrial engines), partner-led grading relies more on manual expert grading, shifting the cost from capital expense to operational expense.
- ***Network density*:** The cost of establishing visibility and collection varies with the circular loop's geographical spread. Managing a single return centre is more cost-effective for implementing integrated dashboards and control systems than a distributed network of thousands of retail drop-off points. These costs can be mitigated by partnering with specialised logistics or recycling firms.
- ***Grading granularity*:** The most significant cost-driver is the 'depth' of sorting. Systems that must distinguish between dozens of material grades (e.g. multiple polymer types) incur exponentially higher implementation costs than systems using a simple binary (repairable/scrap) triage.

  Managers must therefore audit these three variables: volume, network, and granularity, to estimate their specific return on investment.
- ***The right context*:** These insights are beneficial for supply chain leaders and inventory strategists in high-value B2B industries, specifically those in heavy machinery, medical technology, and IT hardware, where the remanufacturing loop is a central profit engine rather than a peripheral CSR activity. In these sectors, for example, while new equipment sales often yield EBIT margins of ~10%, remanufacturing and aftermarket services can deliver margins between 25% and 40%.[17] Unlike managers in linear retail, these leaders face the unique 'double jeopardy' of managing uncertainty in both demand and supply. Solving this is not just a process fix, it needs a clear mandate from the top.
- ***Leadership imperatives*:** For CEOs, the transition to circularity demands rethinking systems and mental models. Beyond individual awareness, leadership teams must institutionalise behavioural learning. This means designing regular 'bias audits' in planning cycles, requiring structured reviews of past decisions to identify where human judgement deviated from system forecasts. Create reflection forums where managers discuss not only operational results but also the reasoning behind key decisions. Some firms are also experimenting with cognitive dashboards that flag when decisions consistently contradict historical evidence. Such tools do not replace human judgment; they discipline it.

Circularity – mind & matter

The circular economy is not only about material loops but also mental loops. The true competitive advantage lies in training managers to anticipate feedback, trust data, and avoid intuitive overreaction. Behavioural efficiency will separate firms that make circularity profitable from those that make it an expensive experiment.

Glossary of technical terms used

*** Digital twin** is a virtual model of a supply chain that uses operational data to monitor performance, test scenarios, and support better decisions.

(*Source: IBM, "What Is a Digital Twin?," October 17, 2025, https://www.ibm.com/think/topics/digital-twin. Siemens, "Logistics Digital Twin". https://www.siemens.com/en-us/products/digital-logistics/consulting/logistics-digital-twin/*)

+ Beer Game is a supply chain simulation in which participants manage different stages, such as retailer, wholesaler, distributor, and factory, to understand how local ordering decisions affect the overall system.

(*Source: Harvard Business Publishing, "Supply Chain Management Simulation: Root Beer Game V3," August 31, 2023, https://hbsp.harvard.edu/product/7908-HTM-ENG*)

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