

Scrumbanfall: An Agile Integration of Scrum and Kanban with Waterfall in Software Engineering



Krunal Bhavsar, Vrutik Shah, Samir Gopalan

Abstract: Software industries have been growing with the rise of automation technologies and looking for change in their software development practices to gain the benefits of automation technologies for achieving their business goals. Agile Business Process Reengineering (ABPR) is trending approach for Software Engineering Management (SEM) in software industries, which helps software development organization in transformation of software development practices. Scrum and Kanban are fascinating Agile methodologies adopted by Software Engineering Management practitioners. Scrumban, a mixture of both Scrum and Kanban, has derived strengths of both frameworks, in formation of a robust framework against challenges of Agile Software Engineering (ASE) methodologies like work flow control, lead time management, product delivery that could not be solved by Scrum or Kanban as a standalone framework. But still some of challenges, which are out of scope of Scrumban like project requirement documentation, planning, scheduling, estimation and clear product vision at initial stage of the project. Such issues have raised a request of research for Software Process Reengineering (SPR) in Scrumban by customizing its structure for to form the next level of hybrid framework. The Traditional SDLC methodology 'Waterfall' has answers for such issues. An empirical analysis, for resolution of such issues, with the help of 'Waterfall' model and its life cycle protocols is the main goal this research study by integrating Scrum and Kanban with Waterfall to form a hybrid framework 'Scrumbanfall' aligning Kanban in center of integration under the boundary of Scrum rules. This research also highlights limitations of Scrumbanfall like team members and their roles and capabilities for the large scaled project having team members in distributed environment, which open the door for next level of research to overcome such challenges using further hybridization of Scrumbanfall.

Keywords: Scrum, Kanban, Scrumban, Scrum Challenges, AM - Agile Methodology, ABPR - Agile Business Process Reengineering, BPR - Business Process Reengineering, ESE - Empirical Software Engineering, SPR - Software Process Reengineering, SEM - Software Engineering Management, SE - Software Engineering

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I. INTRODUCTION

Scrumbanfall is the agile hybridization of Scrum and Kanban with Waterfall in Software Engineering Management (SEM). Agile is the roof for the software development practices, built on the principles of Agile Manifesto^[8] and a range of methods have been evolved as a standard SEM practices. Agile changes the way of thinking about product vision as it follows outside-in process flow as a reinvention approach, in terms of customer value, product quality, productivity maximization and roles in the team of software product development^[11]. Out of all, Scrum and Kanban covers and achieves all of these core values for the software development organization. Scrum and Kanban both are agile based frameworks and derive characteristics of Agile Manifesto^[8] principles as base concept. Scrum is very popular^[4] Agile Software Engineering Management (ASEM) framework amongst all Agile Methodologies (AM); due to its characteristics like artifacts, events, pillars, roles and values, which has transformed software practices in software development organizations by enabling organizations capabilities towards Agile Business Process Reengineering (ABPR). Scrum is a first generation method and primary choice, while Kanban is the second generation method and secondary choice amongst the Agile family and both are extensively used in software development organizations. All essential factors should be considered while selecting framework as a standard practices for the software development and management approach.

Scrum is facing some challenges^[12] with software development practices like lead time management and work flow control, direct involvement of external stakeholders as a critical decision maker, team size and their role specific capabilities for large scaled software product development in distributed environment, complete estimation of product and unclear vision of product at initial stage of project. Scrumban^[18] can overcome few challenges like work flow control, lead time management; continuous integration and delivery of software product. Yet Scrumban can't cover all the challenges of software project development. The proposed Scrumbanfall will help in resolving some of the issues like project requirement documentation, planning, scheduling, estimation and clear product vision at initial stage of the product.

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Estimation of software development ensures cost (budget) and time limitation for building quality software [34] along with specification of functional and non-functional requirement of the project [35]. ABPR needs proper PLCF (Process Life Cycle Framework) [24] suitable to organizational structure using power of automation technologies like AI (Artificial Intelligence) [29] and ML (Machine Learning) [36] for Software Project Management (SPM) frameworks in software development organizations as the emergence of such automation technologies have capabilities to automate the project tasks and business operations as per organizational requirement [37].

II. RESEARCH OBJECTIVES

Agile integration of Scrum and Kanban with traditional SDLC methodology 'Waterfall' to overcome challenges of Scrum using empirical analysis of Agile Business Process Reengineering (ABPR) practices; is the goal of this research study.

Following are core objectives of this research study:

- Conceptual vision about agile integration of Scrum and Kanban with Waterfall.
- An empirical analysis on how Scrumbanfall can help in resolving challenges of Scrum and Scrumban.
- Proposed structure of Scrumbanfall system flow and its lifecycle phases.
- What can be next form of hybridization for the challenges that could not be covered by Scrumbanfall?

Optimization of SEM (Software Engineering Management) practices towards achievement of desired result along with productivity and quality goals of software product, by selecting optimal solutions from the frameworks – Scrum, Kanban and Waterfall; is the aim of this research.

III. SCRUMBANFALL

Scrumbanfall is an agile integration of Scrum and Kanban with Waterfall model using the mixture of traditional SDLC protocols with the empiricism, agility and workflow management.

Scrumbanfall = Scrum + Kanban + Waterfall

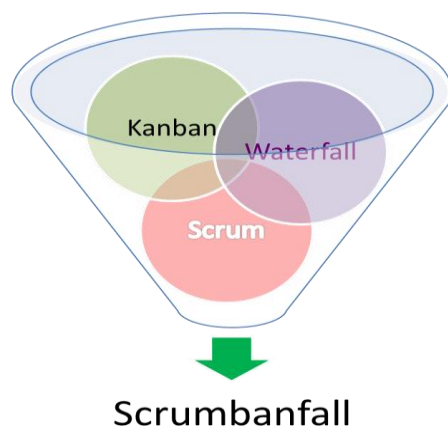


Fig. 1. Combination of Scrum and Kanban with Waterfall

Figure 1 represents combination of Scrum and Kanban with Waterfall for the formation of Scrumbanfall. Scrum is on the base of Scrumbanfall, by keeping Kanban in the center of the

Scrum and wrapping Waterfall prior to Scrum Sprints. Following are core elements selected from each of Scrum, Kanban and Waterfall models in the formation of Scrumbanfall.

A. Scrum

Scrum is empiricism based agile framework, built on the base of control theory of empiricism under the roof of agility, which helps in addressing complex operations and improves productivity and quality of software product development. [4] The characteristics of Scrum can be selected for the formations of Scrumbanfall are:

- Pull and push control system for workload control
- Events, Artifacts, Pillar and Values of Scrum
- Creativity and productivity
- Self-organizations and servant leadership

B. Kanban

Kanban is value optimization theory based agile framework for the transparency of work flow movement and limited work in-progress [6]. The characteristics of Kanban can be selected for the formations of Scrumbanfall are:

- Limited WIP system
- Work item movement management
- Little's law and Flow theory
- Kaizen and JIT
- Continuous integration and delivery

C. Waterfall

Waterfall was the first tradition SDLC, introduced in 1970 by Winston Royce, as linear sequential process flow model for the software product development. Process flow is divided into several SDLC phases like requirement analysis, planning and scheduling, system design, implementation, testing, deployment and maintenance. The characteristics of Waterfall can be selected for the formations of Scrumbanfall are:

- Requirement Analysis & Documentation
- Project Planning and Charter

IV. SCRUMBANFALL LIFE CYCLE MODEL

The life cycle model for Scrumbanfall includes following phases, which are derived from the Scrumban [18] (Scrum + Kanban) and Waterfall as Scrumbanfall is a combination of all of them.

- Requirement Analysis
- Project Planning
- Sprint
 - Sprint Planning
 - Daily Scrum
 - Work Item Management (WIM)
 - To – Do
 - In Progress
 - Done
 - Continuous Integration and Continuous Delivery (CICD)
 - Sprint Review

○ Sprint Retrospective

● Product Release

Figure 2, shows a proposed system flow for the Scrumbanfall.

A. Requirement Analysis

Requirement Analysis & Documentation is derived from the Waterfall model, during which the requirement specifications are analyzed and documented using various standard project documentation procedure, whichever is applicable according to structure of the product, project and organization. It is essential for software project development to visualize the conceptual view of the product, project planning, estimation and prediction about risk in the project, if there will be any feasibility during the project process life cycle. According to rulebook of Waterfall model the output of RAD phase will be the input for the Project Planning & Charter phase. With the help of requirement analysis documentation the Product Backlog Item (PBI) pool is generated in the form of User Story Document (USD) is the base artifact of the Scrumbanfall. Product Backlog (PB) pool is the output Requirement Analysis and Documentation phase. Stakeholders that should be involved in the requirement analysis and documentation are Scrumbanfall product owner, business analyst, project coordinator, project manager, operational team manager or team member, management of the organization, external stakeholder (client) for the external project or any other stakeholders who are authorized by the development organization can contribute in Product Backlog Pool Management (PBPM) but Scrumbanfall product owner will be accountable and responsible for the PBPM, as he/she will be allowed to participate in project planning, estimation and charter along with other Scrumbanfall team members.

B. Project Planning

Project Planning and Charter is the second phase of the Scrumbanfall, which uses the Product Backlog (PB) pool as an input which undergoes PBI refinement process where each user story epic is converted into multiple user stories, if epic is generated in PB; each user story divided into Kanban Cards in the form of list of technical tasks specification. Each Kanban card may have a list of technical tasks and then all PBIs are arranged in a sequential order according to their priority. Priority of PBI is decided based on system flow and internal or external dependencies, critical requirement by client or business; and availability of resources like infrastructure, technology and developer. PBI prioritization is used in project planning and scheduling that help in estimation at project level. Documentation, Project Planning and Charting takes place whenever the PB pool is updated.

C. Sprint

Sprint is the next phase of Scrumbanfall, consisting events of Scrum and workflow of Kanban; like Sprint Planning, Daily Scrum, Sprint Review and Sprint Retrospective. Sprint planning generates Sprint Backlog Pool (SBP) with the help of project planning and scheduling charters by keeping PBI prioritization in the center of the Sprint Planning.

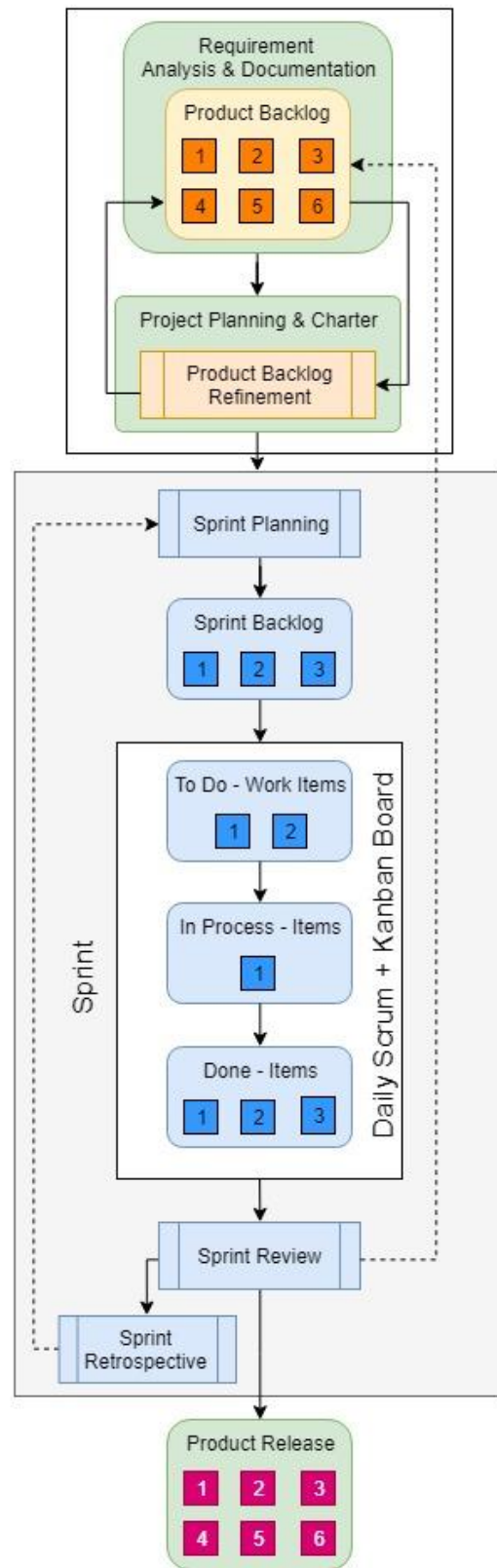


Fig. 2. Proposed Scrumbanfall Process Flow

DoD (Definition of Done) is the result of Sprint Planning meeting and a goal for the Sprint, which will be investigated during the Sprint Review meeting, while DoW (Definition of Workflow) is the structural procedure to be followed by Scrumbanfall Team, which will be discussed during Sprint Retrospective meeting.

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Daily Scrum is a formal meeting every day in the beginning or end of the day, during which Kanban WIM is undertaken by the development team using Scrumbanfall board, by visualizing 'To-Do', 'In Progress' and 'Done' items on the board. CICD is an optional phase of the cycle which takes place if there is an urgent requirement for the delivery of the developed items, in between the Sprint. Sprint Review is an investigation of developed items at the end of Sprint. Completed items are pushed into PRP (Product Release Pool) in the form of Product Increment (PI) and incomplete items are returned to PBP. Sprint Retrospective is WIM flow investigation event, followed by Sprint Review, as an opportunity of ABPR for the upcoming Sprints.

D. Product Release

Product release is the delivery management of developed items, available in PRP (Product Release Pool) in form of PI (Product Increment). Any change request or bug reported post product release will be forwarded to PBP.

V. SCRUMBANFALL ARTIFACTS

Scrumbanfall artifacts are base of the framework in the form of customer value, documentation, workflow management, transparency, increment and opportunity for Scrumbanfall team and other stakeholders.

- Product Backlog Pool (PBP)
- Scrumbanfall Document (SD)
- Sprint Backlog Pool (SBP)
- Product Increment (PI)
- Product Release Pool (PRP)

A. Product Backlog Pool (PBP)

PBP is core collection of requirements for product development and its documentation in form of BRS (Business Requirement Specifications), UCS (Use Case Specifications), FRS (Functional Requirement Specifications), SRS (System Requirement Specifications), USD (User Story Document) along with WMD (Wireframe Mockup Designs) and SFD (System Flow Diagrams) etc. whichever is applicable according to project, product and organizational structure. Any change or amendment in PBP requires refinement of PBI and rearranged in PBP sequential order according priority.

B. Scrumbanfall Document (SD)

Scrumbanfall document consists of planning and scheduling information which helps in estimation of at project level with required level of accuracy. It's an epic collection of Sprint Planning describing time duration required based on information available in PBP. Any change in PBP results into redesigning Scrumbanfall document and results into recalculation of product estimation.

C. Sprint Backlog Pool (SBP)

Sprint Backlog Pool is the small chunk of PBP and follows Scrumbanfall document without any alteration. SBP is generated during Sprint planning and results into DoD and DoW. Product backlog reconsidered for refinement exact prior to Sprint planning meeting, if it is required. Items that should fall under CICD are also discussed and planned.

D. Product Increment (PI)

PI is the result of Sprint and outcome of Sprint Review meeting by keeping DoD in the center of the event. The developed items meeting DoD are investigated and forwarded to PRP as an increment of product.

E. Product Release Pool (PRP)

PRP is a collection item, for which development is completed, in the form of product increment and considered for deployment and delivery, as and when required, according to Scrumbanfall document plan.

VI. WHY SCRUMBANFALL?

As each method has its own characteristics and drawbacks; a standalone framework Scrum or Kanban or Waterfall cannot provide complete solutions for all the challenges of Software Engineering Management (SEM) processes. Scrum and Kanban are trending agile software project management frameworks while Waterfall is the first traditional SDLC and still in existence in some of the software development organizations, who have not yet adopted agile frameworks. Agile frameworks are very suitable for large or medium range of software project, where project requirement and its feasibility is changed frequently over the time, while Waterfall is suitable for the projects having small duration and clear requirement at the initial stage of project, it can be predicated that project requirement may not going to change during its life cycle until the final project delivery.

According to rulebook of Waterfall, only one phase can be considered as 'In-Process' at a time because the result (output) of one phase is an input for the next phase, which is the biggest drawback of Waterfall model to follow and implement it into today's software development practices but the same is biggest advantages for Scrumbanfall as it inherits initial two phases – Requirement Analysis and Documentation, and Project Planning and Charters from Waterfall. A complete documentation of project requirement specifications and its planning are the biggest drawback for Scrumban^[18] (Scrum + Kanban). Requirement analysis is an essential and critical aspect of any change request in software development^[32].

Project planning and scheduling help in cost estimation at project level, which is essential information for the management of development organization and other internal or external stakeholders in budgeting. An accurate estimation of assets and resources involved into software project has a great importance to measure the length (in terms of timeline duration) of the project and its cost calculation, which are critical factors for the project owners like client or the stakeholders organization who will be going to bear the cost of software product development.

Scrum was introduced to deal with the challenges of complex projects having no straight forward requirement defined and the product requirement keeps changing very often. With the help of such characteristics, the requirement changes will go under requirement analysis as soon as product requirement changes and it will be pushed into PBP for the backlog refinement process.

As PBP is the source of input for the project planning phase; any change or amendment in Project Requirement; results into additional cost to the software product owners and organizations, which needs redefinition of project estimation and budget. Scrumbanfall document improves accuracy level and decision making capabilities of the organizations.

Transparency of each and every phase of the project is one of the pillars of the Scrum. WIM enables visibility of each state of work item and visualizes work in process report and helps in tracking progress of the project. Kanban allows indication of state for each work item thought the development phase. While considering integration of Kanban with Scrum, the Sprint is the development phase of Scrum. Hence WIM as a concept of Kanban is integrated with the events of Sprint. 'WIM' of Kanban should be integrated with 'Daily Scrum' of Scrum; as Scrum does not have any specification about visualization of internal state of work items in the Daily Scrum event.

CICD is an optional event in Scrumbanfall as its provision is essential for the delivery of critical and urgent work update requirement, for which team and stakeholders can't wait until the end of Sprint. CICD overrules the event of Sprint Review as it takes place in between the Sprint and the team. The product owner and stakeholders of the project will be responsible to ensure the feature which is delivered by CICD, meets DoD.

The integration of Scrum and Kanban with Waterfall provides a great strength to Software Engineering Management (SEM) practices in the form Scrumbanfall.

VII. EMPIRICAL ANALYSIS

The combination of empiricism and WIM with linear sequential procedures empowers the strength of software development organizations.

Cocco et al ^[20] developed a system dynamics model for the comparison of means of simulation techniques for prescriptive approach using Scrum and Kanban on Waterfall in 2011, and evaluated that each of them have their own strengths and weaknesses and proposed further research work on the combination of all them to resolve the agile software development issue. In 2011, Cuellar ^[13] concluded that Kanban has very less detailed definition about processes and principles to be followed in the software development practices, compared to Scrum but it is less rigid in handling capabilities for the work flow of development practices. The case study of Nikitina and Kajko-Mattsson ^[9] evaluated in 2012, that training and CICD are two pivotal parameters that can be achieved by integration of Scrum and Kanban. Tripathi et al ^[19] have investigated on implementation of Kanban to address the challenges of Scrum in large scaled project using empirical case study in 2015 and concluded that visualization of project activities like product backlog, Work Item Management using shared Scrum and Kanban board with the distributed team can resolve such challenges. In 2016, Taani and Razali ^[10] analyzed requirement prioritization process for the product backlog in agile software development practices and carried out factors like customer value and feedback, estimated process duration, dependencies, clarity on backlog item; which are essential and should be considered. Ahmad et

al ^[15] conducted a survey in 2016 and thematically analyzed challenges of Scrum like visibility of work flow, prioritization of work items, and failure of Sprints and evaluated that such challenges could be mitigated with the help of Kanban. In 2017, Alqudah and Razali ^[7] performed a comparative analysis about the factors which are effective for software engineering practices from Scrum and discovered that user roles and responsibilities; team and batch size; lead and adoption time; cost and quality are appropriate. Due to lack of statistical evidence for the comparison of the mythologies which helps in dealing with challenges of traditional software engineering, Lei et al ^[14] conducted a statistical comparison in 2017, evaluating effectiveness of Scrum and Kanban in SEM (Software Engineering Management) practices and concluded that Kanban is better than Scrum for work flow management but dependent on project planning and scheduling techniques of traditional SDLCs like Waterfall while estimating at project level. Dennehy and Conboy ^[22] performed a case study in 2018, on challenges of 'Flow' based system for the project management in the world of Scrum and concluded that Scrum follows time boxed concept which potentially different than flow based concept of Kanban. They suggested that project management practices leading toward continuous integration and delivery of developed product which can be achieved using Scrum and Kanban both.

Hidalgo ^[21] presented a case study in 2019, on the adoption of agile Scrum in the distributed environment by observing and analyzing activities of participants and evaluated that interdisciplinary explicit policies are required for collaboration in distributed environment.

In 2019, Joseph et al ^[23], developed a crowdsourcing SDLC model by integrating processes of traditional SDLC Waterfall with agile based frameworks like Scrum, RAD (Rapid Application Development) by redefining role and responsibilities of team members in the staffing processes and they evaluated that proposed Crowdsourcing model is strengthen software development activities compared to conventional models. In 2019, Mohan et al ^[25] combined the rules of Scrum with Kanban flexibility in the form of Scrumban and implemented in government sector software application development that reduced the stress of overhead development and increased software efficient.

In 2019, Takawale et al ^[26] performed research on implementation of Scrum in academic sector to reduce the ratio of incomplete project delivery and evaluated that Scrum reduces errors in process, help in meeting project deadline and improves quality. In 2019, Rai et al ^[27] performed a qualitative analysis for risk identification with help of ML based MATLAB simulator; on software projects developed with the help of Scrum and XP models and they have discovered risks with the project out them 50% risks were very serious, which are training to team members, team of focus and role and responsibility of product owner. Structure of such risky elements should be redefined to reduce their impact on software project delivery.

In 2019, Jayraj and Bhaskaran ^[28] argued that agile does not have any specifications about effort estimation,

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which is serious drawback as requirement analysis and its estimation in terms effort and time duration required to accomplish the tasks of the project are very critical factors and they proposed a HEETAD as hybrid form of the SDLC model to overcome these challenges for software projects and development teams. In 2019, Suresh and Sivakumar [33] analyzed factors affecting project schedule and plan management and carried out that project scheduling is essential for time management by providing operations monitoring facility during life cycle phase of project and helps in identification risk during the progress of project. In 2019, Narayanan and Ganesh performed [30] research on impact of Scrum and XP in SCM processes in material management section where they concluded that Scrum is well suited for time box management but it very critical to follow time boxed Sprint and achieve predefined result in real world. They also found the involvement of team members in collaboration between them is the biggest challenge. In 2019, Yadav et al [31], proposed integration of ML technique K-means Data Clustering with software project management model Scrum that visualize project progress report by eliciting Daily Scrum event and ideal utilization of resources. In 2019, Sivakumar and Sureshkumar [38] argued that cost and time duration estimation are significant factors for success of the project. They proposed the project fitness measurement model in terms of time duration analysis by optimizing the coefficient values and proved that premature estimation influences the accurate cost estimation for the software project. In 2019, Malik et al [39] examined project management achievements by case study of Malaysian public university transformation project. They measured team engagement, monitoring, management and leadership criteria using a quantitative survey and as a result of the research they analyzed that by recognizing critical issues in the project, the lagging cases of the project can be reduced like resources, time and cost management. In 2019, Aziz et al [40] argued that planning and

scheduling of the project are hardest phases of the project during which uncertainties may be arise at initial stage of the project. They performed empirical analysis using a survey for non-software projects and revealed that project planning and scheduling have greatest impact on the success of the project. In 2019, Gayatri et al [41] proposed a software defect prediction model for the selection of optimal feature with reusability and reduce that data size; with an argument that such optimization are essential for qualitative and reliable software. Requirement analysis is an early stage of project development where most of the software risk can be predicted using technical feasibilities assurance. Patchaiammal and R. Thirumalaiselvi [42] also argued that fault prediction in most important and critical process of the software project development and as a resolution they suggested ML based technique for fusion of classification using hypothesis tests, which reduces rework in the project. In 2019, Averineni and Rama Swathi [43] empirically explored and recommended the concept of Agile practices has been gaining potential in perception of people and it should be implemented in organization as an Agile HR practices also. In 2019, Singh et al [44] argued that calculation of accurate estimation is the core activity for the software engineering projects and they proposed a PSOT (Particle Swarm Optimization Technique) which improves the results for estimation process using the calculation approaches based on SLOC (Source Line of Code) and FPA (Function Point Analysis) techniques. SLOC result shows 12.09% improvements per 733 SLOC while FPA shows 60.88% improvements.

The summary of empirical analysis of this research represents requirement analysis, cost estimation, project planning, scheduling, quality measurement, error identification and error prediction at early stage of project are very critical factor and they have grate impact on success of the project.

Table I: Limitations of Scrumban and support of Waterfall in formation of Scrumbanfall

Parameter	Limitations				
	Scrum Limitation Description	Scrum	Kanban	Scrumban	Scrumbanfall
External Stakeholder	Restricted involvement of external stakeholders as a team member.	Yes	NA	Yes	No
Team Size	Restricted team size.	Yes	NA	Yes	Yes
Role	Limited roles in a team	Yes	NA	Yes	Yes
Project Tracker	Progress view at project level.	Yes	Yes	Yes	No
Product Vision	Unclear product vision.	Yes	Yes	Yes	No
Estimation	Full product development estimation is not feasible.	Yes	Yes	Yes	No
Distributed Environment	Collaboration issue in distributed environment.	Yes	NA	Yes	Yes
Skill and Expertise	Unavailability of specific skilled resource.	Yes	NA	Yes	Yes
Documentation	No or minimum documentation.	Yes	Yes	Yes	No

VIII. RESULTS AND RECOMMENDATIONS

Scrumbanfall is combination of characteristics of Waterfall, Scrum and Kanban, each of them having their own pros and cons that they can't resolve challenges of software

development world, as a standalone framework.

The strengths of all of them are inherited into Scrumbanfall to empower its capability towards achievement of Software Engineering Management (SEM) goals. Table I shows the result of the research against the limitations of Scrum^[12] and support from Waterfall, Scrumban and Kanban by indicating limitations of each framework using keyword 'Yes' and strength using 'No'.

A. Strengths of Scrumbanfall

Table I represent strength of Scrumbanfall against Scrum, Kanban and Scrumban, where 'No' keyword is marked again limitations^[12] of Scrum in the column titled 'Scrumbanfall' and described as follows:

- Documentation: Requirement Analysis and Project Planning are initial phases of Scrumbanfall, derived from waterfall, which supports documentation of the PBP and planning charters.
- Estimation: Project planning and scheduling charts along with task level of documentation with help of user story and Kanban card, provides accurate estimation which is essential for product owner in identifying risk with the project.
- Project Tracker: Project Planning helps in designing a tracker at project level, which is used by development team during the Sprint and updated as soon as work item state changes in a Kanban card.
- Product Vision: An accurate estimation of project requirement and its planning enables product vision and tracker which helps in progress report and risk identification.
- External Stakeholders: Just like Scrum, Scrumbanfall does not allow direct involvement external stakeholder into during the Project planning and other next level of phases during the life cycle. But it allow external stakeholder to actively manage PBP during Requirement Analysis phase.

B. Limitations of Scrumbanfall

The combination of Scrum and Kanban with Waterfall gives a great strength to Scrumbanfall but still it can't cover all the limitations^[12], which are represented in Table I, using 'Yes' keyword in the column titled 'Scrumbanfall' and described as follows:

- Distributed Environment: Communication between team members in the distributed environment is still limitation and general issue.
- Roles: As there is no specification about roles of the team members in Kanban and Waterfall, they are inherited from the Scrum, which is limitation of Scrumbanfall.
- Team Size: Yet the Scrumbanfall follows Scrum, which limits between 3 to 9 team members, for each Scrum team. For large scaled project development, large team is required that cannot be fit according to Scrum rule.
- Skill and Expertise: Scrum believes^[16] that scrum team is cross functional and there is no explicit policy about skill of the resources, while skill expert resources are required in a team to accomplish skill specific tasks^[17].

C. Recommendations

The result of this research extensively recommends that

Scrumbanfall is has a great strength compared to Scrumban^[18], Scrum^[5] and Kanban as Scrumbanfall resolves challenging limitations with the power of Waterfall, Kanban and Scrum. Along with the strengths, Scrumbanfall derives few limitations of Scrum^[12] represented in Table I, that requires further research by integration of the robust framework, which can resolve such limitations. Software development organizations should consider such limitations and their impact on their projects prior to considering Scrumbanfall as a standard Software Engineering Management practices.

IX. CONCLUSION

Software development organizations have been seeking ABPR (Agile Business Process Reengineering) to optimize their SEM (Software Engineering Management) practices. Scrum and Kanban are trending agile methodologies for software project development and management. This research has concluded that the proposed integration of Scrum and Kanban with Waterfall in the form of hybrid framework for SEM (Software Engineering Management) practices, to overcome the limitations of Scrum^[12] and Scrumban^[18]; and empower the strength of software development organization by combining required characteristics of Scrum, Kanban and Waterfall into Scrumbanfall which has a great strength compared to stand alone framework and capabilities to answer the challenges of software development and management practices like direct involvement of external stakeholder into project requirement and analysis documentation; project planning, estimation and tracker. An accurate estimation of complete project; prior to the development activities begins; is the biggest challenge for Agile methodologies and hybrid frameworks formed using pure Agile Manifesto principles like Scrumban^[18], as they do not prioritize project documentation. Inaccurate estimation invites risks into project and unclear vision about software product, which result into unexpected cost in the project for the software project owners or software development organizations that bear the cost of project development.

FUTURE ENHANCEMENT

Scrumbanfall can't end the journey of research in Software Engineer (SE) practices. Automation technologies like Artificial Intelligence^[29] and Machine Learning^[36] have been rising nowadays. Software development organization should gain benefits of such technologies to improve accurate, productivity and quality of software product by automating their standard SEM practices, which will be our next stage of research.

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with traditional approaches, as an extreme solution for the Software Engineering Management (SEM) challenges and our next goal will be integration of AI and ML with SEM.

ABBREVIATIONS

A

ABPR – Agile Business Process Reengineering
AI - Artificial Intelligence
AM – Agile Methodology
ASEM – Agile Software Engineering Management Framework

B

BPR – Business Process Reengineering
BRS - Business Requirement Specification

C

CICD – Continuous Integration and Continuous Delivery

D

DoD – Definition of Done
DoW – Definition of Workflow

F

FRS - Functional Requirement Specification

J

JiT –Just in Time

M

ML – Machine Learning

P

PB – Product Backlog
PBI – Product Backlog Item
PBP - Product Backlog Pool
PBPM - Product Backlog Pool Management
PI - Product Increment
PLCF – Process Life cycle Framework
PPC - Project Planning and Charter
PRB - Product Release Build

S

SB – Sprint Backlog
SDLC – Software Development Life Cycle
SE – Software Engineering
SEM – Software Engineering Management
SFD - System Flow Diagram
SPB - Sprint Backlog Pool
SPM – Software Project Management
SRS - System Requirement Specification

R

RAD - Requirement Analysis and Documentation

U

UCS - Use Case Specification

W

WFM – Work Flow Management
WIP – Work in Process
WMD - Wireframe Mockup Design

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