Stochastic Modelling and Computational Sciences

INNOVATIONS IN PROJECT MANAGEMENT METHODOLOGIES: AGILE VS WATERFALL

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ABSTRACT

Since the inception of Agile Manifesto and in the 15 years since agile project management (APM) has been in use, it has become a cutting-edge approach practiced, primarily although not exclusively, in the software industry. APM is slowly breaking through into other domains as well. Therefore, the objective of this study is to summarize and critically examine contributions of past research and existing knowledge concerning APM applicability beyond software industry and its co-existence with traditional project management (TPM) practice, and to identify the potential challenges and benefits of APM in innovation and new product development processes. Systematic literature review (SLR) protocol was developed to systematically locate, assess and aggregate the outcomes from all relevant studies in a transparent way. Gaps identified in this SLR will be used to suggest areas for further investigation and to provide a framework for appropriate position of future research activities.

Keywords: *agile, agile project management, innovation, new product development*

In the last decade the research on APM and its adoption beyond software industry has emerged expeditiously due to the fact that projects are being more complex with uncertain outcomes and goals changing over time. Generally, todays' business environment increasingly changes in every aspect. Competition is global, opportunities are dynamic, and business processes are highly complex. These circumstances were traditionally dealt by project experts that would attempt to predetermine every possible detail prior to implementation, but project managers are becoming aware of the relative shortcomings of traditional project-based structures to deal with the need to effect change and to take advantage of new or emerging opportunities [1]. In order to be competitive organizations are forced to recognize changes and to be more flexible when they meet them. In this context, extending agile methods beyond software community is becoming desirable response to fast-changing and challenging business environment. Agility turned out to be a buzzword in a modern business world. But it goes much beyond being a popular phrase, and becomes a way of survival in a current world of accelerating change. In order to survive divergent thinking, willingness to innovate, ability to manage changing priorities is needed in order to keep up with the fast-paced technology and continually changing requirements and customer's expectations.

The concept of APM has emerged in the past decade from the software community, supported by the development of a set of practices, tools and techniques encapsulated in so-called "agile methods" or "lightweight" methods [2]. Agile methods are used to deliver customers value while dealing with inherent project unpredictability [3] relying on people and their creativity rather than on processes [4], as a counter to the traditional "waterfall" approach [2] which involves very disciplined and deliberate planning and control methods stressing the importance of requirements, but limited in a way that projects rarely follow the sequential flow, and clients usually find it difficult to completely state all requirements early in the project [5]. It is important to emphasize that the agile movement is not anti-methodology [6], and the truth is that agile approach requires just as much or more discipline as traditional approaches, but it's a different kind of discipline [7]. Instead of relying on rigidly defined and prescriptive methodologies agile approach rely much more heavily on training and skills of collaborative cross-functional team to adapt the methodology to a problem that they are attempting to solve [7] and to deliver projects piece by piece while make rapid adjustments as needed in order to speed up the phases of the project [8].

With its roots in the Agile Manifesto, which expresses the key principles and values of the movement, and after 15 years of maturation, APM now becoming mainstream and a cuttingedge project management approach in fast competitive markets, with fast changing technologies, innovation-driven clients, and high level of uncertainties.

Up to now, APM has been adopted in thousands of companies around the world for software development and it is on the rise according to 2015 PMI's Pulse of the Profession report [8] with 38 percent of responding companies reporting its frequent use, which is 8 percentage points up since 2013. According to Denning [9] the winners in the rapidly changing world of manufacturing will be those firms that have mastered the agility needed to generate rapid and continuous innovation.

Although agile-related topics are discussed, primarily, in IT and software related literature, ability to manage changing priorities, team productivity, customer satisfaction, effectiveness in resolving unexpected risks, as building blocks of APM, are for sure something that is desirable beyond software industry but still there is a lack of understanding and well defined instructions how to apply approach agile in other domains, how to identify situations when APM might be a better solution and how to help organizations integrate agile practices into their traditional processes.

In recent years there has been a particular rising interest for modifications in management paradigms and defining or redefining a theory of project management that can be used in the new economy, characterized by more complex and uncertain situations. Interest for these, so called hybrid methods, has been raised in academic literature. As agile took root in the software industry, a few larger IT firms that already had formal development systems in place, began to build it into their existing processes thus creating hybrid models. Their experience suggests that agile and traditional processes can be used together [10], by introducing hybrid methodologies, taking advantage of some benefits of agile development without abandoning the stability provided by traditional methods [11]. But the question is if it is, and how it is, possible to combine both approaches in a single project management methodology. The choice of project management methodology, which determines how a project is planned and executed, is of strategic importance to a company. Chosen management methodologies are often cited among top reasons projects fail [12], [13].

Therefore, the objective of this research is to summarize and critically examine contributions of past research concerning APM applicability beyond software industry and its co-existence with TPM practice, and to identify the potential challenges and benefits of APM in innovation and new product development processes. Systematic Literature Review (SLR) is conducted in order to obtain multiple prospective. Gaps identified in this SLR will be used to suggest areas for further investigation and to provide a framework for appropriate position of future research activities.

BACKGROUND

A. Agile Movement and Agile Project Management

In 2001, prominent software development practitioners' convened to arrive at a consensus on how the software development industry could produce better results and overcome limitations [5] of traditional software development process in order to increase the quality, enhance flexibility and accelerate time to market. The agile thinking is expressed in Agile Manifesto, consisting of 12 principles and 4 values, for agile software development and compacts the basic idea of agile movement. The agile values are [6]: (1) individuals and interactions over processes and tools, (2) working software over comprehensive documentation, (3) customer collaboration over contract negotiation, (4) responding to change over following a plan. The agile principles are [6]: (1) early and continuous delivery of valuable software,(2) welcome changing requirements, agile processes harness change for the customer's competitive advantage, (3) deliver working software frequently, (4) people interaction daily (business and developers), (5) build projects around motivated individuals, (6) face-to-face communication, (7) working software is the primary measure of progress, (8) constant pace , (9) continuous attention to technical excellence and good design enhances agility, (10) simplicity, (11) self-organized teams, (12) at regular intervals, the team reflects on how to become more effective.

It is generally accepted that APM has emerged from principles and values expressed in Agile Manifesto. APM can be defined as the work of energizing, empowering, and enabling project teams to rapidly and reliably deliver business value by engaging customers and continuously learning and adapting to their changing needs and

environments [3] in an iterative fashion [14]. Highsmith [15] defines APM in terms of five key business objectives: (1) Continuous innovation — to deliver on current customer requirements, (2) Product adaptability — to deliver on future customer requirements, (3) Reduced delivery schedules — to meet market windows and improve return on investment (ROI), (4) People and process adaptability — to respond rapidly to product and business change, (5) Reliable results — to support business growth and profitability. APM institutes a set of management practices based on iterative cycles and incremental development, where requirements and solutions evolve and prioritize through collaboration between self-organizing, cross-functional teams and their customers [9], [16]. APM practices includes[17]: (1) use of the "product vision" concept , (2) use of simple project plan communication tools and processes, (3) use of iterative planning, (4) developing activities using self-managed and self-directed teams in the project plan, (5) use of self-managed and self-directed teams in the project plan monitoring and updating activities, (6) frequently apply project plan monitoring and updating processes. The main difference that APM bring is a shift from the traditional project-base structure with the focus on planning then executing the contents of that plan, to a focus on execution [15] with key decisions that determine the success or failure of the project being made during that execution [18].

Motivation Behind Research

APM was born out of the chaos and problems software development projects placed on traditional management approach. But other projects share many of the same challenges that APM has resolved in software development: turbulent environments in which changes inevitably happen at the most unwelcome time, unstable requirements that never complete, customers who don't know what they want until they see it, technology that moved faster than the project can react, nimble competitors who put the project manager in a continual catch-up mode [19]. The ideology of agile is a good fit with the business reality of the 21st century TPM approach, which exclusively pursue the success criteria of costs, time, quality and meeting technical requirements, have become considered ineffective [20], [21]. Organizations today must increasingly view their competency development challenges through one unified lens: the need to be agile [22]. Intense industrial competition and ever changing customer requirements have led organizations to deviate from TPM approaches and seek for innovative alternatives [23]. There are some, real life, examples of companies using APM methods beyond IT: John Deere uses them to develop new machines and Saab to produce new fighter jets. National Public Radio employs agile methods to create new programming. Intronis, a leader in cloud backup services, uses them in marketing. C.H. Robinson, a global third-party logistics provider, applies them in human resources. Mission Bell Winery uses them for everything from wine production to warehousing to running its senior leadership group [24]. The Lonely Planet legal team adopted agile after seeing technology teams using it. Commercial airplanes material and process technology engineers use agile development methodology to drive out waste in the Boeing Fabrication facility. Nokia sought to decrease its development and they implemented scrum as the user development method [25]. Robert Bosch Power Tools has gathered a lot of experiences with agile methods and APM approaches in the development of both hardware and software. Spotify, the popular music-streaming company, has geared its entire business model, including everything from product development to marketing and general management, to support agile innovation [24].

But most of the scientific literature, available today, refers to APM exclusively in software development and, even though, scholars and practitioners have provided some valuable and essential knowledge on APM effectiveness in the software industry [3], [4], [7], [15], [18], [27]–[30], the project management community still knows little about APM applicability beyond software domain. According to Griffiths [31], the popularity of agile methodologies in other industries started around 2002 and therefore the methodologies are still evolving.

With an increased use of the APM concept in the last decade, it is of utmost importance to clarify if and how this concept translates in into other domains outside of the software industry and whether it co-exists or replaces traditional project management. Researchers were inspired and motivated to conduct this research, due to a lack of a coherent and consolidated knowledge on this topic.

RESEARCH METHODOLOGY

Each study is inevitably limited in scope, so in order to help researchers identify and to critically examine contributions of past research, SLR protocol was developed in a grounded literature analysis to systematically locate, assess and aggregate the outcomes from all relevant studies in a transparent way.

While developing research design researcher partly followed the guideline proposed by Keele [32]. It is important to emphasize that SLR was pioneered for medicine after which it was introduced into software engineering; therefore, there has been a need to adapt the methodology, through experimentation, so as to be able to make SLR work in this field. The SLR was conducted through the following phases: definition of research objectives; design of search strategy; definition of search strings and inclusion/exclusion criteria; article screening; data extraction and synthesis and discussion of results. Researchers used both automated and manual research. Digital databases used were: SCOPUS, ScienceDirect, ACM Digital library, ProQuest, EBSCO host, Emerald, IEEE. The articles were selected using a series of iterative reading filters, with the support of a set of inclusion criteria and quality evaluation requirements.

Article selection process was conducted in 4 phases: identification, screening, eligibility and including. In the first identification phase articles were identified through a database search. The search yielded 379 articles (Scopus: 90; ScienceDirect: 64; ProQuest: 24; EBSCO host: 125; Emerald: 41; IEEE: 35). Once an initial pool of papers was selected, the snowballing technique was used to expand the list of relevant papers. 16 additional records were identified, giving in total 395 articles. Firstly, all duplicates were removed according to exclusion criteria. In the screening phase most of the retrieved articles fell within the defined inclusion and exclusion criteria as these criteria were adjusted manually in search engines along with the search terms. After reviewing their titles and abstracts more than half of the articles were excluded. As a result of the Screening phase, we ended up with 82 retrieved articles to be fully read for Eligibility. In Eligibility phase, the pre-selected articles were assessed for full text screen. Out of the 82 articles, 52 were excluded on the grounds that they did not discuss any topic directly related to the scope of our investigation. Therefore, our final sample consisted of 26 articles.

RESEARCH FINDINGS

Researchers aimed to generate findings on APM application outside of software industry, and specifically to identify the potential challenges and benefits of agile in innovation and product development processes. This SLR jas found that a wealth of literature discusses agile related topics primarily regarding software development but also researchers identified a wave of interest from authors which proposed and investigated the application of APM in non-software projects, in variety of domains. Table 1 summarize the selected articles clusterd in four different domains, with extracted benefits of agile approach identified in these domains.

APM in New Product Development and Innovation Processes

Researchers identified a rising interests for APM application in the context of innovation and new product development, in different industrial sectors. In his paper [33] conducted a pilot empirical quantitative research involving projects in manufacturing enterprises in order to determine whether these companies already use any of the agile practices and techniques, and the actual contribution of different agile practices on project success. The majority of projects were divided into short iterations and regularly updated during execution with the requirements defined in an agile way. Client collaboration, though, was not addressed in these projects. On the other hand, Lehnen [36] conducted a research on APM in lead user projects where the high involvement of collaboration with the customer is present. The integration of lead users is extremely useful for companies since the new product development is aligned to the future market needs. They developed agile model to increase the flexibility and practicability of the lead user approach. [17], [34] suggested the application of APM, for innovative new products, using a model entitled IVM2 (Iterative and Visual Project Management Method). IVM2 model consists of five components (phase and project deliverables model, project planning and controlling whiteboard, weekly activity planning whiteboard, simplified performance indicator system, opensource project management software tool for supporting the portfolio control) that are integrated into planning and controlling the projects in a simple, visual, and interactive way. The application of this method in companies under review proved the benefits

of using simple, iterative, visual, and agile techniques in delivering what the customer expected and provided the flexibility to deal with uncertainty in innovation efforts, reducing planning time and improving communication in combination with TPM best practices, such as standardization. In another research, [17] conducted an exploratory survey among companies operating in different industrial sectors, with respect to practices, and enablers related to the implementation of the APM approach to new product development projects. These authors recognized that some of these "practices" were dependent on the organization's environment and the project context within which they were used. The companies under analysis had some characteristics and organizational enablers similar to companies from the software industry and they used some agile management practices even though they did not belong to the software industry sector. Hannola et al.[37] and Gutiérrez et al. [38] analyse the applicability of agile methods for improving the efficiency of the innovation process. Hannola et al. [37] founded that agile methods provide several improvements regarding to organisational practices, transfer of knowledge and know-how and understanding of customer needs that could be applied to the innovation process. Gutiérrez et al [38] have approached a new way of conducting R&D projects that can integrate APM and innovation management best practices. As a result, their paper formulates a methodology for agile new product and process development that can match the actual product cycle development requirements, shortening project life cycles but keeping space for innovation and creativity. Blindenbach-Driessen et al. [35] suggested that APM should be used in predevelopment stages of innovation as the APM approach encompasses all key processes in the predevelopment stages: idea generation, preliminary assessment, concept, opportunity evaluation, and strategy formulation, and it can positively improve effectiveness and speed.

B. "Hybrid" Approach in New Product Development and Innovation Processes

Empirical performance studies of combined or hybrid models, beyond software domain, are still scarse, but they do exist. Sommer et al.[39], conducted in-depth case studies within seven manufacturing companies (producers of wind turbines, valves and sensors, insulin, plastic toys, music amplifiers, windows, and power cables) in order to explore how agile/stage-gate hybrids can improve product development performance. These companies where investigated retrospectively. They showed that industrial companies can gain substantial performance benefits from implementing agile/stage-gate hybrid processes for new product development. They proposed the Industrial Scrum framework for managing projects. Conforto & Amaral [40] case study reports an empirical analysis of a hybrid management framework combining APM and stage-gate model implemented in a technology-driven project. The results indicate a positive impact on the project and product development performance and suggest that combining these two approaches to balance stability with flexibility is a potential solution for managing innovation projects in high technology based companies. Grushka-Cockayne et al. [41] proposed a multi-dimensional framework for project methods selection, extending the TPM trinity of scope, budget, and time, to include multiple attributes according to which a project can be characterized. They showed how the positioning of a project on the attributes suggests a preferred, and most likely hybrid approach to project management through several industry case studies. According to Lehnen [36] by following the agile/stage-gate hybrid adopted for lead user projects in new product development, companies are able to overcome typical challenges. Taken as a whole, APM facilitates self-managed teams. It reduces bureaucracy, focuses effectiveness instead of efficiency, and favors leadership and collaboration instead of command-and-control and values social aspects over hierarchical ranks since everybody in the team is equal. Adapted agile/stage-gate hybrid for lead user projects provides a management framework that is, on the one hand, stiff enough to create reproducibility and, on the other hand, flexible enough to quickly and effectively respond to the unforeseen. Cooper [10] investigated two large-company best-practice examples to illustrate how to run a hybrid model. He claimed that for physical product developers, an agile/stage-gate hybrid product development model is feasible and may yield positive results. In Table 2 we extracted the benefits and challenges of hybrid approach identified in aforementioned articles.

TABLE II: Benefits and Challenges of Hybrid Approach

Benefits	Challenges
Improving project efficiency across development projects Reducing process iterations Improving resource allocation High-performance of agile teams **Higher** team independence **Better** internal team communication Increased cross-organizational communication and collaboration Better-definition of goals Improving process visibility Increasing team morale and employee motivation	Delays due to resource distribution Lack of agile culture in the organization Mismatches between the requirements of Agile and the company's reward system Insufficient knowledge of management across functions Project documentation and the system remains too bureaucratic Dedication of full-time teams to the project Proper adaptability of these practices for different types of projects in the portfolio Management resistance to a new hybrid system
Reduced rework and latestage change Increased market success Improved prioritizing of tasks Absorbing changing requirements more effectively Improved customer collaboration and feedback Better fit between work process and methods Increased flexibility in design process Clearer resolution of documentation issues	Lack of scalability Difficulties in linking project teams to the rest of the organization Project leaders and teams tended to become too focused on the sprints that the team lost sight of the ultimate goal

DISSCUSION

In response to the research objective APM is suggested and investigated in domains such as a construction, education, services and area that is receiving a particular attention recently is the field of innovation and new product development. For software development, agile techniques have revolutionized the filed over the past decade, especially in uncertain or changing environments, which are just where innovation is most likely to occur [19]. So it is not surprising that APM is emerging in this field. Innovation is what agile is all about. According to Denning[9] the winners in the rapidly changing world of manufacturing will be those firms that have mastered the agility needed to generate rapid and continuous innovation. Many companies need to retool their innovation management processes in order to survive and grow in such a rapidly changing environment. Very interesting is the fact that there is a rising interest for APM in construction and though it is characterized by a fairly considerable diversity and flexibility researchers highlighted the iterative nature of construction and real estate development. Also there is a rising interest for agile in academia. Education and research work has features that parallel the reasons APM is needed for IT.

According to literature some project characteristics signal a better fit for APM [50], [56], [57]: (1) poorly defined scope, (2) unknown and perhaps unknowable task times, (3) unknown number and set of tasks implies unknown task dependencies, (4) unknown availability of resources , (5) small project teams, collocated teams (6) unclear or creative and innovative requirements, (7) close and frequent collaboration with users, (8) projects size-smaller projects, (9) structurally complex and iterative project plan. As it can be seen APM is not for every project and probably will not gain much in a very predictable environment, as it has the flexibility to more easily adjust to changes in project requirements [56] so it is beneficially for projects that operates in an environment of high uncertainty [18]. Necessity to properly match the project management approach to the project characteristics is crucial to project success [56].

Implementing agile practices can be challenging for organizations. It is not just about forming a team and practicing APM. It is also about having the right agile culture and the right alignment to project environment. The agile approaches scare corporate bureaucrats[6] because introducing it in to an organization, a tremendous amount of organizational change must occur to empower and enable agile teams in their pursuit of delivering business value [27]. Decision on which methodology to use should be handled with care, considering both project characteristics and organizational environment. Most corporate cultures embrace TPM thinking involving the enforcement of strict standard. Such cultural changes are likely to be the most difficult aspect of shifting to a agile style [19]. Simply making a one-time decision to be agile maybe insufficient for the organization or even for the life of a particular project.

CONCLUSION

Both APM and TPM are a good project management approaches suited to different scenarios. There are different types of projects and circumstances that require different approaches. This implies a diversity of solutions is required and each organization should reflect on its own context. Apparently, APM is applied partially or completely depending on the nature of the project, although in certain circumstances, it is not referred to as APM. It is just taken as the normal practice of overcoming challenges associated with TPM for specific projects. Emerging literature attempts to offer agile/traditional "hybrid" solutions that will enable projects to take advantage of a" command and control" management style while gaining the benefits of agile development such as adaptability to changing requirements, improved team performances, etc. It could be argued for hybrid models that APM is an extension of the stage-gate phased methodology, rather than a dramatically different way of achieving projectbased work. APM can be viewed as a new foundation element, perhaps just a single post, that will help support the extension of a TPM platform in such a way as to enable practitioners to more effectively manage projects in an uncertain environment [18].

If we formulate one general question- does agile methodology work for all organizations and all types of projects? The answer would be - probably not. Just like with everything else, there is no one size fits-all. Clearly, beyond software development it is unable to adopt all components and practices, but that doesn't mean that some important parts of APM cannot be incorporated in management practices outside the software industry. It is not an all-or-nothing methodology. Both traditional and agile approaches have their advantages and disadvantages, if viewed according to different project characteristics. They differ in terms processes, personnel, modularity of work, leaderships, customer involvement, documentation and tools, team roles and organization but, it can be acknowledged, that in project management practice, it seems as if APM and TPM are most often combined. Since both APM and TPM are strong in their own right it might be necessary to blend the two in order to benefit from both.

It could be concluded that despite the growing popularity of APM in the software domain, it has not yet been well established in other domains, even though this question is emerging in literature and among practitioners. And, even if it is debatable whether APM will be systematically and widely adopted, there are sufficient results, which represent a solid base, to believe that certain agile practices can be utilized for innovation and new product development projects outside the software domain and it is likely that APM will have something to offer to project practitioners for their more effective execution of projects, in particular, when faced with certain types of projects and project scenarios.

LIMITATIONS OF THE STUDY

A major difficulty faced in this SLR was that this field is still in its infancy with a very few scholarly-written articles and insufficient coherent findings, signaling a gap in the literature. Not many empirically grounded studies at the moment exist and those that are present are limited by sample size, industry or geography, which does not allow for generalizations. These examples are good and represent a diverse set of applications, but they still only illustrate a very small subset and are relevant only for the sample of organizations investigated. In addition, SLR was pioneered in medicine where the predominant methodologies are quantitative. Our research was qualitative in nature and there was a need to adjust the methodology through experimenting with the process

to make SLR work. The basic limitations of any SLR are the bias during a selection of studies and the possible imprecision in data extraction, from various sources.

Implications and Future Work

Findings attained through this research point to a number of recommendations and interesting questions for further research. We would like to stimulate broader empirical quantitative research and in-depth case studies regarding the use of APM beyond the software domain. Future research should examine the interrelationship and inter-influence of different managerial practices that could facilitate APM in different domains. Another challenge is to define a "hybrid" project management methodology that could be based on a mix of different project management approaches, and to empirically explore the ways of combining them when each one would make the most sense. How to effectively tailor this approach to suit a specific organization or specific project is a challenge yet to be addressed. To fully answer the question, which project scenarios signal a better fit for APM, future research should first define which project characteristics are important for that decision. Empirical data comparing the effectiveness and limitations of agile and non-agile approaches would greatly enhance our understanding of the true benefits and limitations of agile processes. There is also a need to investigate the problems that an agile approach may cause in different environments. No less interesting would be to explore if it is more beneficial to adopt and implement agile methods bottom-up or top-down. Further research in this area will help, both practitioners and researchers, gain a better understanding of APM benefits and challenges in different domains and will encourage the introduction of agile techniques wherever proven to contribute to the successful execution of projects.

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