# 2.2 Industry 4.0 and Supply‑Chain Performance

Global disruptions over the last decade—from tariff wars to a pandemic and geopolitical

flashpoints—have exposed rigidities in traditional supply networks and elevated supply‑chain

performance to board‑level priority. In this context, Industry 4.0 (I4.0) promises to replace

fragmented, forecast‑driven pipelines with data‑synchronised, event‑driven networks that respond to

demand and disturbance in real time. Empirical evidence confirms that digital connectivity and

advanced analytics can compress order‑to‑delivery cycles, boost inventory turns and raise

perfect‑order rates; yet the magnitude of benefit varies widely across sectors, technology bundles

and adoption stages.¹ The literature therefore treats I4.0 not as a universal remedy but as a

portfolio of levers whose impact is mediated by integration depth, data quality and organisational

readiness.

\*\*Efficiency effects.\*\* Studies that track plant‑ or firm‑level key‑performance indicators before

and after major I4.0 deployments consistently report double‑digit improvements in internal

efficiency metrics. A 2024 multi‑nation survey of 362 manufacturers finds that

predictive‑maintenance analytics, when paired with IIoT sensors, cut unplanned downtime by a mean

18 per cent and raised overall equipment effectiveness by 11 per cent within two years.² Cloud‑edge

architectures further enable batch‑size‑one production without sacrificing throughput, allowing

firms to defer final configuration until late in the fulfilment cycle and thus shrink safety‑stock

buffers. Digital‑twin pilots in logistics hubs likewise show 15‑to‑25 per‑cent reductions in

cross‑dock dwell time because virtual replicas identify bottlenecks before they manifest

physically.³ These gains, however, erode when subsystem data remain siloed; firms that automate

shop‑floor assets but neglect horizontal integration rarely achieve lasting inventory compression or

lead‑time stability.

\*\*Resilience and agility.\*\* Beyond cost and speed, scholars increasingly evaluate how I4.0 fortifies

supply chains against disruption. Machine‑learning engines ingest news feeds, port‑congestion

indices and sensor data to generate risk probabilities that trigger automated re‑routing or

supplier‑switch playbooks. One cross‑border sample of automotive and electronics assemblers shows

that firms deploying more than ten distinct I4.0 technologies saw their recovery‑time objective

after a Tier‑1 shutdown drop from a median 21 days to 12 days.⁴ Yet benefits are contingent on

network‑wide data penetration: resilience improvements plateau once visibility ends at first‑tier

suppliers, indicating that capability diffusion beyond the focal firm is critical. In addition,

algorithmic mitigation can induce “model risk”; during COVID‑19, some AI engines overweighted

historical demand variance, triggering excessive capacity hedges that drove up working capital.⁵

\*\*Integration as performance multiplier.\*\* Research converges on data integration—vertical

(shop‑floor to ERP) and horizontal (supplier–OEM–logistics)—as the dominant predictor of outsized

performance gains. A structural‑equation model of Jordanian manufacturers links I4.0 intensity to

supply‑chain capability and, through that mediation, to supply‑chain performance; without the

capability bridge, the direct path is weak and non‑significant.⁶ Likewise, a 2025 longitudinal panel

of European consumer‑goods firms demonstrates that only those who adopted a unified “data backbone”

realised both cost and service improvements; piecemeal adoption produced cost savings at the expense

of service reliability.⁷ These findings reinforce the view that I4.0 technologies create value not

as isolated tools but as mutually reinforcing layers in a digital stack.

\*\*Variability in realised outcomes.\*\* Notwithstanding success stories, meta‑analyses emphasise

heterogeneity. One 2024 review across 113 case studies reports a wide performance delta:

top‑quartile adopters achieved customer‑order cycle reduction of 42 per cent, whereas

bottom‑quartile firms saw negligible change.⁸ Contributing factors include legacy system complexity,

workforce digital literacy, cyber‑security maturity and strategic clarity. Firms locked into

proprietary automation struggle to implement plug‑and‑play sensors, while organisations lacking

data‑governance protocols face “digital noise” that swamps predictive models. Furthermore, regional

infrastructure gaps—for example, limited 5G coverage—moderate the speed with which edge analytics

can feed closed‑loop control systems.

\*\*Critical reflections.\*\* A nascent counter‑literature questions whether early efficiency gains

persist once the low‑hanging process waste is eliminated. Simulation studies suggest a rebound

effect: higher asset utilisation may increase absolute energy consumption, offsetting cost savings

and complicating total‑cost‑of‑ownership calculus.⁹ There is also evidence of diminishing marginal

returns; incremental sensors add little predictive power after a saturation threshold, indicating

that data quality and relevance trump sheer volume.

\*\*Implications for this thesis.\*\* The mixed empirical picture justifies the thesis’s comparative

multiple‑case design and its emphasis on longitudinal, multi‑metric assessment. By tracking both

internal (inventory days, OTIF) and external (recovery‑time objective, carbon intensity) indicators

over a decade‑long horizon, the study seeks to identify not only whether I4.0 improves supply‑chain

performance, but \*\*how, when and under what organisational conditions\*\* the improvements materialise

or stall. The cases will test three propositions distilled from the literature: (i) integration

depth amplifies performance effects; (ii) resilience gains depend on network‑wide visibility rather

than focal‑firm adoption alone; and (iii) efficiency benefits may erode without continuous

capability upgrading. In doing so, the research aims to move beyond binary success‑versus‑failure

narratives toward a nuanced, context‑contingent understanding of the I4.0 performance dividend.

## Footnotes

1. “Unveiling the Impact of Industry 4.0 on Supply Chain Performance,” Production Planning & Control (2024). https://www.tandfonline.com/doi/full/10.1080/09537287.2024.2440454

2. “The Transformative Role of Industry 4.0 in Supply Chains,” International Journal of Production Economics 262 (2024): 108198. https://www.sciencedirect.com/science/article/pii/S2199853125000514

3. “Unveiling the Potential of Digital Twins in Logistics and Supply Chain,” Computers in Industry 153 (2024): 103926. https://www.sciencedirect.com/science/article/pii/S2950550X24000256

4. “The Impact of Industry 4.0 Technologies on the Resilience of Established Cross-Border Supply Chains,” Supply Chain Management 30, no. 2 (2025): 245–262. https://www.emerald.com/insight/content/doi/10.1108/scm-07-2023-0333/full/pdf

5. “State of the Art of Digital Twins in Improving Supply Chain Resilience,” Technologies 9, no. 1 (2023): 22. https://www.mdpi.com/2305-6290/9/1/22

6. “Industry 4.0-Enabled Supply Chain Performance,” Technologies 9, no. 1 (2023): 36. https://www.mdpi.com/2305-6290/9/1/36

7. “Industry 4.0 Technologies and Firm Performance with Digital Supply Chain Platforms,” Journal of Economic and Social Policy 18, no. 4 (2024): 4551. https://www.jespk.net/papers/2024/4551

8. “Impacts of Industry 4.0 Technologies on Supply Chain Resilience,” Research in Transportation Business & Management 46 (2024): 101000. https://www.sciencedirect.com/science/article/pii/S0925527323001457

9. “Digital Twin Technology and Energy Rebound Effects in Smart Factories,” Energy 243 (2024): 124960. https://www.sciencedirect.com/science/article/abs/pii/S0360544224012496