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An empirical study to design an effective agile knowledge management framework

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Abstract

Despite the profusion of research about knowledge management within larger organizations, fewer studies tried to analyze knowledge management in small and medium enterprises. The study contributes to research by providing a more nuanced classification of knowledge management approaches and guides managers about the types of knowledge management approaches that should be adopted based on the size, geographical dispersion, and task nature of the organization. A purposive sample of 34 companies was selected for this study along with a survey that focused on the objective of investigating awareness and implementing strategies of knowledge management. The various phases and processes of knowledge management were accounted for. Organizations were bifurcated on the criteria like the core area of the company, the size of the company, the type of company, etc. Knowledge management implementation was judged through each dimension. Different statistical tests were carried out to test a set hypothesis. Having established that wide variation in overall adoption of knowledge management practices exists across the software engineering organizations, the different characteristics associated with knowledge management adoption were tested: organization size in terms of employee strength, the domain of the software engineering, team distribution, and type of organization. To a surprise, most of the organizational characteristics are not found in the significantly associated with knowledge management adoption except knowledge management adoption level in full and partial agile organizations and the relationship between

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the organization KM level and the number of software developers in organization for only product development companies is found significant. Opposite to the claims of many researchers, this study does not find any significant difference between knowledge management adoptions between distributed and co-located agile teams.

Keywords Knowledge management · Knowledge sharing · Agile software development · Extreme programming · SCRUM

1 Introduction

This paper implants the foundations for knowing the best practices in knowledge management and investigates the intensity of awareness and implementation of knowledge management principles and practices by the Indian software industry working in Agile Methodologies. Besides large organizations, the success of Small and Medium Enterprises (SMEs) can be related to how well they manage their knowledge. The Indian software industry is growing with every passing day; Nasscom predicted that India's technology industry is expected to record a positive growth of 2.3% in FY2021 to touch $194 billion and India's exports of software services (excluding exports through commercial presence) were estimated at US$ 133.7 billion during 2020–21, This corroborates the dominance of the Indian software industry in the global scenario. To attract more clients, Indian industry has started working in agile methodologies [39]. Agile methodologies to support better communication and practice-driven structure that helps in generating closed collaboration among team members and customers. Agile methodologies are based on four basic values called agile manifesto (www.agilemanifesto.org). One key value supports in favor of working software without documentation rather than a non-working software with a huge amount of documentation ([22]; Singh and Singh, 2012). Opponents of the agile methodologies argue, what will happen if a person leaves the company in between software life cycles and it will be almost impossible for a new person to understand the product without documentation or knowledge transfer. The success of organizations across all scales (large, medium, and small) can be linked with how well the organizations have been managed knowledge. Although large organizations are well observed from Knowledge Management (KM) perspective, fewer studies tried to analyze KM in SMEs, moreover, there is limited research linking KM in Multinational Companies (MNCs) and SMEs working in agile methodologies [19, 24, 33, 46].

A framework is being proposed and depicting the determinant role of KM approaches on organizational characteristics. This study presents a more critical classification of KM approaches that have been adopted based on size, geographical dispersion, and type of organization. This paper offers a new context, showing agile organizational characteristics into KM approaches. The study contributes to research by providing a more nuanced classification of KM approaches and types of KM approaches that have been adopted based on the size, geographical dispersion, and task nature of organizations. This will also provide insight for the managers and authorities responsible for implementing KM using agile methodologies.

The organization of rest of this paper presents as section 2 briefly introduce agile knowledge management practices and its related research work. Section 3 discusses motivation behind presenting this research work and objective with which this research has been conducted. Research problem is framed in section 4 and section 5 discusses the research approach i.e. the methodology that has been followed in the present study. Results are presented in Section 6, and Section 7 presents Fuzzy Analytic Hierarchy Process to understand the multi criteria decision making process. In section 8, study has been concluded and directions for future work have been discussed.

2 Agile knowledge management

The most vital resource/asset in an organization is knowledge and the people who create knowledge [16, 21]. These organizations produce new knowledge origins by skilfully transmuting tacit, explicit, individual, and collective knowledge reservoirs with the help of a dynamic spiraling process [30]. Criticism on agile methods is its applicability and scalability in a geographically distributed environment [44]. In such a case, a tailored KM framework is required that can be integrated and synchronized with the collocated and distributed development to generate value for the business. KM can be easily accepted and employed in Agile Software Development (ASD) environment [49]. The culture of agile development comprises communication, cooperation, and knowledge sharing as basic values [25]. KM is about learning, and agile software development establishes an environment that supports learning processes [17, 32]. Many agile practices such as on-site customer, collective code ownership, collaborative workspace, whole team, pair programming, pair rotation, stand-up meetings, and sprint planning meetings foster KS and KM in agile projects. It acts as a key to some of the challenges faced in implementing KM in organizations because KM practices are naturally embodied in agile practices and help in improving the KM process [39].

Some of the experienced reports published by Vanhanen and Korpi [45], Cao et al. [6], Sfetsos et al. [37], Sison and Yang [41], Beecham et al. [3] conclude that XP/pair programming helps in greater learning and knowledge sharing. The researcher claims that agile methodologies are effective in the dissemination and retention of knowledge and have a positive impact on KM practices. Some of the case studies on the agile methodologies from a knowledge perspective also directed towards embeddedness of KM in agile practices: Study of two software development organizations highlights the significance of tacit knowledge in agile methodologies and knowledge management aspects of agile development [18]. Pair programming also seems to benefit teamwork, knowledge transfers, and learning (Vanhanen and Lassenius, 2005; [2, 10]).

A conceptual framework for knowledge sharing of Misra and Amritesh (2014) emphasis on learning of the individual practitioners for the sustainability of an agile team. This learning framework attempts to create and exchange knowledge among the involved entities. Agile methodologies have been practiced by practitioners for more than a decade, but still, there is very little research work has been steered to relate it to the domain of KM research. In late 2000, Bjørnson and Dingsøyra [4] noticed the possible application of cartographic school of KM to ASD because of its low-cost technical infrastructure. This agrees with Chau and Maurer [7] that floats a framework to handle the technological infrastructure for synchronous as well as asynchronous knowledge sharing among co-located as well as distributed agile team members. But the framework fails to explain the integration of KM practices of traditional and agile methods where organizations use traditional and agile methodologies for software development i.e. Partial Agile organizations [12]. Cases have been reported that organizations customize agile processes/practices to fit in their corporate model. Skipping some practices (Hodgkins and Hohmann, 2007, [42]), stripping some and enhancing other agile practices [9], replacing the agile terminology with traditional vocabulary [31] are some of the poorly reported customization implemented in large organizations. Furthermore, modifying the agile practices for distributed sites can negatively affect the development process (Paasivaara, 2008). The distributed organization will impose an additional burden on communication and knowledge sharing, but distribution and agile would still be used together [39]. Applying agile in scale will require deviations from some of the suggested practices [20]. Deficiency of communication in a distributed environment may affect sharing of knowledge and experience among agile teams [26].

3 Motivation and objective

Agile software development and management practices provide a platform where agile teams create and share their knowledge. The exchange of experience and knowledge increase the abilities of teams to cope with uncertain and ambiguous situations. However, contextual factors e.g. unstable teams, distributed teams, traditional culture may hinder knowledge sharing process, thus leading to mistrust, waiting times, and delays in delivery. Organizational forms are heavily based on collaborative relationships among small, medium, and large organizations. SMEs have generated competitive and dynamic environments where knowledge fertilization in SMEs is important in supporting the network of collaboration and the competitiveness of the whole system [14, 15, 35]. Knowledge sharing and learning models developed for the sustainability of ASD practices can be integrated with the existing KM infrastructure that can justify the scale and economic viability of the system. Large organizations are reaping the benefits of knowledge management practices, whereas small and medium enterprises have not exploited the adoption of these practices and show poor performance as compared to large originations [13, 27]. Similarly, few studies show KM practices that are naturally embodied with agile practices run in parallel [40]. Although many researchers have highlighted the processes and dimensions of knowledge and their adoption in large organizations, concerning small and medium organizations, there is hardly any consensus on the framework of KM, and it is still fragmented. Therefore, the level of adoption of KM within SMEs is heterogeneous and in the absence of a general framework for the adoption of KM among SMEs is making hindrance to take advantage of agile software development methodologies [19]. This research paper aims at addressing the importance of knowledge in software engineering and exploring the way agile practices support knowledge management systems within software organizations. Forms of knowledge present in agile processes can help in developing the KM strategy for the development and sustainability of SMEs working in agile methodologies by integrating these strategies with the existing KM framework.

The research is conducted with the objective tobring out KM adoption varies among small, medium, and large organizations working in agile methodologies. Exploration of features of agile methodologies will help in understanding the various forms of knowledge present in these practices and further integration of these practices in the KM framework can give fruitful results to the practitioners. This aspect of agile practices in an evolutionary phase, although research regarding KM in SMEs working in agile methodologies is increasing, more research efforts are still needed especially for analyzing KM from the viewpoint of agile methodologies. So, the following detailed questions have been framed for the analysis:

a) Is there any variation in the adoption of KM practices at the organizational level?

b) Is there any relationship between the core area of software engineering, team distribution, type of organization?
c) Is there any relationship between the number of employees and KM practice level, keeping in mind all the characteristics of the organization?

The following are alternative hypotheses that have been investigated.

HA_1 The size of the organization plays a determinant role in the adoption of KM practices
HA_2 The core area of working of software organizations plays a determinant role in the adoption of KM practice.
HA_3 Team distribution plays a determinant role in the adoption of KM practices
HA_4 Type of organization plays a determinant role in the adoption of KM practices
HA_5 The adoption of KM practices is positively associated with the size of the organizations across different dimensions.

4 Research problem

Researchers have listed three aspects that avert SMEs from adopting KM practices in their routine work [33, 46]: Tacit nature of knowledge; common knowledge that is shared by every employee of the organization; Deficiency of human and financial resources in SMEs. Agile practices hold the key to some of the problems faced by KM (especially in the medium and small-scale industry) as several KM practices are naturally embodied in the agile practices. However, there is a gap in studies that deal specifically with agility and knowledge management [5, 38]. Inter-organizational and intra-organizational knowledge transfer involve the transfer of knowledge between the development team and customers and within a development team, respectively. The need is to comprehend the factors that contribute towards the formation, retention, and dissemination of knowledge in agile processes [1]. Thus, it is of practical significance to examine the acceptance of agile methodologies from a knowledge management perspective.

From literature review it was prominently surfaced that there are for main pillars that may affect the KM practices embedded in Agile Software Development: Size of organization, type of organization, core area of work of the organization and types of team. Most of the studies discussed in previous sections explore the togetherness of agile and KM practices, but fail to consider other organizational characteristics/dimensions that can play a vital role in implementing KM in organizations like the size of the organizations, types of teams working for the development of the software, number of employees in an organization, distribution of the teams, etc. Based on these broadly defied 4 parameters we have further classified each parameter into further sub parameters. These all factors can play a major role in deciding how KM infrastructure can be implemented in organizations [39]. In most of the large organizations, KM would have been formally introduced in organizational structure, but it is not the same case with medium and small-scale organizations. It will be unfair if one says that SMEs do not have a KM strategy in place. If an organization practices agile methodology somehow there is a KM infrastructure in place, as many KM practices are naturally embedded in agile methodologies so it must have to explore what different types of KM practices knowingly and unknowingly being practiced in these kinds of organizations.

As the world is becoming a global village, collaborative relationships among small, medium, and large enterprises working with collocated or distributed teams have gained popularity, exploration of the extent of adoption of KM practices among different dimensions is not much explored. Exploration of the literature leads to a considerable question, faced by many KM researchers that have not paid enough attention to is: whether different dimensions of the organizations (Scale of the Industry, Core area of operations, Team distribution, type of organization) affect the adoption of KM practices (Connelly and Kelloway [11], [36], Davis et al., 2007 and Zanjani et al. (2009))? To answer these questions, a framework is proposed that categorizes different KM practices in small, medium, and large organizations and makes propositions about how the size, core area of work, type of organization, and geographical dispersion affect the adoption of KM practices (Fig. 1). The survey is used as an instrument for measuring the variation in adoptions depending upon the characteristics of the organizations. The survey is directly adopted from the Knowledge Management Assessment Tool (KMART) (Andreson, 1996). A questionnaire was based on five constructs of the KMART tool: knowledge acquisition, knowledge sharing, training and mentoring, KM environment, and KM technology.

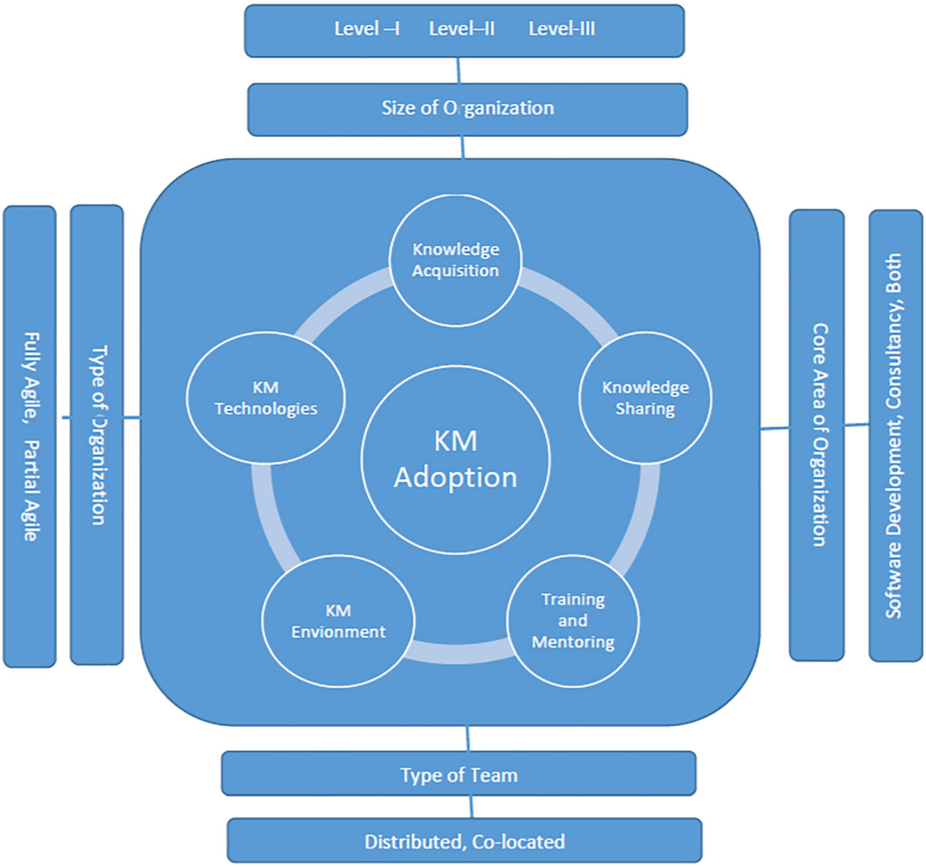

Fig. 1 KM adoption framework

5 Research approach

The survey is used as an instrument for measuring the adoption variation depending upon the functional specifications of organizations like size, the core area of work, type of organizations, and team distribution. Initially, organizations were classified into three categories: largest (having employees more than 5000), medium (having employees between 501 and 5000), small (having employees between 50 and 500) depending upon the strength of their employees. Respondents from organizations are also divided into three levels: A (Strategic Managers), B (Tactical Managers), C (Operational Managers). It was not possible to cover the whole universe of the study. A sample of only those SE organizations has been chosen which use many of the agile practices and have some knowledge Management System (KMS) in place. Top 500 Companies in terms of average business per employee registered with NASSCOM were identified and 100 companies were randomly approached to participate in the survey. Even distribution, 20 organizations in each category were approached, but eventually, 34 companies agreed to participate in the survey. Ten respondents from different levels are taken from each company making 340 responses in total. SPSS toll has been used for analysis of the data. A stratified sampling technique was used for the selection of the respondents. Level A population of the cluster has a lesser number of the population as compared to level C, so 1:6 responses were collected to maintain balance among the population as mentioned in Table 1.

To gain insight of KM practice level, organizations are divided according to different characteristics (Table 2) where fully agile means that all the development operation of the organization are carried out in agile methodologies only and partial agile means some of the projects/teams in the organization are proceeding with these methodologies.

The Shapiro-Wilks test was used to check the normality of the data. A value of 0.120 indicates that the distribution is normal.

6 Results and discussion

6.1 KM adoption and organization size

Levene's test for homogeneity of variance was also calculated at 0.102 assuring that the population variances by size are approximately equal. Descriptive analysis (Table 3) of the data shows that the medium size organizations show a tendency of least adoption of KM practice (69.0%) with the highest variance of 19%. Large organizations display the highest rate of KM adoption of 77.13% whereas the variation in the adoption was lowest in small organizations (7.5%). Small organizations exhibit the least variation 9.88% in adopting KM practices with minimum KM practices adoption of 60.44% and a maximum of 83% of the small organizations.

Table 1 Plan and size of the samples for 34 respondents

Level	Number of respondents for each level	Total responses for each level	Response received
A	01	34	30
B	04	136	106
C	06	204	204
Total	11	374	340

Table 2 Dimensions of the organizations

Bifurcations Characteristics	Dimensions	Number of Organizations
Size	Large	VII
	Medium	XI
	Small	XVI
Core Area	Product Development	XIV
	Consultancy	VIII
	Both	XII
Type	Fully Agile	XV
	Partial Agile	XIX

The mean difference in KM adoption based on the size of organizations within each group is calculated with One-way ANOVA as depicted in Table 4.

One-way ANOVA is not found significant ($p > 0.05$), indicates no variation in the adoption of KM Practice level with the size of the organization, Therefore, hypothesis HA1 can be rejected based on a significant level. The discoveries of the research support the argument that regardless of size, knowledge issues apply to all organizations. Results contradict with the results of Connelly and Kelloway [11], Serenko et al. [36], Davis et al. (2007), and Zanjani et al. (2009) that apprehend no relationship between size and knowledge sharing in the organization whereas Xu and Quaddus [47] complements to our results and asserted that size does not affect knowledge systems. Our findings support Moffet and McAdam's [28] argument that irrespective of organizational size issues related to knowledge does not apply to all organizations. The results confirm that the notion of KM applies to all organizations, with hardly any significant difference in the adoption of KM among the large, medium, and small-scale organizations.

6.2 KM adoption and area of engineering

Software engineering organizations can also be divided by the core area of software engineering: product development; consultancy; or both (product and consultancy). The non-significant value of Levene's test (0.281) indicates that the population variation for groups is almost equal. Descriptive analysis in Table 5 shows the Mean and standard deviation for each group, where product development (PD) shares the highest adoption mean of 81.2%, whereas organizations providing consultancy and organizations providing software development and consultancy both are sharing almost similar adoption levels of 68%. The mean of KM adoption is the highest for product development organizations (81.23%).

Table 3 Descriptive analysis of KM adoption level by organizational size

Size	No. of Org.	Mean	Std. Deviation	Coff. of Variance	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Large	**16**	**77.137**	**16.887**	**21.892**	**4.221**	**68.1389**	**86.1360**	**41.24**	**97.76**
Medium	11	69.024	19.004	27.533	5.730	56.2570	81.7921	30.58	95.00
Small	7	76.138	7.526	9.8849	2.844	69.1777	83.0990	60.44	83.20
Total	34	74.307	16.225	21.835	2.782	68.6456	79.9684	30.58	97.76

Table 4 KM adoption by organization size

One-way ANOVA	Sum of Squares	Df.	Mean Square	F	Sig.
Between Groups	458.607	2	229.303	.864	.431
Within Groups	8229.323	31	265.462		
Total	8687.930	33			

Results of one-way ANOVA (Table 6) do not show any significant disparity in the mean KM adoption. Although the confidence value is close to 0.05 it can be concluded that hardly any significant relation is found between KM adoption and working area of organization ($p = 0.083$) as depicted in Tables 7, 8 and 9. So, the H03 hypothesis can be rejected based on the results obtained.

Outcomes from the study coincide with Sant (2011) on Indian IT consultancy service organizations where authors comment that the growth of knowledge management practices in India has been limited mainly in the service industries like IT, Consultancy, and some of the electronics and communication industries. There is hardly any difference in KM practices applied in software development and services companies. [8]. A similar study that overlap with the results of the author is on one of the Indian Giant software development and services Industry in comparison to the pure service industry from KM perspective was conducted. Major software companies like Infosys and Unisys have visualized the significance of the KM and imparted the KM system into the organizational structure that suits their working environment. A survey of these organizations does not highlight any significant difference in implementation of KM practices and both organizations have achieved a benchmark in implementing KM in their organizational structure [29].

6.3 KM practice level and team distribution

Globalization has given the advantage to the organizations to build their offshore offices and take advantage of the low-cost development of software from resource-rich countries like India. KM practice level of teams working in co-location and distribution was checked. KM adoption is highest for the team working in co-locations but has a greater variation in the adoption of KM practices as compared to teams working in a distributed environment. Variation in the adoption of KM practice is found high in co-located (23.93%) as compared to distributed agile teams (20.66%). A detailed analysis is given in Table 7.

Table 5 Descriptive analysis of KM adoption

Area of Working	Org.	Mean	Std. Deviation	Coff. of Variance	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Product Development	15	81.236	13.651	16.8049	3.524	73.6767	88.7970	47.78	97.76
Consultancy	7	68.566	10.649	15.53164	4.025	58.7172	78.4154	50.88	79.04
Both	12	68.993	19.325	28.01133	5.578	56.7143	81.2726	30.58	95.00
Total	34	74.307	16.225	21.83592	2.782	68.6456	79.9684	30.58	97.76

Table 6 KM adoption practice and area modularity

One-way ANOVA	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	1289.842	2	644.921	2.702	.083
Within Groups	7398.087	31	238.648		
Total	8687.930	33			

Variation in KM adoption between distributed and co-located teams is determined by one-way ANOVA, before applying the test homogeneity of variance is calculated and was not significant providing confidence that variation of groups is of equal. Therefore, it is acceptable to use the t-test for equality of means to determine whether differences exist between the KM practices levels of distributed and co-located teams. The T-test is used to determine equality of means did not confirm any statistical difference between means of distributed and co-located teams. So, the null hypothesis (H04) that there is variation in the adoption of KM practices can be accepted. Testes do not confirm any variation in the adoption of KM practices by distributed or co-located teams.

Whereas results of Zenun et al. [48], Kroll et al. [23], Razzak and Mite [34] significantly differ from the present research. These Studies emphasized different approaches/practices for knowledge transfer and knowledge creation in distributed teams. Different strategies were implemented to manage knowledge locally and globally. One of the reasons for disagreement can be both of the research were focused on a single/ some of KM strategies: knowledge transfer [48] and Knowledge creation [23] rather than taking different dimensions of the KM, whereas Lindsjorn et al. [26] have taken other dimensions and a collective KM strategy for comparison between distributed and co-located teams and presents some agreement with the current study as the authors underline that there is hardly any impact of distribution on the management of tacit knowledge in agile teams [43].

6.4 KM practice level and type of organization

Agile software development practices are relatively new in software engineering environments. Term software engineering was coined around 1970, whereas agile alliance came into existence around 2001. The author of this research does not find any research that has focused on KM from the perspective, whether the organization is fully agile or partial agile. Most of the organizations are practicing both methodologies for product development, but when the profile of the organizations was selected significant number of organizations were encountered that explicitly acknowledge being fully agile companies, i.e. software was developed with agile

Table 7 Summary of KM practice level by team distribution

Team Distribution	No of Org.	Mean	Std. Deviation	Coeff. of Variance	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Distributed	226	102.99	21.22933	20.66	1.412	100.2084	105.7739	29.00	141.00
Co-located	114	106.31	25.44372	23.93	2.383	101.5858	111.0282	36.00	145.00
Total	340	104.10	22.74596	21.84	1.233	101.6765	106.5294	29.00	145.00

Table 8 KM adoption: Co-located and distributed teams

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	2.020	.156	−1.270	338	.205	−3.31587	2.61063	−8.45099	1.81925
Equal variances not assumed			−1.197	194.266	.233	−3.31587	2.77001	−8.77903	2.14729

methodologies only. So, it was important to judge KM from this perspective also. Software engineering firms are distinguished based on these technologies: Fully agile organizations mean organizations that are using agile practices in all of their software development projects and partially agile means organizations which are using agile practices to only some of their projects i.e. they are using both traditional and agile practices for different product developments (Table 9).

Fully agile companies show greater adoption of KM practices 80.95% compared to partially agile organizations which adopt 69.05% of KM practices, while partially agile organizations show a greater variation of 25.7% as compared to 13.97% of fully agile organizations. Variation in the adoption of KM by fully or partially agile organizations was conducted using an independent t-test. Value of 0.083 of Levene's test gives the confidence that variation of groups by team distribution is almost equal (results in Table 10).

Statistical analysis suggests that the null hypothesis can be rejected as value confidence ($p = 0.031$) less than the threshold value. Therefore, the test confirms that KM adoption does vary between full and partial agile organizations (Table 10). This variation can be directly related to the claims of the researchers that KM practices are naturally embodied in agile practices whereas KM must be artificially induced in traditional development techniques.

6.5 The relationship among KM practice level and number of employees

The association between an Organization's KM adoption and the number of employees is investigated from different dimensions such as organization size, core area, and type. Pearson

Table 9 Summary of KM practice level by type of organizations

Org. Type	No. of Org.	Mean	Std. Deviation	Coff. of Variance	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Fully Agile	15	80.957	11.3096	13.9703	2.9201	74.6943	87.2204	59.99	97.76
Partially Agile	19	69.056	17.8108	25.7940	4.0860	60.4722	77.6413	30.58	95.12
Total	34	74.307	16.2256	21.8371	2.7826	68.6456	79.9684	30.58	97.76

Table 10 Independent samples test comparing KM levels of type of organizations

Levene's Test			t-test to check Means Equality						
	F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	3.196	.083	2.250	32	.031	11.90064	5.28805	1.1292	22.672
Equal variances not assumed			2.370	30.76	.024	11.90064	5.02228	1.6544	22.146

product-moment correlation test is used to measure the association between KM adoption and the strength of employees in the organizations. No significant association among all sizes of SE organizations was found.

Statistics show that for the size A organization significant values come out to be 0.65, for size b it is 0.38 and for size cit was 0.33, all values above the threshold value of p (Table 11). Hardly any difference is found between KM adoption patterns of all sizes of organizations and the strength of the employees. Another area to evaluate is, whether there is an association between the type of organization and the strength of employees (Table 12).

A test was conducted for organizations working fully in agile practices for every product development and organizations use agile practices partially (only for some of the product development). A significant relationship was found between fully agile organizations and employee strength of the organizations whereas hardly any association was found between partial agile organizations and the number of employees ($p = 0.037$ and 0.931, Table 13).

Table 11 KM adoption and strength of organizations

Size			Org. KM Level	No. of Emp.
A	Org KM Adoption	Pearson Correlation	1	−.123
		Sig. (2-tailed)		.651
		N	16	16
	No. of Emp.	Pearson Correlation	−.123	1
		Sig. (2-tailed)	.651	
		N	16	16
B	Org KM Adoption	Pearson Correlation	1	.289
		Sig. (2-tailed)		.389
		N	11	11
	No. of Emp.	Pearson Correlation	.289	1
		Sig. (2-tailed)	.389	
		N	11	11
C	Org KM Adoption	Pearson Correlation	1	.428
		Sig. (2-tailed)		.338
		N	7	7
	No. of Emp.	Pearson Correlation	.428	1
		Sig. (2-tailed)	.338	
		N	7	7

** Correlation is significant at the 0.05 level (2-tailed)

Table 12 KM adoption and area of working

Core Area			Org. KM Level	No. of Emp.
Development	Org KM Level	Pearson Correlation	1	.537*
		Sig. (2 Tailed)		.039
		N	15	15
	No. of Emp.	Pearson Correlation	.537*	1
		Sig. (2 Tailed)	.039	
		N	15	15
Consultancy	Org KM Level	Pearson Correlation	1	−.245
		Sig. (2 Tailed)		.596
		N	7	7
	No. of Emp.	Pearson Correlation	−.245	1
		Sig. (2 Tailed)	.596	
		N	7	7
Both	Org KM Level	Pearson Correlation	1	.409
		Sig. (2 Tailed)		.187
		N	12	12
	No. of Emp.	Pearson Correlation	.409	1
		Sig. (2 Tailed)	.187	
		N	12	12

** Correlation is significant at the 0.05 level (2-tailed)

7 Fuzzy analytic hierarchy process

It is a combination of fuzzy set theory and Analytic Hierarchy Process (AHP) and considered as one of the most influential approaches for multi-criteria decision making (MCDM). Initially, the authors (Laarhoven and Pedrycz, 1983) have shown the effort to work on fuzzy ratios by using the triangular membership function (TMF). The popular fuzzy approach was given by the author (Chang, 1996) for extent fuzzy analysis, in this, he used the triangular fuzzy numbers for pairwise judgment scale. AHP offers a broad and balanced hierarchical structure for addressing decision problems on a common goal and related criteria. AHP helps quantify the weight of the appraised criteria in the form numeric basis. The criteria weight of each element determines its relative importance with the other elements of the hierarchy. Hence, it facilitates the decision-makers to identify and prioritize significant factors. FAHP has been

Table 13 KM adoption and type of organizations

Type of Organization			Org. KM Level	No. of Emp.
Fully Agile	Org KM Level	Pearson Correlation	1	.503
		Sig. (2 Tailed)		.037
		N	15	15
	No. of Emp.	Pearson Correlation	.503	1
		Sig. (2 Tailed)	.037	
		N	15	15
Partially Agile	Org KM Level	Pearson Correlation	1	−.021
		Sig. (2 Tailed)		.931
		N	19	19
	No. of Emp.	Pearson Correlation	−.021	1
		Sig. (2 Tailed)	.931	
		N	19	19

**Correlation is significant at the 0.05 level (2-tailed) used in this paper to find out the critical factors in adoption KM in an organization. Sub-criteria that have been identified form literature are globally ranked with the help of FAHP so that organization can understand the hierarchies of the factors that can be kept in the mind before implementing KM in agile process. Stepwise implementation of AHP process have been described below.

Step 1: The fuzzy pairwise assessment matrix is made. The matrix is shown in eq. 1.

$$\widetilde{A} = \begin{bmatrix} 1,1,1 & \widetilde{a}_{12} & \widetilde{a}_{13} & \widetilde{a}_{14} & \cdots & \widetilde{a}_{1n} \\ \widetilde{a}_{21} & 1,1,1 & \widetilde{a}_{23} & \widetilde{a}_{24} & \cdots & \widetilde{a}_{2n} \\ \widetilde{a}_{31} & \widetilde{a}_{32} & 1,1,1 & \widetilde{a}_{34} & \cdots & \widetilde{a}_{3n} \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ \widetilde{a}_{n1} & \widetilde{a}_{n2} & \widetilde{a}_{n3} & \widetilde{a}_{n4} & \cdots & 1,1,1 \end{bmatrix} \tag{1}$$

where $\tilde{a} = (l_{ij},m_{ij},u_{ij})$ and i = 1,2,3,4,5……n and j = 1,2,3,4,5……n are triangular fuzzy numbers.

Step 2: The fuzzy synthetic extent value (FS_i) related to criteria i is calculated as:

$$FS_{i=}\left(\sum_{j=1}^{n} l_j \ , \sum_{j=1}^{n} m_j \ , \sum_{j=1}^{n} \mu_j \ \right) * \left(\frac{1}{\sum_{i=1}^{n} \mu_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right) \tag{2}$$

Step 3: To calculate the degree of possibility of $P_1(l_1, m_1, u_1)$ and $P_2(l_2, m_2, u_2)$ triangular fuzzy numbers of $P_1 >= P_2$ is defined in eq. 3, eq. 4, and eq. 5 as:

$$\mathrm{V}(\mathrm{P}_1 >= \mathrm{P}_2) = 1 \text{ iff } \mathrm{m}_1 >= \mathrm{m}_2 \tag{3}$$

$$\mathrm{V}(\mathrm{P}_1 >= \mathrm{P}_2) = 0 \text{ iff } \mathrm{l}_1 >= \mathrm{u}_2 \tag{4}$$

$$V(P_2 \geq P_1) = \frac{\boldsymbol{l_{1}-\mu_2}}{(\boldsymbol{m_{2}-\mu_2})-(\boldsymbol{m_{1}-l_1})} \tag{5}$$

The fuzzy weight is calculated as shown in eq. 6.

$$\begin{aligned} \mathrm{FW}^{`} &= \left(\mathrm{d}^{`}(\mathrm{A}_1), \mathrm{d}^{`}(\mathrm{A}_2), \mathrm{d}^{`}(\mathrm{A}_3), \mathrm{d}^{`}(\mathrm{A}_4) \ldots\ldots \mathrm{d}^{`}(\mathrm{A}_n)\right)^{\mathrm{T}} \text{ where } \mathrm{d}^{`}(\mathrm{A}_i) \\ &= \min \mathrm{V}(\mathrm{FS}_i >= \mathrm{FS}_r) \text{ and } i, r = 1,2,3\ldots n \text{ and } i \neq r \end{aligned} \tag{6}$$

The non-fuzzy weight or normalized weight is calculated as shown in eq. 7:

$$FW = (d(A_1), d(A_2), d(A_3), d(A_4).......d(A_n))^T \quad (7)$$

8 Fuzzy analytical hierarchical process

AHP is used to calculate the relative ranks of the criteria that may help organization in implementing KM in it. Enablers are criteria used to achieve the goal i.e., implementing KM in an organization. AHP is used to demonstrate the relative and global ranking of all the criteria's that can help in achieving the goal (Table 14). KM Technology is the most important criteria for enabling KM in agile organizations, followed by training and mentoring and knowledge sharing. Whereas the KM environment is found to be the least important factor in implementing KM in agile methodologies. It is surfaced by some authors that [39, 40] agile practices by default create an environment of knowledge management in the organizations so it not necessary to do something extra to feel like an inclusive KM environment.

It is worth mentioning here that the sub-criteria technological solution for transferring knowledge is the most important factor for successful implementation of KM in agile process among others, furthermore, the criteria KM Technology is ranked 1 among other criteria for implementation of KM in organizations working in Agile methodologies. Globally first and second sub-criteria for implying KM belongs to the KM technology group. Thus, we can say that 'technology for implementing KM' plays the most vital role in agile software development. After technological support, Human-centric IT is 2nd most important factor in the implementation of KM. This seems to be in concessions with the agile manifesto where the human-centric approach is given preference over tools and techniques. The third factor comes out to be knowledge acquisition through peers. Self-organizing team structure gives a boost to this factor as this is the best possible way to acquire knowledge through peers of self-organized and cross-functional teams. In KM environment criteria knowledge sharing culture is the most important sub-criteria whereas open spaces are the least important criteria. Similarly, in knowledge sharing, discussion forms come out to be the best practice for applying KS, and the Rotation of people among projects is the least important factor. It's important to note here that this sub-criterion is also the least important criteria among all sub-criteria for implementing KM and is ranked at 17th place.

AHC helps understand the important criteria that can help in achieving a set goal. Ranking help in understanding the weightage that one can give while implementing KM in the organization working in agile methodologies.

9 Conclusion

The conceptual framework presented in this study has both theoretical and practical contributions, whereas on one side it provides researchers more insights on the embeddedness of KM in agile practices on the other side, it gives practitioners practical aspects of KM and agility. So, from the perspective of theoretical contributions, this paper provides a fresh viewpoint for viewing and synthesizing aspects that can influence the acceptance of KM and agile practices

Table 14 Ranking of criteria and sub-criteria

Criteria	Relative Preference Weights	Relative Rank	Sub-Criteria	Relative Preference Weights	Relative Rank	Global Preference Weights	Global Rank
KM environment	0.117	5	Fairs within organization	0.190	4	0.0222	15
			Best practice repositories	0.210	3	0.0246	14
			Knowledge Sharing Culture	0.227	1	0.0266	12
			Strong Networking among employees	0.212	2	0.0248	13
			Open spaces to encourage communication	0.161	5	0.0188	16
Knowledge Sharing	0.202	3	Rotation of people among projects	0.075	5	0.0152	17
			Direct people-to-people contact	0.210	3	0.0424	10
			Documents and database for KS	0.237	2	0.0479	9
			Cross functional and self-organizing teams	0.167	4	0.0337	11
			Discussion forums	0.312	1	0.0630	7
Training and Mentoring	0.230	2	Formal training related to knowledge management	0.355	1	0.0817	4
			Formal mentoring practices	0.334	2	0.0768	5
			Transfer of knowledge	0.311	3	0.0715	6
KM Technology	0.313	1	Technical solution for transferring knowledge	0.577	1	0.1806	1
			"human-centered" information technology	0.423	2	0.1324	2
Knowledge Acquisition	0.138	4	Knowledge Documentation	0.362	1	0.0500	8
			KA through hierarchies and peers	0.638	2	0.0880	3

depending upon different characteristics of the organizations. From a practical viewpoint, this paper highlights the current knowledge of agile practices forms a KM perspective and adoption patterns of KM in agile practices among different organizational demographics. This can guide practitioners regarding adoption patterns of agility and KM, and they can reap the benefits by combining the best of both worlds. The study found a variation in the overall adoption of KM practice by organizations. Responding organizations have adopted, on average, 73% of the KM practices put forth in the survey. The standard deviation of 16% and 21.83% of the coefficient of variance indicates variation across organizations in the adoption of KM practices (total 29). More than 11% of organizations are using less than half of the practices, 35% of organizations are using KM practices ranging from 50% to 75%. The organization with minimum adoption has implemented only 30% of practices and the organization with the highest adoption rate has adopted more than 97% of the KM practices. To a surprise, most of the organizational characteristics are not found in the significantly associated with KM adoption except KM adoption level in full and partial agile organizations and the relationship between the organization KM adoption and the number of employees in the organization for product development and fully agile companies are found significant. Opposite to the claims of many researchers, this study does not find any significant difference between KM adoptions between distributed and co-located agile teams. At the end, fuzzy AHP has been introduced to prioritize all KM criteria as well as sub-criteria in implementing KM in agile organizations. The ranking of criteria in decreasing order is KM technology, Training and Mentoring, Knowledge sharing, Knowledge Acquisition and KM environment respectively. The most important and least important sub-criteria are Technical solution for transferring knowledge and Rotation of people among projects respectively.

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