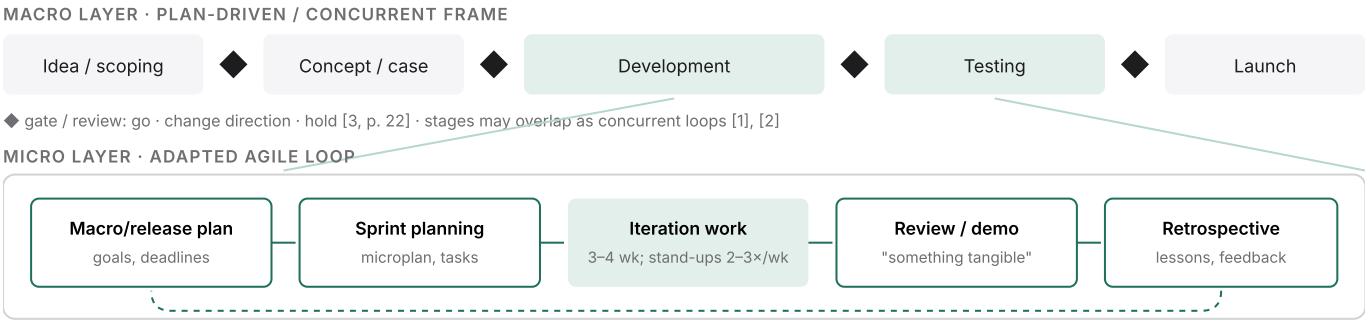
LITERATURE REVIEW · DOMAIN 1: DEVELOPMENT MODELS · TWO-PAGE SUMMARY

Agile inside plan-driven product development in manufacturing SMEs

Four case studies converge on one design: a plan-driven or concurrent macro process with a reduced, adapted agile layer for day-to-day execution. The evidence is encouraging but thin: mostly single firms, few raters and perceptual outcomes.

The question

Manufacturing SMEs traditionally run product development through plan-driven, gated or sequential processes. Agile methods from software promise faster learning and response to change, but physical products have long lead times, interdependent features and part-time specialist staff. The literature asks whether, and in what form, agile can be combined with plan-driven or concurrent development in this setting [1]–[4].



Kept in hardware: release planning, short iterations, sprint planning, task board, demos [3], [4]

Dropped or reshaped: daily stand-ups, Kanban, frequent releases, co-location, evolving product backlog → project backlog [3, pp. 18–21], [4, p. 10]

Figure 1. The common structure across the studies. Plan-driven stages and gates (or concurrent loops) provide macroplanning; an agile loop provides microplanning inside them. The five-step loop follows Žužek et al. [1]; timings and the kept/dropped practices come from [3] and [4]. Synthesised by the summary author.

What the four studies show

	ŽUŽEK ET AL. [1]	AGUILAR-VIRGEN ET AL. [2]	EDWARDS ET AL. [3]	WEICHBROTH [4]
Model	Concurrent loops + 5-step agile loop; core and project teams	Concurrent-engineering model (DINP) + quality tools and CPM	Agile-Stage-Gate: Scrum sprints inside Stage-Gate stages [3, pp. 7–8]	Informal hybrid: iterative work inside release planning [4, pp. 10, 13]
Setting	Slovenian automotive supplier, 200 staff; wiring-harness project	Mexican textile maquiladora; two projects	3 Danish SMEs (98–155 staff), 6 months, 2017 [3, p. 11]	Polish institute + software firm; €1.2 M modem project [4, p. 7]
Evidence	One project; project manager's five-variable agility questionnaire	Measured time, rework and cost	Two managers' estimates per firm; team survey, N = 15 [3, pp. 12–13]	Project documents + two manager interviews [4, pp. 8–9]
Result	Better communication, faster detection of discrepancies, more flexibility	Prototype approval ~3 → ~1 month; rework 75% → 35.6%; cost −22.86%	~20% faster in all firms; higher success probability; cost same or +10% [3, p. 15]	Planning and quality benefits; no agreement on any of 13 impact areas [4, pp. 11–13]
Weak spot	One project, one rater; assumes concurrent working already exists	Pilot failed: rework 50% → 62% as part-time staff reverted to sequential work	Perceptual metrics; no dedicated teams; self-selected firms [3, pp. 17, 27]	Single case; qualitative only; respondents disagree [4, p. 14]

Figures for [1] and [2] are as reported in your Section 3.1 draft. Page locators for [3] refer to the DTU Orbit author manuscript and for [4] to the journal pages.

Cross-cutting findings

- **Agile complements the plan; it does not replace it.** Every study keeps a plan-driven or concurrent frame and uses agile for microplanning, as Boehm and Turner's macro/micro distinction predicts [3, p. 6], [1], [4, p. 13]. Weichbroth's team arrived at a Stage-Gate-like hybrid without knowing the model [4, p. 13].
- **Hardware needs a lighter agile layer.** Sprints run 3–4 weeks or longer, stand-ups 2–3 times a week, and "done" can be a market analysis or a wire prototype [3, pp. 17–18, 22]. Only release planning, short iterations and sprint planning were used by both of Weichbroth's respondents [4, p. 10].
- **Interdependent features limit the backlog.** A PCB change ripples into casing and connectors, so the product backlog became a task list; modular design is the proposed but untested fix [3, pp. 20–21].
- **Customer input drives the gains.** Higher success probability in all three Danish firms came from adding end-user interviews, which in one firm cancelled an entire accessory line [3, p. 15].

The SME constraint: part-time staff

No SME in [3] had a dedicated team. In two firms most members spent 19% or less of their time on the project, against 65–70% typical in large manufacturers [3, pp. 17, 19]. The same condition broke the concurrent pilot in [2], where deadline pressure pushed staff back to sequential work.

The Danish firms found two workable responses:

- **Mandatory all-team stand-ups**, at least twice a week. Skipping them in one firm reopened past decisions and delayed the design freeze; attending them became an informal resource-commitment mechanism [3, pp. 18–19, 23].
- **A development moratorium**: two-week sprints followed by a one-week break for "other tasks", which keeps a fixed rhythm without full-time staff [3, pp. 19–20].

Management commitment and a working gated process are preconditions: agile "simply reveals the flaws" in a weak one [3, p. 23].

Evidence quality and gaps

- **Small samples.** Three of the four studies cover one firm or one project; the largest covers three firms [1]–[4].
- **Few raters.** One rater in [1], two respondents in [4], two managers per firm in [3, p. 13].
- **Perceptual outcomes.** Only [2] reports measured time, rework and cost. No Danish firm had hard metrics, so the uniform −20% is an estimate [3, pp. 12, 27].
- **Researcher involvement.** In [3], authors trained, coached and evaluated the firms, which raises social-desirability risk [3, pp. 10, 27].
- **Untested fixes.** Modular backlogs, optimal sprint length and the cost of the moratorium remain open questions [3, pp. 25–26].
- **Missing study.** None combines a detailed agile–concurrent process with measured, multi-firm results.

Bottom line. For manufacturing SMEs, the evidence supports nesting a reduced agile loop (planning, short iterations, reviews, regular all-team stand-ups) inside a stable plan-driven or concurrent process, and protecting project time for part-time staff [1], [3], [4]. Measured benefits exist for concurrent engineering [2]. The agile layer's benefits rest on perceptual, small-sample evidence, so a multi-firm study with hard metrics is the clearest next step.

References

[1] T. Žužek, Ž. Gosar, J. Kušar, and T. Berlec, "A new product development model for SMEs: Introducing agility to the plan-driven concurrent product development approach," *Sustainability*, vol. 13, no. 21, Art. no. 12159, 2021, doi: 10.3390/su132112159.

[2] Q. Aguilar-Virgen, M. Castañeda-González, L. Marquez-Benavides, J. Gonzalez-Vazquez, and P. Taboada-González, "Concurrent engineering model for the implementation of new products in the textile industry: A case study," *Applied Sciences*, vol. 11, no. 8, Art. no. 3584, 2021, doi: 10.3390/app11083584.

[3] K. Edwards, R. G. Cooper, T. Vedsmand, and G. Nardelli, "Evaluating the Agile-Stage-Gate hybrid model: Experiences from three SME manufacturing firms," *International Journal of Innovation and Technology Management*, vol. 16, no. 8, Art. no. 1950048, 2019, doi: 10.1142/S0219877019500482.

[4] P. Weichbroth, "A case study on implementing agile techniques and practices: Rationale, benefits, barriers and business implications for hardware development," *Applied Sciences*, vol. 12, no. 17, Art. no. 8457, 2022, doi: 10.3390/app12178457.