Agile Software Development Models TDD, FDD, DSDM, and Crystal Methods: A Survey

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***Abstract*—Software development is a critical task that requires a detailed and well-structured guideline in the form of software development process model. A good software development process model can play very important role in developing high quality software. Traditional software development models like Water fall, RUP, V-Model and Spiral Model remained dominant in software industry for a long time but to cope with growing needs and technology change in software industry, software developers tried to explore more improved software development models that lead to advent of agile development models. Agile models were warmly welcomed by software community because of their focus towards customer satisfaction, changing requirements and early software delivery. This paper provides a comprehensive review of different agile models which are used in software industry.**

***Keywords*— Software Development Process Models, Agile Models, FDD, TDD, DSDM and Crystal Family**

I. INTRODUCTION

Agile software development methodologies provide a more efficient and lighter way of development that build a software iteratively and incrementally. Intention behind agile software development models was to find out new and more efficient ways of software development that can overcome the limitations of traditional software development models. Lesser user interaction, prolong development duration, high cost, no adoptability and most importantly no response to changing user's requirement were major problems in traditional software development models that forced software experts to find new directions of software development.

The term agile was coined in 2001 when seventeen well known software developers met in Utah to explore new and improved ways of software development. They shared their experiences and observed that there were some common software engineering practices, helpful in developing high quality software within predefined time limit [1]. Agile software development models shifted the development focus from process to people and valued things that were neglected in traditional models. As stated in agile manifesto "*we are uncovering better ways of developing software by doing it and helping other do it. Through this work we have come to value.*

- *Individuals and interactions over processes and tools*
- *Working software over comprehensive documentation*
- *Customer collaboration over contract negotiation*
- *Responding to change over following a plan*

That is, while there is value in the item on the right, we value the item on left more [1], [2]".

Agile manifesto defined twelve agile principles that make foundation of agile software development. These principles include [1]:

- Customer satisfaction by early and continuous delivery of workable software.
- Changing requirements are welcomed even in later development stages
- Frequent collaboration and communication among customers and developers.
- Frequent delivery of working software.
- Support and motivate trusted people involved in software development.
- Use face to face communication.
- Working software is main measure of progress
- Constant pace is maintained through sustainable development.
- Pay attention to good design continuously.
- Keep things simple.
- Self-organizing teams can develop better architecture, requirements and design.
- Team regularly reflects how to become more effective.

There are many agile models like Extreme Programming (XP), Scrum, Test Driven Development (TDD), Dynamic System Development Model (DSDM), Feature Driven Development (FDD) and Crystal methods etc. All these agile models follow agile values and principles with some key practices. These practices may not be new for software industry but provide much better result when applied under agile values and principles [3]. Agile principles make it possible for a development process to be more adoptable to change, reduce cost and time of development as mentioned in [4], [5].

Agile software development models build software in multiple iterations and increments [2], [3]. Each iteration end with a workable product that help in getting early feedback of customer. Agile teams are self-organizing teams in which members work in close collaboration with each other. Simple design with no extra details is preferred over complicated ones. This help in delivering product more reliably and timely.

In contrast to traditional models, customer remain involve throughout the development process to keep it on right way. Unnecessary documentations is avoided in order to pay more attention towards productive activities. Due to these features agile models are more flexible and adoptable [2]. This study is conducted to explore agile models that are relatively lesser known. This paper discusses Test Driven Development (TDD), Feature Driven Development (FDD), Dynamic System Development Model (DSDM) and Crystal Method in detail that will be greatly helpful for researchers, academicians and developers.

Rest of the paper is organized in following sections. Section II is about literature review. Section III provides detail study of agile models including TDD, FDD, DSDM and crystal methods. Section IV is discussion that sums up then agile models. Finally section V concludes this paper.

II. LITERATURE REVIEW

Due to features like, ability to incorporate change, rapid development and emphasis on quality, agile software development models received a huge acceptance from software industry. A number of agile models exist that have their own advantages and disadvantages. Researchers tried to explore these models in different studies; however most of them focus on different aspects of agile models and lacks complete picture of whole process. Some of these are listed here. In [2] authors explained concept of agile development and discussed different agile development models. In [3] authors reviewed and analyzed agile models for the sake of comparison. In [6] authors discussed and compared Scrum, XP and Kanban agile methodologies. In [7] authors have provided overview of some agile methodologies including XP, Scrum, DSDM, FDD, Crystal methods and Lean development. In [8] authors discussed different agile models with their strengths and weaknesses and checked their applicability in industry. A review of agile development models is conducted in [9].

III. PROCESS MODELS

A. *Test Driven Development*

Test driven development (TDD) is an agile software development process model. Like other agile models, it builds software in small iterations which required to write an automated test first followed by a small piece of code that can pass that test, code is refactored later for improvement. TDD is actually opposite of traditional software development approach that starts from design and coding followed by testing. In TDD, testing is performed before coding. The intent behind TDD was to reduce defect rate and improve code quality. TDD helps in writing clean code to implement a requirement by getting quick feedback through testing. Code is refactored accordingly, to make it concise [10]. TDD usually requires an automated testing framework like JUnit, NUnit, CppUnit.

TDD was formally introduced as a software development model in 2003 by Kent Beck in his book "Test Driven Development: By Example". However an approach similar to TDD, was already used by NASA developers in 1950 while working on project Mercury [11] [12]. Kent Beck used *Test first* technique as a practice in Extreme Programming where programmers write unit test before development [13]. Successful application of test first technique gave an idea to use it as a development model. Use of test first development with refactoring results in Test Driven Development (TDD) process model. In [14] two rules for TDD has been defined:

- Always write a code only if a test fails.
- Always remove duplication.

In the light of these two rules, TDD can be defined as an iterative development model in which programmer drive test cases using requirements, before writing the code then code is written for small increment of functionality to pass the test and in case of test failure code cab be refactored iteratively to enhance the quality and design. TDD helps to reduce the defect rate in code. This improves the code quality that ultimately reduces test cost and testing effort. More detailed five step process for test driven development is discussed in Fig. 1 [14].

- Add a new test case for small functionality.
- Run all the test cases and check if new test case fails.
- Write code that passes the test.
- Run all test cases again to see whether all test pass.
- Refactor code to remove duplication.

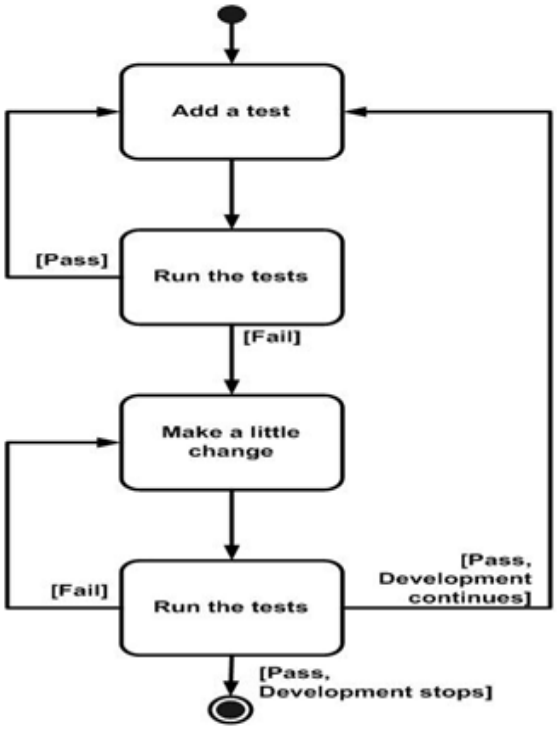

Fig. 1: Work flow of Test Driven Development

1) TDD Life Cycle: Test driven development life cycle consists of five steps.

Add a test: In TDD, development cycle starts by writing a test for new functionality. Developer writes an automated test for new functionality. This require a deep understanding of requirements. Writing tests before code helps developers to concentrate on requirements and exceptional conditions of feature to be added. User requirements and use cases are used to draw these tests.

Run all test cases to check if the new test case fails: In this step developer run all the tests. Which obviously leads to failure of new test as there is no code available to implement required functionality.

Write the code: Developer write code enough to pass the test. This code may not be a perfect one but at this stage, only concern is to write a code that will pass test. This code can be refined in later steps.

Run all test again: Developer run all the test to check whether the new code works. If it works without effecting the already passed tests, it means that new code satisfy all the requirements and not damage the existing code. If it is not the case then new code should be changed until all tests pass.

Refactor code: This step helps in refining the code and making it more clean and concise by removing duplications. Refactoring code, is actually changing the code without disturbing its external behavior. This reduce complexity and increase readability and maintainability of code. This stage also insists to review the code according to design patterns.

These steps are repeated for each required features.

2) Foundation Principles of TDD: There are three foundation principles of TDD that make it popular among programmers and also help to enhance the productivity, quality and maintainability of software [15]. These principles are test first, incremental development and frequent testing.

Test First: Being a test driven development, tests play central role in whole development process. Tests are used to steer the whole process. Every development cycle starts from writing a test for required functionality. TDD use automated testing framework usually that help to test any time. These provide an opportunity to get exact and quick feedback about program behavior.

Incremental Development: Incremental development naturally decomposes the project in small more manageable chunks. This improves the programmer's concentration about problem and also offers a chance to plan better and develop better.

Frequent Testing: Frequent testing provide feedback to programmer about developed tasks. This helps to catch the defects near its origin and decrease possibility of their propagation any more. This ultimately improves quality and productivity.

3) Test's Quality in TDD: Test used in TDD have different purpose and intent than tests written to check software quality. Test in TDD are written by programmer rather than testers. These tests should be small, compact, more focused to a single feature of software [14], [15]. These execute quickly to provide quick feedback to programmer. The basic objective of these tests is to drive the development process. However TDD also incorporates other testing mechanism for verification and validation of software quality.

In [14] author stated some directions that should be followed to write TDD's special tests. Here are some guidelines about writing these tests.

- These tests are written by programmer not by testers. Programmer should feel easy to write a test about a requirement in order to correctly use its results. It will be helpful to use familiar test tools and languages, with which programmer feel comfortable.
- Test should be readable that not only served as test cases but also help in understanding source code.
- These tests should execute fast otherwise it will not be helpful in test driven activities.
- Test used in TDD should be independent of each other. One test failure should not affect output of other tests. However executing any combination of these tests should be possible.
- Deterministic tests helps in increasing programmer's confidence. A test having no guarantee about its execution leave a negative impact.
- Test should be executed automatically with no human interaction. This will be helpful in avoiding human errors and improving the confidence on test results. TDD mostly use automated testing framework.
- Writing test also give deep insight into design decision. So test will be helpful in designing activities.

4) Misconceptions about TDD: Although TDD is getting popularity and acceptance in software industry however there are still some misconceptions about TDD that must be cleared.

One of the most common misconception about TDD is due to its name. A common thought is that TDD is a testing or quality assurance activity using unit tests alone [15], [16]. TDD uses testing for software development not for testing purposes. Tests are used to get feedback to refactor code. These are not simple unit tests.

It is considered that test written by programmers also serve a purpose of software testing completely. Actually this is not the case along with these tests, independent testing and quality assurance activities have their own role that cannot be replaced. Programmer have ability to write TDD's tests but may not have skills required to write stress test, performance test, system test etc.

People think while using TDD, all possible tests should be written before starting actual development [16]. In fact in TDD programmer write a single test at a time that relates to a small required functionality of software. This process goes on iteratively to build a complete software.

It is considered that TDD is difficult to learn and practice. Actually it is not the case but it requires a change in thinking with a disciplined decision making and problem solving capabilities of programmers.

5) Advantages of TDD: TDD is a relatively new agile model that is gaining popularity among developers due to its benefits. Here are some of the advantages of TDD.

- In traditional development methods testing activity is performed very late. In later stage of development, defect debugging and maintenance becomes more tedious and may cause more defects injection in software. Test first approach of TDD helps in finding defects earlier and near to its origin. This reduces defect rate and cost of debugging greatly [17]. Due to incremental approach and quick feedback from testing, external quality of code can be enhanced greatly [18].
- TDD improves efficiency as it works in small iterations. In each iteration tests provide quick feedback whenever a new code is added. This helps in finding and correcting defects earlier and stops defect propagation.
- Automated test written during TDD iterations are very helpful in enhancing the code quality. These test are used in regression testing during maintenance activity.
- TDD works in small iterations that divide the overall development in small and shorter more manageable parts. This provides opportunity to concentrate and develop more effectively [19].
- Code refactoring improves software design related issues. TDD helps in writing code having loose coupling and high cohesion.
- Programmers write simple classes and modules to implement a small functionality that reduce the size and complexity of code [16].

7) Disadvantages of TDD: TDD is a good development approach but there are some limitations also.

- TDD is a disciplined approach requires some special skills (like writing test cases which is duty of testers usually) that programmers feel difficult to practice [11].
- TDD cannot be used in all situations especially software projects that require synchronization [11] [14]. Developer must be able to check whether TDD can be applied or not.
- Managing test suits is another problem with TDD. Proper maintenance is required to use these test suits.
- TDD lacks documentation. Documentation helps in maintenance process but in TDD only test cases are used for that purpose [20].
- Sometimes, TDD become more time consuming because of repeated test failure.
- TDD does not provide any guidance about management aspects of software projects. It only focus on engineering related activities.

D. Feature Driven Development

Feature Driven Development (FDD) is an agile model that uses short iterations to develop a functional software. FDD was first used by Jeff De Luca in a large project in 1997 when he realized that traditional models are not useful in delivering large, complex software project in time. In 1999, Jeff De Luca and Peter Coad presented the FDD model by combining the concept of feature with software development process in their book Java Modeling in Color with UML [3], [21]. Later in 2002 Stephen Palmer and Mac Felsing presented its more generalized form in their book "*A practical Guide to Feature Driven Development"*.

FDD is highly adaptive agile software development model that focus on quality during all phases of development. As its name suggests, feature is very important aspect of FDD. A feature is any valued function that user wants in software. However FDD mainly focus on design and building phases [3]. It develop frequent tangible results and provide progress and status information about project.

1) FDD Life Cycle: FDD process consists of five sequential processes that are performed iteratively to build software in increments. These processes are Build a feature list, Plan by feature, Design by feature and Build by feature [3], [22].

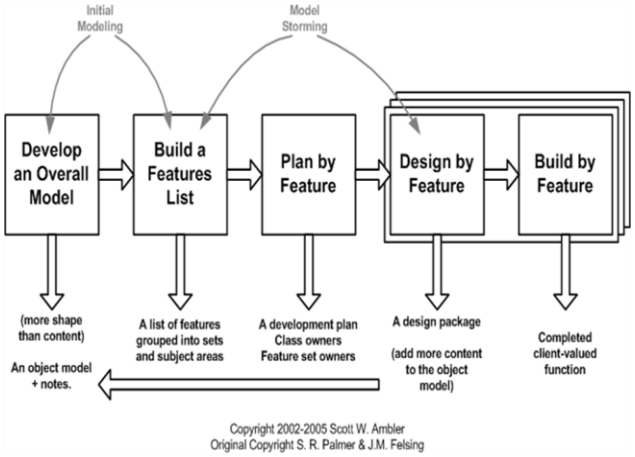

Fig. 2: FDD Process Life Cycle [3]

Develop an overall model: In this phase team members including domain and development experts, try to define the context and scope of the project to be developed. For this purpose a high level walkthrough meeting is conducted followed by a detailed walkthrough for each domain area. After completing this, multiple object models are developed by different domain expert which are then reviewed. One of them is selected as a model of domain area [21]. In some cases more than one model are merged to form a final object model for the problem. This model can be refined further in later stages of development. There is no specific requirement gathering and managing activities used in FDD.

Build a features list: Being a feature driven model, FDD development process focus on features. A feature is a valuable function that has some business value in software. After making the object model it is easier for team to define a comprehensive list of features to be developed. These features are defined for all domain areas and grouped in features sets. Features in the list should be implemented in maximum two weeks. Any feature requiring more than this can be broken down in to smaller tasks. The features list is finally approved by the customer.

Plan by feature: Project manager, development manager and chief programmer are the roles who are involved in

planning. In this phase priorities are assigned to features by keeping in view the features dependencies, risk involved, complexity and team workload. Then chief programmer assign each feature class to a specific developer called class owner. Schedule detail is also assigned to each feature class.

Design by feature: This is an iterative activity that can last from few days to two weeks maximum. In this phase design packages are produced for each class by chief programmer and class owners. Sequence diagrams are developed by chief programmer and class owner collectively however class diagrams and object models are developed by respective class owners. Finally design packages are reviewed and inspected for approval.

Build by feature: This is an iterative phase in which multiple features teams actually implement the design classes and modules. After coding, code inspection, unit testing and integration testing is performed. Classes are built in the sequence which these are defined in plan by feature phase. After completing an iteration successfully, developed features are included in main build and another iteration with new features set is started again. Every feature has to achieve six milestones that are domain walkthrough, design and design inspection from design phase and code, code inspection and promote to main build, from build phase. When all milestones are completed, track by feature chart and burn up chart is updated to reflect the progress. All these activities should be completed in maximum two weeks.

2) FDD Roles: In FDD there are three types of roles; key roles, supporting roles and additional roles [3]. This section explain key roles in FDD which includes, project manager, development manager, chief architect, chief programmer, class owner, domain expert and feature team.

Project Manager: Project manager is the leader who is responsible of providing administrative guidance throughout the project. He manages the staff and provide best available working environment by protecting them from outside interference. Project manager also decide about scope, schedule of the developed project. He reports project progress and manages finance and budgetary issues.

Chief Architect: He is responsible of overall design of the system. His decision is considered final about design related issues. He also guides and provides necessary training session to team.

Development Manager: Daily development activities are supervised by development manager. He must have good technical skill to resolve the issues not handled by chief programmer. He is also responsible of resolving resource conflict among team members.

Chief Programmer: Chief programmer actually leads overall development activities. He leads the small teams during analysis, design and coding different feature sets. He should have good experience in development to lead the team. Chief programmer select features set and respective class owner for each iteration and resolve any issue in implementing these classes.

Class Owner: These are responsible of designing, coding and testing features sets assigned by the chief programmer. They work under the supervision of chief programmer.

Domain Expert: These are the persons having clear understanding of the business for which software is being developed. These can be clients, sponsors, users or business analyst. They give directions for the system to be developed by providing sound knowledge. They must have good communication skills to convey the requirements to the development team. Their active participation and good knowledge about domain can enhance the chance of project success.

Feature Team: Feature team is temporary group of developers working on some feature sets during an iteration. This team disbanded when a feature set is implemented successfully and promoted to main build.

3) FDD Artifacts: Document and artifacts produced during FDD process are Features list, Design packages, Track by feature chart and Burn up chart [22].

Features List: A feature is a small valuable function that have some business value for client, Collection of these features in a list makes features list. Each feature in the list should be implemented in two weeks duration otherwise it can be broken down in smaller features.

Design Packages: This includes sequence diagrams, class diagrams and module design information designed by chief programmer and class owners.

Track by Feature Chart: This chart is used to track the project progress. This contains all the features to be developed and dates of completed feature sets.

Burn up Chart: This is also used to track the project progress. This chart plot dates along X-axis and number of completed features along Y-axis. Slop length shows the tasks completed by the team.

4) Advantages of FDD:

- FDD is highly adoptive development model that greatly stress on designing and modeling aspects of project [23].
- FDD teams specially focus on quality throughout the development phases [3].
- One to four weeks iterations help to get quick feedback about developed product.

5) Disadvantages of FDD: However there are some disadvantages of FDD that limit its use.

- FDD does not provide any guidance about requirement gathering, requirement analysis and risk management therefore need some supporting methods [23].
- FDD needs team member who are highly skillful and experts in designing and modeling field.
- FDD does not address the issues related to project criticality [2], [23].

E. Dynamic System Development Model

Dynamic System Development Method (DSDM) is an agile project development framework that uses rapid application

development approach with great emphasis on quality [3]. It provides complete assistance throughout the software development life cycle. Like other agile models it also used iterative and incremental approach to deliver quality software with constant user involvement. It defines time and resources and then adjusts the functionality to be developed [3], [24].

It was developed in United Kingdom in 1994 by practitioners of a consortium, who were trying to improve quality aspect of rapid application development processes [25]. It was later developed as a complete framework of rapid application development. Initially DSDM consortium was only for the consortium organizations but in 2007 it was made available openly as a free to use model.

1) DSDM Phases: DSDM is an iterative and incremental development method which build important functionality first. Its incremental nature helps in getting client feedback as product evolves. DSDM combines the project management and product development related activities in a single process. DSDM life cycle consists of six phases: Pre-project phase, Feasibility study, Business study, Functional model iteration, Design and build iteration, Implementation and Post project phase [2], [26] Fig. 3.

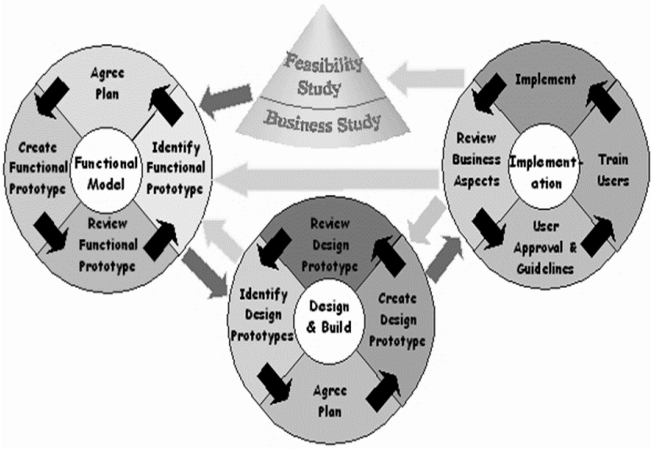

Fig. 3: DSDM Phases [3]

Pre-Project Phase: In this phase, project to be developed is selected by considering DSDM suitability. Scope and objective of the project is defined clearly which are used to estimate the financial requirements. Important roles like project manager and development team are also identified in this phase. Feasibility study phase is also planned during pre-project phase.

Feasibility Study: In this phase feasibility of the project is judged. Project type, risk involved, technical staff availability and organizational issues are considered to check the feasibility. This phase may include a prototyping activity if the business requirements or technology is not familiar. This phase ends with feasibility report and a high level plan of development.

Business Study: This phase is facilitated by workshops in which experts from customer's side sit together with development team to find and prioritized the system requirements. Business and technology characteristics are identified to understand the business domain. High level description of the processes, object model, system architecture and outline plan of prototype is developed that can be refined further in later stages.

Functional Model Iteration: This is an iterative phase in which analysis; coding and prototyping activities are performed iteratively. These prototypes are analyzed and its results are used to improve the analysis model. Prototypes are built to identify requirements however these are not discarded completely and can be used in final solution. Aim of this phase is to find out, what is to be developed, when it should be developed and how it will be developed. Final outputs of this phase include prioritized list of functional requirements, prototyping review document, non-functional requirements list and list of risk involved. These documents provide sound base for the next iteration.

Design and Build Iteration: This is an iterative phase that actually implements the requirements identified in previous phase. System developed in this phase is tested and analyzed by the user. User's feedback is used to improve the developed system iteratively. Final output of this phase is a tested software that implement at least minimum set of requirements.

Implementation: In this phase, final software is handed over to the users, necessary training is provided. User manuals and other increment review documents are produced to guide the user. Depending upon system complexity and size this phase can be performed in iterations.

Post Project Phase: After the project is closed formally, a review is conducted to check how good project has been developed. Have the decided business benefits are achieved or not? This phase may generate a benefit assessment document for whole project or for individual release depending upon project type.

2) DSDM Roles: There are fifteen different roles defined in DSDM framework [25]. Some of the important roles in DSDM are as follows:

Developer: These are development staff responsible of carrying development activities under the supervision of senior developer. Senior developer is selected on the bases of experience and knowledge. Development team includes analyst, designer, programmer and tester [3].

Technical Coordinator: Technical coordinator takes care of business and technical aspects of project. He is responsible of designing system architecture and maintaining technical quality of the system.

Ambassador User: This person is from users, who eventually use the developed system. He should have ability to convey user's needs to the development team and progress of developed system back to the other users.

Advisor User: Ambassador user cannot represent whole user community so an additional role is defined called advisor user. He can contribute by giving specific project related information.

Visionary: Visionary is a user having good understanding of the business objectives. He assures that most important and critical requirements are found and developed correctly in system. He provides guidance to keep project in right direction.

Executive Sponsor: He is the person from customer's organization having responsibility of providing necessary financial support for the project.

3) DSDM Principles: DSDM based on eight principles [26]. These foundation principles of DSDM help in finding best business solution. These principles are as follows:

- Focus on Business needs.
- Deliver on time.
- Collaborate and Cooperate with each other.
- Always focus on quality, never compromise on quality.
- Build solution incrementally.
- Develop solution in iterations.
- Communicate continuously to get feedback.
- Establish control through plans.

4) Advantages of DSDM:

- DSDM provide rapid application development with the integration of agile principles [23].
- It is an adoptable framework that can incorporate best practices from other approaches [2].
- It provide proper guidelines for different project aspects like project management, risk control and development techniques [23].

5) Disadvantages of DSDM:

- A large number of roles in DSDM can create administration issues during development process [23]
- DSDM does not consider project criticality [2]
- Being a framework, DSDM does not provide specific guidance about issues related to team size and iteration length [2].

F. The Crystal Methods

Crystal family is collection of agile software development methodologies that can be used for different software projects depending upon size, complexity, criticality and number of people involved.

It was developed by Alistair Cockburn in early 1990 while working at IBM. He interviewed different team working on different projects to find best practices followed by teams. He found that these teams did not following the formal methodologies or not using specific technology for delivering successful software. However they communicated frequently to discuss about project. On the other hand, delayed or failed project teams tried to follow formal methods with little team collaboration [2]. This helped him to conclude that frequent communication among team members can improve the software success rate. According to Cockburn's philosophy "To the extent that you can replace the written documentation with face to face interaction, you can reduce the reliance on written 'promissory' notes and improve the likelihood of delivering the system" [27]. Crystal methods focus on people and communication among people rather than process to frequently deliver a working software.

Crystal family includes a number of methods represented by different colors arranged in ascending opacity. Cockburn named it "Crystal Methods" after a gemstone with different facets. Different method of crystal family represents different facets of crystal family. Agile methods of this family are crystal clear for small projects followed by crystal yellow for medium, orange for large and red for very large projects. Based on project attributes, like project size, complexity, criticality, skill level, available technology or team size, best suitable methodology can be selected for an individual project Fig. 4. This methodology can be tailored according to emerging needs of project.

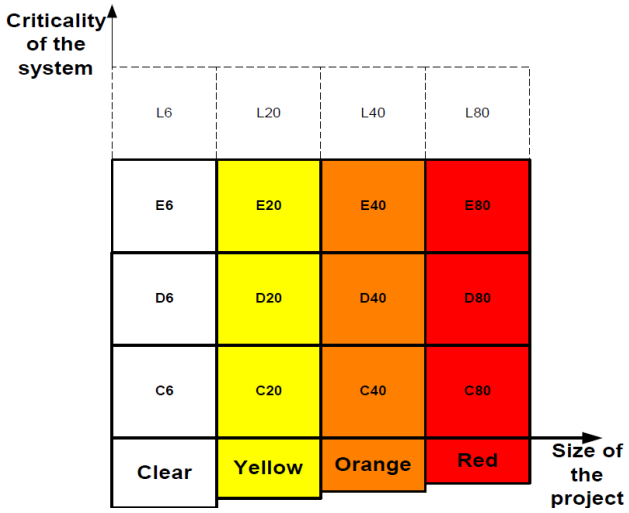

Fig. 4: The family of Crystal Methods [3]

In Fig. 4 characters C, D, E and L shows potential loss due to system failure, here C represents comfort, D represents discretionary money, E represents essential money and L represents life [3]. Project and project criticality is plotted against X-axis and Y-axis respectively. D20 means a project with team size 20 with criticality of discretionary money. Each method mentioned in figure has its own set of practices, roles, work-products and techniques however these methods follow some common rules and value to deliver successful software [22]. Crystal methods focus on people collaboration and communication rather than process solely. It develops system incrementally, and Time duration for each iteration should not exceeds from four months. There are only two crystal methods are defined and used that are crystal clear and crystal orange [3].

1) Policy Standards: Crystal clear and crystal orange use some policy standards that provide guidance throughout the development process [3]. These are listed below:

- Incremental delivery of tested work product.
- Direct user participation.
- Automated regression testing.
- Project progress tracking by using milestones (working software).
- Workshops after each delivery to adjust methodology according to changes.

2) Crystal Clear: Crystal clear is designed for the small projects having 6 team members (D6 projects). However it can be used with E8 and D10 project after tuning communication practices. Crystal clear needs project team to be located at same place due communication structure [22]. Team members discuss about project requirements, design,

tools and priorities daily. It develop software incrementally with each iteration ranges from two to three months. Team sets standards for coding, regression testing and user interface. Two reviews are conducted per release. Project progress is measured by software deliverable or by completion of some important decision.

Documents and Artifacts: Documents for crystal clear method include release sequence, use cases, object model, user manuals and test cases. Schedule is mentioned in user viewings. For design documentation it uses screen drafts and design sketches only [7], [22].

Roles: There is only one team working on the project in crystal clear that includes following roles.

Sponsor, business expert, senior designer, senior programmer, documenter and unit tester [3], [22].

3) Crystal Orange: This is used for medium sized project with team size of 20 to 40 members (D40 projects). More than one teams work on these project which lasts from one to two years [3]. However this method does not work in distributed environment. This method focus on time to market aspect of the project and deliver product incrementally. Each increment can lasts from three to four months. Teams efficiently communicate with each other and response to changing requirements. This limit the number of deliverable but reduce the cost of maintaining also. Two reviews are conducted for a release. At the end of each iteration a retrospective meeting is conducted to tune the methodology.

Documents and Artifacts: In contrast to crystal clear, this method uses requirement document and detailed project schedule. It uses release plan, object models, user interface design, test cases, user manuals and working code [7], [22].

Roles: In crystal orange, more than one teams work on project according to project size. Due to large project size and complexity it includes many other roles to the roles used in crystal clear. These roles are as follows: user interface designer, technical facilitator, database designer, business analyst, usage analyst, tester and writer [3].

4) Advantages of Crystal Methods:

- Effective team communication is key feature of successful projects. Crystal methods provide proper guidance about team communication of varying team sizes [23].
- Different crystal methods can be used for different project sizes and criticality [2], [3].
- Crystal method provides good risk control and technical practices [23].

5) Disadvantages of Crystal Methods:

- Only two method (crystal clear and crystal orange) are defined out of four [3], [23].
- These methods lack design and code verification activities [3].
- Crystal methods do not provide any guidance about business enterprise [23].
- Crystal methods lack system validation practices which make them inappropriate for the development of life critical systems [3].
- There is no well-defined team structure in crystal methods [3].

IV. DISCUSSION

A large number of agile software development methodologies have proved the acceptance of agile development in software industry. Different agile models like TDD, FDD, DSDM, Crystal methods etc. have their own strengths and weaknesses which make then suitable for different project type, team size and development environment. Rapid response to changing requirements, quick feedback, early software delivery, cost reduction and good time management are some of advantages of agile software development models that make them suitable for the present software projects. However agile development models are not exempt from the drawbacks completely. Lack of management/staff control, lesser focus on design and documentation, scalability issues, product ownership, product quality and maintenance are some major problems with agile models [28]. Agile software development models cannot be used for all software projects especially for large, complex and safety critical projects [8], [28].

To overcome the limitations of both traditional and agile development models, software practitioners integrated different models from both sides to enhance their advantages and suppress their shortcomings. Some also tried to enhance the agile models to overcome the limitations. Some of such studies are stated here. In [29] authors proposed Enhanced Extreme Programming (EXP) which tried to cover some deficiencies of XP. A hybrid model called XSR is suggested in [30]. This is a generalized framework that integrates XP, Scrum and RUP. A new process model called eXRUP is proposed in [31] that integrate XP with RUP.

Following Table I present a brief overview of agile software development models discussed in section III [2], [3], [22], [32].

V. CONCLUSION

Agile software development models are widely accepted and acknowledged by software developers now. These models have ability to meet the requirements of today's fast pace software development projects. This paper discusses Test Driven Development, Feature Driven Development, Dynamic System Development Model and Crystal Methods in detail. This study will be greatly helpful for researchers, developers and academicians as each model is discussed in detail with complete development life cycle, major roles, artifacts, advantages and disadvantages. Provided information can be used to choose a suitable model for some specific project. This can also provide a solid base to start a new research. However it is needed to provide empirical proof by applying these models in industry that help in finding more hidden aspects still not revealed to software industry.

TABLE I: AGILE SOFTWARE DEVELOPMENT MODELS

Sr. No.	Model	Team size	Iteration length	Project Size	Key Features
1	TDD	1- 3 or can be added accordingly	Variable based on project type	Small	• Tests are written first before development • Code is refactored to pass the tests • Incremental approach
2	FDD	4-20	1-4 weeks	Large	• Scalable to larger teams • Highly-specified development practices • Five sub-processes, each defined with entry and exit criteria • Development are architectural, object models and sequence diagrams (UML models used throughout)
3	DSDM	2-6	Variable based on project type	Large	• Uses rapid application approach • Continuous emphasis on quality • Multiple teams can work on same project
4	Crystal Method	Variable Based on project type	Variable based on project type	All	• Family of methods • Represented by colors • Different method can be used for different types of projects

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