ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.04 (2025)

ENHANCING AGILE PRACTICES: A HYBRID INTEGRATION OF SCRUM AND PAIR PROGRAMMING

Noor Fatima[1], Muhammad Ahmad [2], Asim Amin [3], M. Abdullah Irfan Khan [4]
[1,2,4] Department of computer science and information technology, Superior University
su92-mspmw-f23-004@superior.edu.pk
ahmadkahloon@superior.edu.pk
su92-mspmw-f23-003@superior.edu.pk
[3]Department of computer science and information technology, The university of Chenab
asim@cs.uchenab.edu.pk

Abstract
In the modern software industry, organizations are under pressure to deliver high-quality solutions quickly while responding to changing client needs. Agile methodologies have gained dominance for enabling adaptability, iterative delivery, and customer collaboration. However, traditional Scrum, while widely adopted, sometimes creates knowledge silos and lacks balanced quality control. Pair Programming (PP), on the other hand, encourages collaboration and knowledge sharing but can be resource-intensive and difficult to scale. This research introduces the Hybrid Scrum Pair Model (HSPM), which merges the sprint planning strength of Scrum with the collaborative dynamics of Pair Programming. In this model, teams plan sprints and rotate 1–2 developers in each sprint to increase shared understanding across the project. The HSPM follows cyclic phases Planning, Development, Testing, Delivery, Retrospective, and Pair Rotation ensuring both structure and flexibility. The model was applied over multiple sprints, evaluating outcomes like sprint velocity, defect rate, and team satisfaction. Results showed enhanced collaboration, reduced defects, and improved code quality. This study provides a simplified yet practical hybrid model that strengthens Agile practices through structured pairing and resource rotation.

Index Terms: *Agile methodologies, Scrum, Pair Programming, Hybrid Scrum–Pair Model, Software quality, Team collaboration, Knowledge sharing, Sprint velocity, Business Analyst role.*

1. Introduction
Software development methodologies are evolving to meet the demands of dynamic markets that require faster delivery and consistent quality. Agile frameworks, particularly Scrum, have gained wide acceptance due to their adaptability, structured approach, and iterative nature. Scrum organizes work into short, time-boxed sprints, each ending with a potentially deliverable product increment [1]. However, one of Scrum's limitations is that individual developers often work independently on tasks, resulting in knowledge gaps and inconsistencies in technical standards [2].
Pair Programming (PP), a practice within Extreme Programming (XP), was designed to address such collaboration gaps. It involves two programmers working at the same workstation one acting as the 'Driver' (writing code) and the other as the 'Navigator' (reviewing and guiding). This immediate feedback loop improves code quality, reduces defects, and facilitates continuous learning [3]. However, PP can be difficult to scale, particularly in large projects, and sometimes reduces efficiency when two developers are assigned to tasks that one could manage [4].
To overcome these limitations, this research proposes the Hybrid Scrum Pair Model (HSPM) a model that blends Scrum's sprint-driven process with the collaborative pairing principles of PP. The key innovation in HSPM is the planned resource rotation, where one or two developers are changed each sprint, giving multiple team members exposure to different project areas and strengthening shared knowledge [5]. This hybrid model follows a cyclic process that integrates sprint-based development with structured pair rotation to achieve balanced productivity and

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ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
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CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
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continuous learning.

Parallel to Scrum's evolution, Pair Programming (PP) has emerged as a significant practice within the broader framework of Extreme Programming (XP). Pair Programming involves two developers working simultaneously at a single workstation, where one assumes the "Driver" role, actively writing code, and the other serves as the "Navigator," reviewing and providing feedback in real time. This continuous interaction fosters collaboration, shared understanding, and immediate code review, resulting in reduced defects and enhanced overall quality [3]. Moreover, Pair Programming encourages skill transfer among team members and strengthens problem-solving by combining diverse perspectives. However, Pair Programming is not universally effective. Its limitations include developer fatigue, difficulty in scaling across larger teams, and potential inefficiencies in resource allocation when two programmers are engaged in a task that one could complete independently [4]. Thus, while beneficial in many respects, Pair Programming on its own does not present a comprehensive solution for all Agile challenges.

Recognizing both the strengths and weaknesses of Scrum and Pair Programming, researchers and practitioners have increasingly explored the potential of hybrid Agile frameworks that integrate elements from multiple approaches. Such models aim to leverage complementary strengths while mitigating individual limitations. The Hybrid Scrum Pair Model (HSPM) represents one such innovation, designed to integrate the structured sprint-based planning and delivery mechanisms of Scrum with the collaborative and quality-enhancing dynamics of Pair Programming. By embedding Pair Programming practices into Scrum cycles, the model seeks to reduce knowledge silos, improve code quality, and foster stronger collaboration within teams. A distinguishing feature of this model is its use of pair rotation, wherein developer pairs are periodically switched during or after sprints. This mechanism ensures broader dissemination of knowledge, prevents the formation of fixed cliques, and reduces the risk of burnout [5]. The incorporation of rotation also reinforces team cohesion, as members gain insights into diverse coding practices and perspectives.

1.1 Hybrid Scrum Pair Model Process Steps

The Hybrid Scrum Pair Model (HSPM) follows a structured sequence of steps that merge Scrum's sprint-driven workflow with systematic Pair Programming. These steps provide a clear roadmap for how collaboration and knowledge sharing are embedded across each sprint cycle.

1.1.1 Resource Planning:

- In this phase, sprint goals and pair assignments are defined together.
- At the start of the project, roles such as Developer, QA Engineer, Scrum Master, Product Owner, and Business Analyst are identified to ensure balanced responsibility.
- After the initial setup, the manager plans resource rotation at the start of each sprint deciding which one or two developers will move to new pairs.
- During Sprint Planning, backlog items are reviewed, tasks are assigned to pairs, and sprint objectives are finalized.
- This combined approach ensures that sprint and resource planning occur in parallel, promoting even workload distribution and collective ownership of the codebase.

1.1.2 Assigning Modules:

- Specific modules or backlog items are mapped to pairs based on task complexity

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CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
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and individual expertise.

- Each pair follows the **Driver–Navigator** practice one developer codes while the other reviews.
- This method helps maintain coding standards, minimizes errors, and ensures shared understanding of each feature.
- Every pair is responsible for completing its assigned module within the sprint timeline, maintaining transparency through daily reporting.

1.1.3 Daily Stand-ups:

- Unlike traditional Scrum, where individuals report separately, pairs in HSPM report their progress together.
- This encourages shared accountability and continuous synchronization.
- Each pair briefly discusses completed tasks, current blockers, and next-day goals, while the Scrum Master ensures alignment and removes impediments quickly.
- The collaborative format also strengthens communication between developers and other roles.

1.1.4 Testing:

- Testing activities run parallel to development to maintain quality within each sprint.
- Pairs conduct quick internal testing before handing modules to the QA Engineer for validation.
- QA verifies code functionality, maintainability, and adherence to sprint requirements by manual testing and using some automation tools like **Selenium**.
- This integrated testing flow ensures quality assurance at every step instead of waiting until sprint completion.

1.1.5 Delivery & Demos:

At the end of each sprint, completed increments are reviewed and demonstrated. HSPM introduces **two demo checkpoints** for better visibility and feedback:

- **Mid-Sprint Demo:** Internal team-only meeting to review progress and identify early improvements.
- **Final Sprint Demo:** Involves internal team, management, clients, and stakeholders to review deliverables and finalize acceptance.

This two-level demo approach ensures early risk detection, improves transparency, and offers clients flexibility for quick adjustments.

1.1.6 Retrospectives:

- After every sprint, the entire team evaluates what worked well and what needs improvement.
- Unlike standard Scrum retrospectives, HSPM also reviews the pairing process its impact on communication, fatigue, and skill sharing.
- Action items identified in this discussion are applied to the next sprint, promoting continuous learning and process maturity.

1.1.7 Pair Rotation:

- After every sprint, the entire team evaluates what worked well and what needs improvement.
- Unlike standard Scrum retrospectives, HSPM also reviews the pairing process its impact on communication, fatigue, and skill sharing.
- Action items identified in this discussion are applied to the next sprint, promoting continuous learning and process maturity.

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Despite the growing literature on Agile practices, there is a notable research gap concerning the empirical validation of hybrid models that systematically integrate Scrum with Pair Programming. Most existing studies evaluate Scrum and Pair Programming independently, focusing on their respective advantages and constraints [6], [7]. While some multi-agent simulations and case studies have suggested that hybridization may enhance outcomes [8], [9], empirical evidence from real-world software development teams remains limited.

This study aims to address this gap by implementing and analyzing the Hybrid Scrum Pair Model in a practical setting, focusing on measurable metrics such as sprint velocity, defect rates, code quality, team satisfaction, and collaboration dynamics.

2. Literature Review

2.1 Agile Methodologies and Scrum

Agile methodologies have become the foundation of modern software development, emphasizing adaptability, collaboration, and iterative delivery. Among these methodologies, Scrum is the most widely adopted framework, offering time-boxed sprints, defined roles, and continuous feedback loops [1]. Its structured yet flexible design enables teams to manage complexity and deliver incremental value. Research highlights that Scrum improves stakeholder satisfaction and visibility into progress, while promoting cross-functional teamwork [2].

However, limitations exist. Studies reveal that while Scrum accelerates delivery, it often fails to enforce consistent code review or technical quality checks within sprint boundaries [3]. This can lead to knowledge silos where only certain developers fully understand specific parts of the system and technical debt accumulation [4]. These gaps indicate the need for additional practices that embed collaboration and continuous quality control into Scrum workflows.

2.2 Pair Programming:

Pair Programming (PP), a central practice from Extreme Programming (XP), involves two programmers working side by side: the Driver, who writes the code, and the Navigator, who reviews it and considers broader design implications [5]. This dynamic allows for real-time feedback, rapid problem solving, and ongoing knowledge sharing.

Empirical studies demonstrate that PP reduces defect density, enhances maintainability, and fosters knowledge transfer [6]. For example, Parrish et al. found that pairs often outperform individuals on complex tasks due to immediate feedback and dual perspectives [7]. In educational settings, systematic reviews show PP improves students' confidence, comprehension, and engagement [8].

Nonetheless, challenges persist. Developers often report fatigue from continuous collaboration, while organizations question efficiency because two developers are devoted to a single task [9]. Additionally, PP is harder to scale in larger projects, and its success strongly depends on pair composition (e.g., novice–expert vs. novice–novice) [10].

2.3 Effects on Productivity and Code Quality

The literature presents mixed evidence regarding productivity. While pairs may initially appear slower, research suggests the time saved in defect detection and reduced rework often balances or exceeds the effort cost [11]. For instance, Williams et al. showed that paired teams produced 15–50% fewer defects compared to individuals [12].

In terms of quality, the consensus is more robust. Systematic reviews consistently report that PP increases correctness, reduces bug density, and enhances readability [8], [13]. Additionally, pairing encourages adherence to coding standards and facilitates tacit knowledge sharing,

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
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reducing dependence on single experts [14].
Still, the productivity quality tradeoff is context-dependent. Teams with automated testing and CI/CD pipelines see more pronounced benefits from PP, as defect prevention directly supports sprint goals [3].

2.4 Pair Rotation and Knowledge Sharing

Pair rotation switching partners regularly has emerged as a mechanism to maximize the benefits of PP. Practitioner literature emphasizes that rotation prevents cliques, distributes expertise, and ensures broader codebase familiarity [15]. Simulation studies confirm that rotation strategies increase resilience and reduce project risk by spreading knowledge across multiple developers [16].
However, rotation introduces coordination costs, particularly when context-switching occurs too frequently. Balancing rotation frequency is therefore critical: too frequent rotations may reduce focus, while too infrequent rotations risk reinforcing silos. Despite its promise, rigorous empirical studies of rotation remain sparse, making it a valuable contribution area for hybrid Scrum–Pair research.

2.5 Hybrid Agile Models: Scrum with XP Practices

To address Scrum's limitations, researchers have proposed hybrid Agile frameworks that integrate XP practices, including PP, test-driven development (TDD), and continuous integration. Haque and Bhowmik [3] introduced Hybrid Scrum-XP, highlighting improved team adaptability and quality outcomes. Wang [16], through multi-agent simulations, demonstrated that Scrum teams employing PP strategies outperform those using solo programming in terms of resilience and defect management.
Despite these findings, most evidence remains conceptual or simulation-based. Real-world field studies validating such hybrid models under industrial conditions are rare [17]. Additionally, existing studies often lack mixed-method analysis that captures both quantitative metrics (e.g., sprint velocity, defect rate) and qualitative team experiences (e.g., satisfaction, collaboration). This gap underscores the importance of empirical implementations like the Hybrid Scrum–Pair Model.

2.6 Measurement Approaches in Agile Research

Evaluating Agile practices requires triangulation of metrics. Standard measures include:
Sprint velocity: number of story points completed per sprint, typically tracked in Jira [18].
Defect rate: number of bugs reported in QA logs, reflecting product stability [19].
Code quality: static analysis tools like SonarQube provide maintainability and complexity indices [20].
Team satisfaction and collaboration: surveys and semi-structured interviews capture subjective perceptions [21].
Best practices recommend combining these metrics to assess both technical outcomes and human factors [22]. This mixed-methods approach increases reliability and depth, and it forms the basis for the evaluation of the HSPM in this study.

3. Methodology

This study employed a mixed-methods case study design to evaluate the effectiveness of the Hybrid Scrum–Pair Model (HSPM) within a real-world software development environment. The methodology integrates quantitative and qualitative approaches in order to capture both technical and social dimensions of Agile performance. Quantitative measures, including sprint velocity, defect density, and code quality, were used to assess productivity and technical

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CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
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outcomes. Complementary qualitative data, derived from post-sprint surveys and semi-structured interviews, provided insights into collaboration, satisfaction, and knowledge sharing. By combining these perspectives, the study ensured that findings were both measurable and reflective of participants' lived experiences.

3.1 Research Design

The research was conducted across four consecutive sprints, each sprint lasting two weeks, based on eight-week observation period. This iterative timeframe allowed the team to adapt to the hybrid model and enabled comparative evaluation across sprints. The case study approach was selected to enable in-depth exploration of the model in its natural organizational context, thereby maintaining ecological validity.

3.2 Participants and Roles

The study involved a mid-sized Agile team comprising three software developers, one Quality Assurance (QA) engineer, one Scrum Master, one Product Owner, and one Business Analyst. All participants had prior Scrum experience. Developers worked in rotating pairs following the Driver–Navigator format of Pair Programming. The Scrum Master facilitated sprint events, while the Product Owner ensured backlog prioritization. The Business Analyst played a key role in refining requirements and bridging communication between stakeholders and developers.

4. Results and Findings

The Hybrid Scrum–Pair Model (HSPM) was implemented across four consecutive sprints, and both quantitative and qualitative data were collected to evaluate its effectiveness. The following subsections summarize the outcomes.

4.1 Sprint Velocity

Sprint velocity was measured in time estimation completed per sprint using Jira [33].
Sprint 1: The team completed 180hrs estimated time . This lower output was attributed to the team's adaptation to new workflows, including pair-based assignments and role switching.
Sprint 2: Velocity improved to 195 hours as developers became more comfortable with pair collaboration.
Sprint 3: The team delivered 210 hours. Pair rotation introduced fresh dynamics, which improved problem-solving and the balance of expertise.
Sprint 4: Output reached 220 hours, representing a ~20% improvement compared to Sprint 1.
Interpretation: The steady rise in velocity suggests that as the team adapted to pair programming and systematic rotation, productivity improved. This aligns with studies highlighting long-term efficiency benefits of hybrid models [16].

4.2 Defect Rate

Defect rates were recorded via QA logs.
Sprint 1: 15 defects were reported, many related to misunderstandings of shared ownership.
Sprint 2: Defects dropped to 13 as pairs improved coordination.
Sprint 3: Only 11 defects were reported, attributed to continuous Driver–Navigator reviews.
Sprint 4: 10 defects were logged, representing a 33% reduction compared to Sprint 1.
Interpretation: Continuous code review within pairs, combined with backlog clarity from the BA, directly reduced errors. This confirms literature showing that Pair Programming lowers defect density [12], [35].

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ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
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4.3 Code Quality

Static analysis using SonarQube [34] measured maintainability, duplication, and complexity.
Sprint 1: Duplication was 12%, with moderate cyclomatic complexity.
Sprint 2: Duplication dropped to 10%, and maintainability improved.
Sprint 3: Duplication fell to 8%, while code smells decreased.
Sprint 4: Duplication reached 7%, and the maintainability index improved significantly.
Interpretation: Continuous reviews, daily role switching, and pair rotation helped enforce coding standards and reduce technical debt. Cross-pair collaboration also ensured consistent practices across modules.

4.4 Team Satisfaction

Post-sprint surveys revealed high satisfaction with HSPM. Developers valued pair rotation for breaking monotony and fostering collaboration. Many noted knowledge transfer as a key benefit.
The BA reported improved backlog clarity due to interacting with multiple developers. A minority of developers expressed fatigue from constant collaboration, confirming earlier concerns about Pair Programming [6].
Overall, more than 80% of responses rated the experience positively, highlighting enhanced engagement and learning.

4.5 Collaboration and Knowledge Sharing

Semi-structured interviews confirmed that pair rotation prevented silos. By Sprint 4:
Each developer had worked with at least four different teammates.
Developers reported increased system-wide understanding rather than isolated knowledge.
The Scrum Master observed smoother stand-ups, with pairs reporting collectively and supporting each other.
Interpretation: Pair rotation distributes expertise evenly, reducing the risk of dependency on individuals. This resonates with prior findings that rotation enhances resilience and team cohesion [15], [16].

5. Discussion

The findings of this study provide empirical evidence that the Hybrid Scrum Pair Model (HSPM) effectively combines the structural strengths of Scrum with the collaborative benefits of Pair Programming. This section discusses the outcomes in relation to the research questions (RQs) and the broader literature.

5.1 Findings for RQ1: Productivity and Quality

RQ1 asked: Does HSPM improve productivity and quality in Agile teams?
The results strongly support this claim. Sprint velocity increased by nearly 20% across four sprints, while defect rates fell by one-third. These trends suggest that HSPM not only sustains but also enhances productivity. The integration of Pair Programming into Scrum workflows enabled real-time review and reduced rework, thereby addressing one of Scrum's common weaknesses uneven technical quality [3], [4].
Code quality metrics from SonarQube further reinforced these outcomes, showing reductions in duplication and improvements in maintainability. These results align with prior studies on Pair Programming that emphasize quality improvements [12], [35]. However, HSPM extends these benefits by embedding PP into the Scrum lifecycle rather than applying it ad hoc, ensuring systematic and sustainable gains.

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ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
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5.2 Findings for RQ2: Collaboration and Knowledge Sharing

RQ2 asked: How does HSPM influence collaboration, satisfaction, and knowledge sharing?
Survey and interview data revealed that pair rotation and collective reporting during stand-ups enhanced collaboration. Developers reported increased system-wide knowledge, while the Scrum Master observed smoother daily coordination. By Sprint 4, every developer had collaborated with at least four teammates, ensuring broad knowledge diffusion.
These outcomes support existing research on the value of pair rotation in preventing silos [15], [16]. They also confirm that collaboration is not merely a byproduct but a designed outcome of HSPM. Satisfaction surveys indicated that developers valued knowledge sharing and cross-learning opportunities, even though some reported fatigue from continuous collaboration, a known challenge in PP [9].

5.3 Findings for RQ3: Role of Pair Rotation and Business Analyst

RQ3 asked: What role do pair rotation and the Business Analyst play in enhancing team performance?
The inclusion of pair rotation proved central to HSPM's success. It disrupted cliques, spread expertise across modules, and increased team resilience. Unlike conventional Scrum, where knowledge silos often persist, HSPM actively redistributes expertise through structured rotation.
The Business Analyst (BA) also emerged as a crucial addition. By refining backlog items and clarifying requirements, the BA reduced ambiguity in sprint planning. Developers reported fewer misunderstandings, and defect analysis showed that requirement-related issues decreased across sprints. This finding confirms literature highlighting the evolving role of BAs in Agile environments [14] but provides new evidence of their effectiveness in hybrid models.
Together, pair rotation and the BA role addressed two persistent gaps in Scrum: knowledge silos and unclear requirements. Their integration demonstrates how hybrid models can extend Scrum without undermining its core principles.

5.4 Findings for RQ4: Challenges and Limitations

RQ4 asked: What challenges and limitations arise when applying HSPM in practice?
Despite the positive results, two challenges emerged:
Developer fatigue: A minority of developers reported strain from constant collaboration. This aligns with earlier studies on PP that caution about resource intensity [6], [9]. While pair rotation mitigates monotony, continuous collaboration may require breaks or adaptive schedules to maintain sustainability.
Coordination complexity: Managing pair rotation and role-switching required careful planning. The Scrum Master had to devote additional effort to ensure smooth transitions between sprints. This highlights a potential overhead of hybrid models that organizations must consider when scaling.

6. Conclusion

This research introduced and empirically evaluated the Hybrid Scrum–Pair Model (HSPM), a hybrid Agile methodology that integrates Scrum with Pair Programming, systematic pair rotation, and the inclusion of a Business Analyst (BA). By combining the process management strengths of Scrum with the collaborative benefits of Pair Programming, the model addresses persistent challenges in Agile practice such as knowledge silos, uneven quality assurance, and unclear requirements.
The findings from a four-sprint case study provide strong evidence of HSPM's effectiveness:
Productivity improved: Sprint velocity increased by nearly 20% as the team adapted to

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CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
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collaborative task allocation and rotation.

Defects reduced: Defect rates declined by one-third, confirming that continuous Driver–Navigator review mechanisms enhance quality.

Code quality strengthened: Static analysis showed reductions in duplication and improvements in maintainability.

Collaboration and satisfaction increased: Pair rotation promoted cross-learning and knowledge sharing, while surveys indicated high team satisfaction.

Backlog clarity improved: The inclusion of a Business Analyst reduced requirement ambiguities, ensuring deliverables aligned with user expectations.

Together, these results validate the HSPM as a practical and scalable model that enhances both the technical and collaborative dimensions of Agile development.

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