LITERATURE SUMMARY · DOMAIN 1: DEVELOPMENT MODELS

Agile inside plan-driven product development: two studies from manufacturing

Two peer-reviewed journal papers that extend the topic of your Section 3.1, which is combining iterative or agile project management with plan-driven or concurrent product development in hardware and SME settings. Each summary was written from the full text of the paper and includes redrawn diagrams. Every statement carries an IEEE-style numbered citation with a page locator, keyed to the reference list on the last page.

Prepared 11 November 2026 · Figures are redrawn from the text and tables of each paper. They are not reproductions of the original artwork. Page numbers for [3] refer to the peer-reviewed author manuscript on DTU Orbit, because the journal article is numbered 1950048 rather than paginated; page numbers for [4] refer to the published journal pages (1–23).

#	PAPER	JOURNAL	DESIGN & SETTING	HEADLINE FINDING
A	**Edwards, Cooper, Vedsmand & Nardelli (2019) [3].** Evaluating the Agile-Stage-Gate hybrid model: experiences from three SME manufacturing firms.	*International Journal of Innovation and Technology Management* 16(8), 1950048 (World Scientific)	Longitudinal multi-case test; 3 Danish manufacturing SMEs; 6 months (2017)	Managers in all three firms estimated about 20% faster development and a higher probability of success. Costs were unchanged or rose. Agile had to be adapted (longer sprints, fewer stand-ups, a "moratorium" week) [3, pp. 15, 17–19].
B	**Weichbroth (2022) [4].** A case study on implementing agile techniques and practices: rationale, benefits, barriers and business implications for hardware development.	*Applied Sciences* 12(17), 8457 (MDPI, open access)	Single case; Polish research institute + software firm; €1.2 M Industry 4.0 project, 2019–2021	Only a "light" iterative subset of agile was used (release planning, short iterations, sprint planning). Its benefits were concentrated in planning and quality. The two managers disagreed on its wider impact [4, pp. 10–11].

Why these two

Your Section 3.1 already covers a concurrent model with an agile loop (Žužek et al. [1]) and a concurrent-engineering implementation with measured outcomes (Aguilar-Virgen et al. [2]). These two papers add complementary evidence. **Paper A** [3] tests the best-known agile and plan-driven hybrid (Agile-Stage-Gate) in SMEs that had never used agile, and it documents the same part-time-staff problem that undermined the Aguilar-Virgen pilot, along with a practical fix. **Paper B** [4] shows which agile practices actually survive in a hardware project and which ones are dropped.

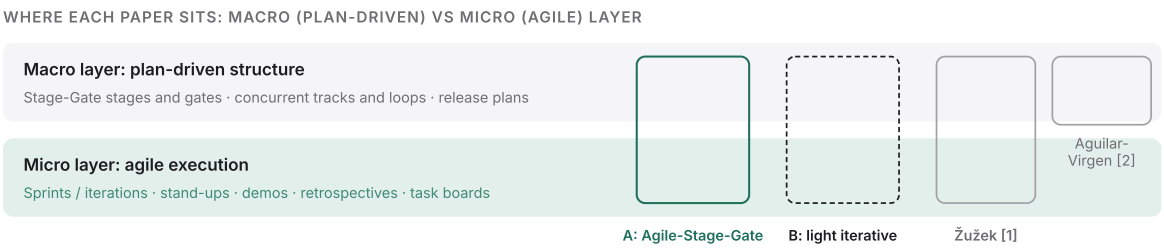


Figure 0. All four studies combine a plan-driven macro structure with iterative micro-execution, except Aguilar-Virgen et al., which works only at the macro (concurrent) level. A box spanning both bands means the study integrates both layers. The dashed box marks a partial or informal adoption. The macro/micro split follows Boehm and Turner [11], who describe gated processes as macroplanning and agile as microplanning, as cited in [3, p. 6]. Sources: [1], [2], [3, pp. 7–8], [4, p. 13].

PAPER A

Evaluating the Agile-Stage-Gate hybrid model in three SME manufacturers

> **Edwards, K., Cooper, R. G., Vedsmand, T., & Nardelli, G. (2019).** Evaluating the Agile-Stage-Gate hybrid model: Experiences from three SME manufacturing firms. *International Journal of Innovation and Technology Management, 16*(8), 1950048. https://doi.org/10.1142/S0219877019500482 · Free peer-reviewed preprint on DTU Orbit. Cited below as [3].

3	6 mo	−20%	13/15
Danish manufacturing SMEs (98–155 employees)	test period, one project per firm (2017)	development time, as estimated by managers in every firm	agile practice items improved (team survey, N = 15)

Aim and context

The authors note that all published Agile-Stage-Gate (ASG) evidence came from large firms such as GE, Honeywell, Volvo and LEGO, and that none came from SMEs, even though SMEs make up the majority of manufacturers [3, p. 2]. They asked whether ASG works for small manufacturers and what modifications those firms need [3, p. 9]. The test was sponsored by the Confederation of Danish Industry (DI) and funded by the Danish Industry Foundation (project 2016-0114) [3, pp. 2, 28].

Method

- **Tailoring:** Before the test, ASG was adapted for SMEs together with innovation managers from LEGO, Danfoss, Grundfos, Coloplast and the SME ForeNAV. The result was a 20-page manual and a tools supplement [3, p. 11].
- **Firms:** DI selected three firms that developed and manufactured in-house, were about to start a project, did not yet use agile, and were willing to try ASG. The firms made B2B convenience food (142 staff), B2B audio equipment (155 staff) and B2B radar systems (98 staff) [3, p. 11, Table 1].
- **Intervention:** A joint workshop was followed by on-site Scrum training (mindset, roles, backlogs, definition of done, burndown) and design-thinking training (personas, user research). Product owners and Scrum masters received intensive coaching during the first two sprints [3, pp. 11–12].
- **Data:** Pre-project interviews with whiteboard process maps; a 15-item Likert questionnaire given to all team members before and after the project (N = 15); post-project evaluation workshops with two senior managers per firm; and group interviews with each team using the Effect Modifier Assessment (EMA) method of Edwards and Winkel [10] [3, pp. 12–13].

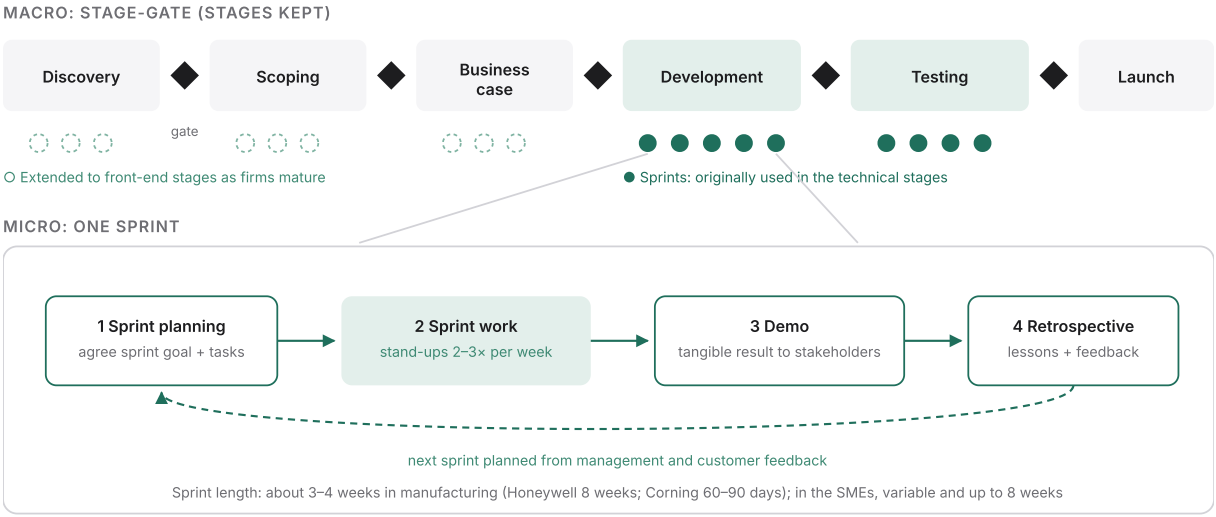


Figure A1. How Agile-Stage-Gate works, as described in Sections 3.2–3.3 of the paper. Stages and gates remain the macro-planning frame. Inside a stage, Gantt charts and critical-path plans are replaced by time-boxed sprints. Redrawn and simplified from the paper's Figures 1–2 [3, pp. 7–8]. The term "Agile-Stage-Gate" was coined by Sommer et al. [8], as noted in [3, p. 7].

How each firm adopted the model

ELEMENT	COMPANY A	COMPANY B	COMPANY C
Industry	B2B convenience food	B2B audio equipment	B2B radar systems
Test project	Convenience snack	Audio headset	Modular power supply
Team size	6	4	5
Stand-up frequency	2× per week	0–1× per week	Daily
Notable adaptation	Personas from customer interviews	Customer-based design document; sprint reviews used as gates	2-week sprint + 1-week development moratorium

Source: [3, p. 11, Table 1; pp. 13–14, Table 2] (simplified). Firm details: A founded 2000, €35 M sales; B founded 1992, €28 M sales; C founded 1977, sales not stated.

Results

None of the firms had hard project metrics, so outcomes are senior managers' estimates comparing the test project with similar past projects (two managers per firm) [3, pp. 12–13].

METRIC	COMPANY A	COMPANY B	COMPANY C
Development time	−20%	−20%	−20%
Development cost	Same	+10%*	Same
Overall innovation process	Better	Better	Same
Estimated probability of success	Higher	Higher	Higher

Figure A2. Senior managers' evaluation of the ASG test project against comparable past projects (the paper's Table 3). Green = improvement; grey = no change; dashed = worse. *Company B's cost rose only because it added a new activity: overseas end-user interviews. Source: [3, p. 15, Table 3].

- **Speed:** About 20% faster in all three firms. Costs and spend rates did not fall [3, pp. 14–15].
- **Process:** Better in two firms, whose planning had previously been ad hoc and based on the lead developer's experience. Sprint planning gave management and the team a shared view of goals and next steps. The third firm already had a working process [3, p. 15].
- **Success probability:** Higher in all three, because the projects included customer insight for the first time. In one firm, end-user interviews cancelled an entire accessory line that customers could already buy cheaply off the shelf [3, p. 15].
- **Behaviour:** 13 of 15 survey items improved. The largest gains were visual feature displays, a strong business case, time-boxed sprints, a stable core team, and user stories. Customer collaboration on new concepts fell, and co-location and cross-functionality did not change [3, pp. 15–17, Fig. 3].
- **Market:** A year later, Companies A and B had launched their products with promising early sales [3, p. 17].

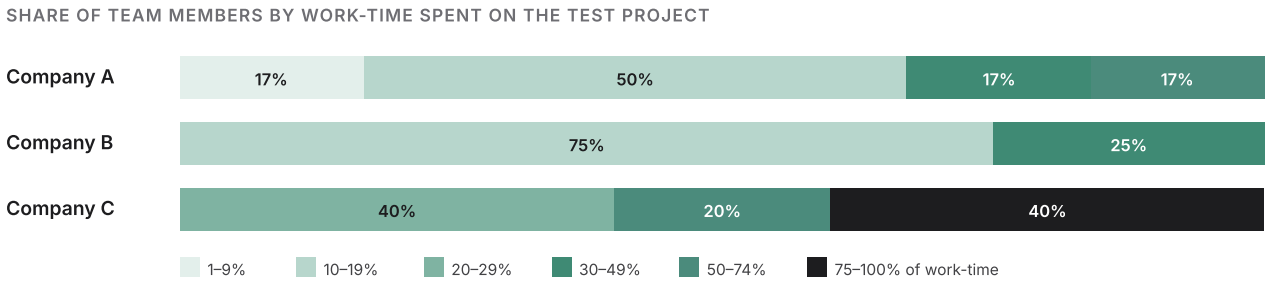


Figure A3. No team was fully dedicated to its project. In A, two-thirds of members spent 19% or less of their time on the project; in B, 75% did. Company C was the most focused: 60% of members spent over half their time on it. For comparison, team members in large manufacturers typically spend 65–70% of their time on the project, according to Cooper and Sommer [9] as cited in [3, p. 19]. Data from [3, p. 17], the paper's second table labelled "Table 3"; Company A's shares sum to 101% because of rounding.

Adaptations the SMEs invented

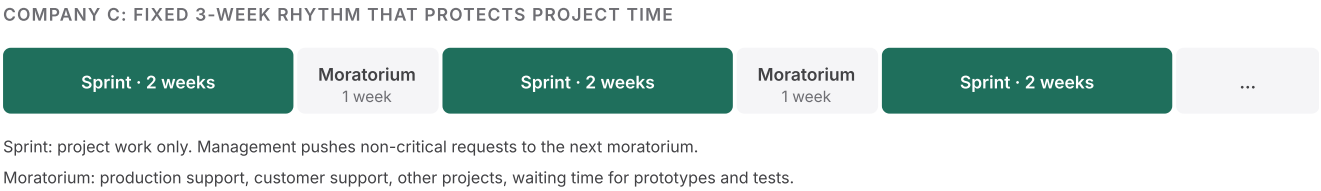


Figure A4. The "development moratorium", which the authors describe as unusual and not found in any software-agile guide. It keeps a fixed rhythm without requiring a fully dedicated team, which the authors judge to be unrealistic for most SMEs [3, pp. 19–20, 23].

SOFTWARE-AGILE PRESCRIPTION	WHAT HAPPENED IN THE SMES	LEARNING
Short, fixed 2-week sprints	Sprints were usually 3–4 weeks, varied in length, and sometimes lasted 8 weeks [3, pp. 17–18].	Longer sprints are acceptable for hardware, but they should be consistent so the team keeps a rhythm.
Daily stand-ups	Only one firm held them daily. In Company A, excusing non-developers from stand-ups meant past decisions kept being reopened and the design freeze came very late [3, p. 18].	Hold stand-ups at least twice a week with the whole team present. They also became an informal mechanism for committing resources [3, pp. 19, 23].
Dedicated, co-located team	No firm had dedicated or co-located teams. Company C co-located the whole team for an afternoon only three times, to resolve interface changes [3, p. 20].	Co-location matters less in hardware because specialists' competences barely overlap [3, p. 20].

SOFTWARE-AGILE PRESCRIPTION	WHAT HAPPENED IN THE SMES	LEARNING
Evolving product backlog	Hardware features are intertwined (for example, a PCB change ripples into the casing and connectors), so the product backlog became a project backlog of tasks [3, pp. 20–21].	Modular design could restore the backlog's role, but no firm tried it [3, p. 21].
Demo = working increment	"Done" covered market analyses, personas, a LEGO concept and wire prototypes. Teams over-promised [3, p. 22].	Broaden the definition of done to include all sprint results.
Go/kill gates	Gates were not investment decisions. Outcomes were go, change direction, or mothball. Sprint demos acted as "mini-gates" judged against strategy with scorecards [3, p. 22].	Put a functioning Stage-Gate in place before adding agile, because agile exposes the flaws in a weak process [3, p. 23].

Limitations (stated and observed)

- Performance figures are **perceptual** estimates from two managers per firm. No firm had hard metrics, and a uniform −20% suggests rounded judgements [3, pp. 12, 27].
- The sample is three self-selected, agile-curious Danish firms, which may amplify the benefits. Each firm also adapted ASG differently, which weakens causal attribution [3, p. 27].
- Some authors trained and coached the firms and also evaluated them, which creates a risk of compliance and social-desirability bias. The authors mitigated this with pre/post surveys and the EMA method [3, pp. 10, 13, 27].

Relevance to your review. This paper directly answers the fragility you note in Aguilar-Virgen et al. [2], where deadline pressure sent part-time staff back to sequential work. Edwards et al. [3] find the same part-time-team condition in all three SMEs [3, pp. 17–19]. They show that a protected rhythm (sprint plus moratorium) and mandatory all-team stand-ups can keep an iterative process running without full-time staff [3, pp. 23–24]. Like Žužek et al. [1], they conclude that agile works as micro-planning inside a stable macro process, not as a replacement for it [3, pp. 6, 23].

PAPER B

Implementing agile techniques in a hardware development project

> **Weichbroth, P. (2022).** A case study on implementing agile techniques and practices: Rationale, benefits, barriers and business implications for hardware development. *Applied Sciences, 12*(17), 8457. https://doi.org/10.3390/app12178457 · Open access (CC BY 4.0). Cited below as [4].

€1.2 M
EU-co-funded Industry 4.0 project, Jan 2019 – Dec 2021

2
hardware iterations of an industrial communication modem

3 of 16
listed agile techniques confirmed in use by both respondents

0 of 13
impact areas on which the two managers agreed

Aim and context

Evidence on agile in hardware manufacturing is described as "sparse and fragmented" [4, p. 1]. The study gives an in-depth account of which agile tools and practices were actually implemented in one hardware project, why, with what benefits, and against which barriers [4, p. 1]. The project, "An Industry 4.0 Mobile Process Management System Supported by Artificial Intelligence", was a consortium between Meritus Software Systems (the project leader, a Warsaw software firm founded in 1990) and the Tele and Radio Research Institute, part of the Łukasiewicz Research Network (the project partner) [4, p. 7]. Its hardware deliverable was a low-cost universal communication modem for M2M and IoT data acquisition in harsh industrial environments [4, pp. 7–8].

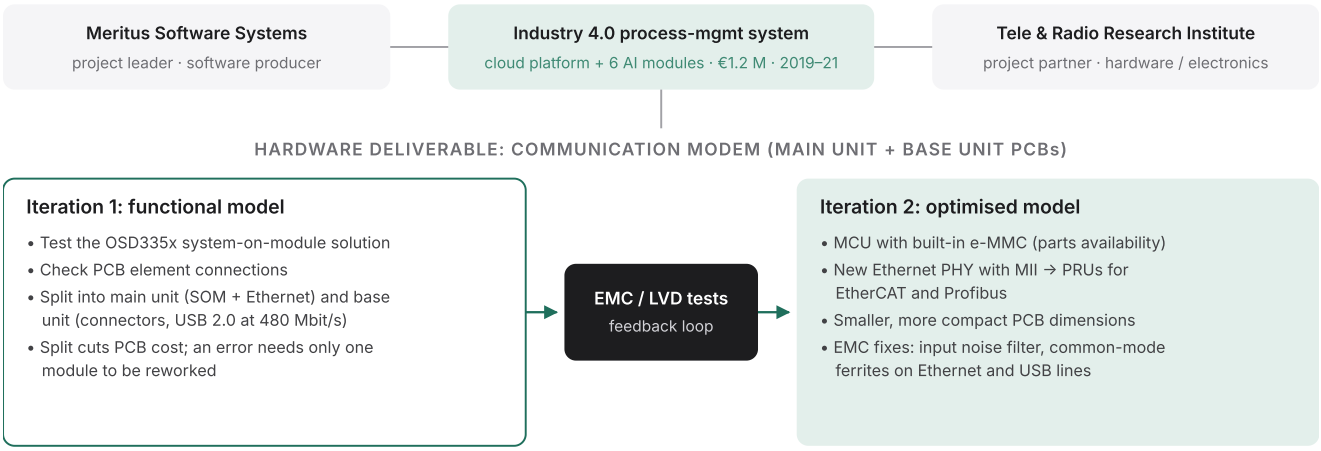
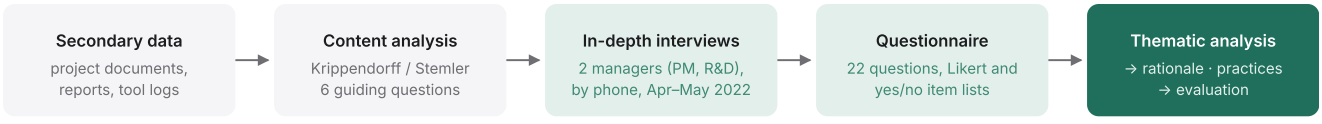


Figure B1. Case setting and the two hardware iterations, redrawn from the paper's Sections 3.1–3.3. Compliance-test results from iteration 1 drove the design changes in iteration 2. The author notes that the project's organisation closely resembled a hybrid Stage-Gate approach, although neither manager knew that model. Sources: [4, pp. 7–8, 13].

Method



Inclusion criteria for respondents: at least 5 years' experience, involved for the whole project, managerial role. Both had over 20 years in IT.

Figure B2. Research design. The interviews and questionnaire were used to validate what the documentation analysis had found. The content analysis followed Krippendorff [12], as cited in [4, p. 8]; the two respondents (project manager and R&D manager, each with 20+ years in IT) were interviewed by phone in April–May 2022 and then completed the questionnaire [4, pp. 8–10].

Findings

Rationale. Both respondents agreed that agile was adopted to accelerate delivery, improve business–IT alignment and reduce project risk, and that it improves the management of changing priorities, quality and engineering discipline [4, p. 10]. They did not agree on whether agile helps a team respond to volatile markets, improves predictability, or raises morale [4, p. 10]. The author concludes that the core motive was to prevent and minimise the risk of project failure [4, p. 13].

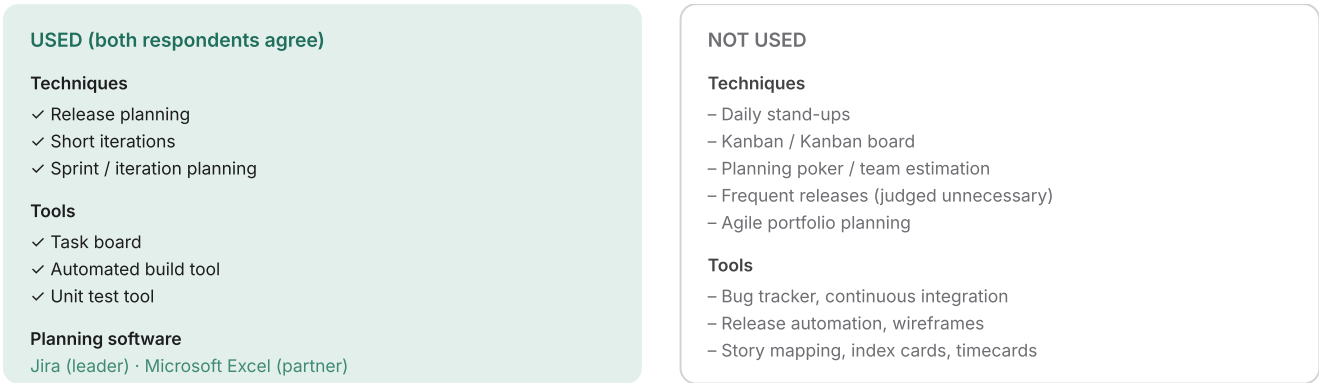


Figure B3. The agile subset that survived in a hardware project (from Q3–Q5 of the paper). The respondents described the method as "iterative" rather than Scrum or Kanban. Several software-centric tools were judged unsuitable for a hardware producer. Sources: [4, pp. 10–11]; the full list of 16 techniques is in [4, p. 16, Appendix A].

Benefits reported

- **Release planning:** efficiency gained by highlighting release goals and deadlines, high-quality plans, and better visibility of planning problems [4, p. 12].
- **Short iterations:** less process overhead (full agreement), more frequent customer feedback, and easier scope management [4, p. 12].
- **Sprint planning:** described as an enabler of product quality and better backlog control [4, pp. 12–13].
- **Task board:** full agreement on all three benefits (spreading information, focus, visibility) [4, p. 13].
- **Build and unit-test tools:** earlier bug detection, higher component quality, time and cost savings [4, p. 13].
- Both respondents agreed that total benefits exceeded total costs [4, p. 13].

Barriers and disagreement

- The only shared barrier was **lack of business, customer or product understanding** [4, p. 12].
- The partner (research institute) alone reported resistance to change, the pervasiveness of traditional methods, fragmented tooling, an unwillingness to admit mistakes, inconsistent processes, and a culture at odds with agile [4, p. 12].
- **Impact:** no agreement on any of the 13 areas. The project manager cited changing priorities, predictability and risk. The R&D manager cited speed, discipline, quality, morale and productivity [4, p. 11].
- **Remote-team challenge:** keeping the final goal in mind, plus gaps in knowledge and agile mindset between sectors [4, p. 13].

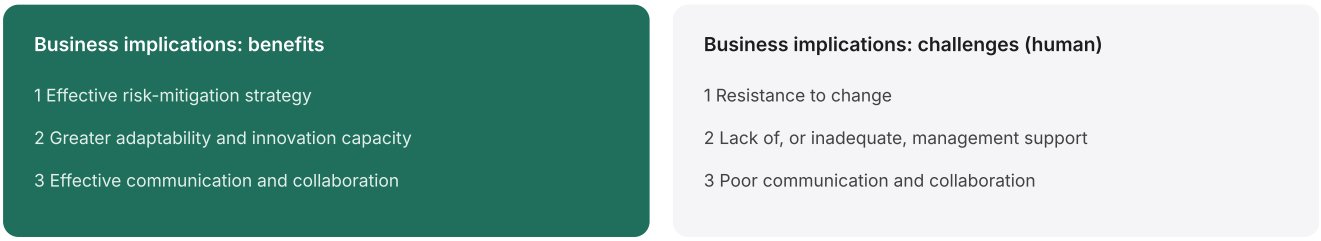


Figure B4. The paper's concluding business implications (Section 6). The author also argues that the hardest shift is in leadership style, from telling the team what to do to mentoring it. Sources: [4, pp. 14–15].

Limitations (stated and observed)

- The study covers one project with two respondents, interviewed after project closure. The author states the results cannot be generalised, and all data are qualitative [4, pp. 9, 14].
- The respondents disagreed on all impact areas, so the evidence describes which practices were adopted more strongly than what outcomes they produced. The study reports no time, cost or quality figures [4, pp. 10–14].
- The consortium was led by a software firm, so the "hardware" view is filtered through IT managers. Many questionnaire items are software-centric (for example, "software quality") [4, pp. 7, 11, 15–17].

Relevance to your review. This paper is a counterweight to Paper A. Without training or a formal hybrid model, a hardware project informally converged on the same structure: plan-driven release planning at the macro level with short iterations, sprint planning and a task board at the micro level [4, pp. 10–13]. It also dropped daily stand-ups, Kanban and frequent releases [4, p. 10]. This supports the claim in Žužek et al. [1] and Edwards et al. [3] that hardware needs a reduced, adapted agile layer. Its two-respondent design repeats the single-rater weakness you flag in Žužek et al. [1].

SYNTHESIS

Comparing the four studies

DIMENSION	ŽUŽEK ET AL. [1]	AGUILAR-VIRGEN ET AL. [2]	EDWARDS ET AL. [3]	WEICHBROTH [4]
Macro frame	Concurrent development loops	Concurrent engineering (DINP)	Stage-Gate	Informal hybrid Stage-Gate
Micro method	5-step agile loop	Quality tools + CPM	Tailored Scrum	Iterations + sprint planning
Setting	1 Slovenian automotive SME	1 Mexican textile maquiladora	3 Danish SMEs (food, audio, radar)	Polish institute + software firm
Evidence	1 rater questionnaire	Measured time, rework, cost	Manager estimates + pre/post team survey (N = 15)	Documents + 2 interviews
Key outcome	Communication, flexibility	Prototype approval ~3 → ~1 month; cost −22.86%	Time −20%; higher success probability	Planning and quality benefits; no consensus on impact
Part-time staff	Not tested	Pilot failed under deadline pressure	Present in all firms; mitigated by moratorium and stand-ups	Not examined

Sources: [1] and [2] as summarised in your Section 3.1 draft; [3, pp. 11–19]; [4, pp. 7–13].



Figure S1. A qualitative positioning by the summary author, not a measured scale. Only Aguilar-Virgen et al. report hard measured outcomes. Edwards et al. combine detailed process adaptations with multi-firm perceptual outcomes. None of the studies yet pairs a detailed agile and concurrent process with measured multi-firm results.

Ready-to-adapt paragraph for Section 3.1

Written in the style of your draft. Citation numbers match the reference list below; page locators can be dropped if your template does not use them.

Edwards, Cooper, Vedsmand, and Nardelli [3] test the Agile-Stage-Gate hybrid, in which Scrum sprints replace Gantt-based planning inside retained Stage-Gate stages. They ran it for six months in 2017 in three Danish manufacturing SMEs (98–155 employees) that had never used agile, after training and coaching each team. Senior managers estimated that each test project ran about 20% faster than comparable past projects and had a higher probability of success, largely because customer interviews were added. Costs were unchanged in two firms and rose by 10% in the third. A pre/post team survey (N = 15) showed improvement on 13 of 15 agile practices [3, pp. 14–17]. However, the outcomes are perceptual estimates from two managers per firm. No team was dedicated: in two firms most members spent 19% or less of their time on the project. The firms had to lengthen sprints to 3–4 weeks or more, hold stand-ups only two to three times

a week, and turn the product backlog into a project backlog because hardware features are interdependent [3, pp. 17–21]. Weichbroth [4] examines a €1.2 million Polish Industry 4.0 consortium that developed an industrial communication modem in two test-driven hardware iterations. Using document content analysis and interviews with two managers, the study finds that only release planning, short iterations, sprint planning, a task board, and build and unit-test tools were used. Daily stand-ups, Kanban, and frequent releases were dropped [4, pp. 10–11]. Both respondents judged that benefits exceeded costs, yet they agreed on none of 13 impact areas, so the study shows which practices survive in hardware rather than what they achieve [4, pp. 11, 13]. Edwards et al. [3, pp. 19, 23] thus show that a protected sprint-and-moratorium rhythm and mandatory all-team stand-ups can sustain iterative work with part-time SME staff, the condition under which the Aguilar-Virgen et al. [2] pilot collapsed. Weichbroth [4, p. 13] shows that, even without a formal model, hardware teams converge on a reduced agile layer nested inside plan-driven release planning.

Further reading (abstract-level check only)

I have not read the full text of these two, so they are not summarised in detail. Verify them before citing.

- **[5] Fargher, G. P., Khan, M., & Al-Ashaab, A. (2025).** LAMPD: a combined lean and agile model for product development. *International Journal of Agile Systems and Management, 18*(6), 1–25. https://doi.org/10.1504/IJASM.2025.149185 (open access). Maps the 12 Agile Principles onto the 5-phase Set-Based Concurrent Engineering process at Atlas Copco Henrob, combines stage-gates with Scrum ceremonies and Kanban, and reports an evaluation by 17 R&D professionals.
  Strong fit: concurrent engineering + agile
- **[6] Žužek, T., Kušar, J., Rihar, L., & Berlec, T. (2020).** Agile-Concurrent hybrid: A framework for concurrent product development using Scrum. *Concurrent Engineering: Research and Applications, 28*(4), 255–264. https://doi.org/10.1177/1063293X20958541. The conceptual predecessor of your source [1].

References

IEEE style. [1]–[2] are the sources already in your Section 3.1; [3]–[4] are summarised in full here; [8]–[12] are works cited inside [3] and [4] that this summary refers to (cite them only via the paper, e.g. "as cited in [3]", unless you read them yourself).

SOURCES IN YOUR DRAFT

[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, Nov. 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, Apr. 2021, doi: 10.3390/app11083584.

PAPERS SUMMARISED IN THIS DOCUMENT

[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, Dec. 2019, doi: 10.1142/S0219877019500482. Page locators refer to the peer-reviewed author manuscript, DTU Orbit.

[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, Aug. 2022, doi: 10.3390/app12178457.

FURTHER READING

[5] G. P. Fargher, M. Khan, and A. Al-Ashaab, "LAMPD: A combined lean and agile model for product development," *International Journal of Agile Systems and Management*, vol. 18, no. 6, pp. 1–25, 2025, doi: 10.1504/IJASM.2025.149185.

[6] T. Žužek, J. Kušar, L. Rihar, and T. Berlec, "Agile-Concurrent hybrid: A framework for concurrent product development using Scrum," *Concurrent Engineering: Research and Applications*, vol. 28, no. 4, pp. 255–264, 2020, doi:

10.1177/1063293X20958541.

[7] T. Žužek, Ž. Gosar, J. Kušar, and T. Berlec, "Adopting agile project management practices in non-software SMEs: A case study of a Slovenian medium-sized manufacturing company," *Sustainability*, vol. 12, no. 21, Art. no. 9245, Nov. 2020, doi: 10.3390/su12219245. (The earlier paper holding the quantitative project-success data that [1] refers to.)

WORKS CITED WITHIN [3] AND [4]

[8] A. F. Sommer, C. Hedegaard, I. Dukovska-Popovska, and K. Steger-Jensen, "Improved product development performance through Agile/Stage-Gate hybrids: The next-generation Stage-Gate process?," *Research-Technology Management*, vol. 58, no. 1, pp. 34–45, 2015, doi: 10.5437/08956308X5801236. Cited in [3, pp. 6–7, 9–10].

[9] R. G. Cooper and A. F. Sommer, "Agile-Stage-Gate: New idea-to-launch method for manufactured new products is faster, more responsive," *Industrial Marketing Management*, vol. 59, pp. 167–180, 2016, doi: 10.1016/j.indmarman.2016.10.006. Cited in [3, pp. 6, 10, 19].

[10] K. Edwards and J. Winkel, "A method for effect modifier assessment (EMA) in ergonomic intervention research," *Applied Ergonomics*, vol. 72, pp. 113–120, 2018, doi: 10.1016/j.apergo.2018.05.007. Cited in [3, p. 13].

[11] B. Boehm and R. Turner, *Balancing Agility and Discipline: A Guide for the Perplexed*. Boston, MA, USA: Addison-Wesley, 2004. Cited in [3, p. 6].

[12] K. Krippendorff, *Content Analysis: An Introduction to Its Methodology*, 4th ed. Thousand Oaks, CA, USA: SAGE, 2018. Cited in [4, p. 8].