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Research paper



Measurement and structural model of agile software development critical success factors

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Abstract

Purpose: Agile methodologies have emerged as an innovative and successful business changing way for software development companies since the success rate for completing the software projects on time and budget is better than conventional methodologies. This study proposes a theoretical framework of success factors for agile software development and validates the proposed framework using structural equation modeling.
Design Methodology: A survey based random sampling was performed for data collection from 201 respondents identified from the pool of agile practitioners in software companies. Structural Equation Modeling performed on the collected data to validate measurement model as well as the structural model.
Findings: The theoretical model was confirmed with modifications and the results showed that required level of fitness indexes have been achieved for the measurement model and structural model. The validation of the factors has also been done.
Originality/Value: This study will guide the agile practitioners, academicians and project managers to focus more on the particular success factors which have high weight towards project success.

Keywords: *Agile Software Development; Agile Methodologies; Measurement Model; Confirmatory Factor Analysis; Fitness Indexes; Structural Equation Modeling; Structural Model.*

1. Introduction

Rapid growth in the complexities, frequently changing customer requirements, risks and failures associated with the projects have forced the software industries to come up with the solution that helps in completion of these types of projects within time and budget. Agile methods are one of the solutions to handle such type of projects rather than following traditional methods [1]. In the survey of the 11th annual state agile report, 94% of respondents have confirmed that their organizations were practicing agile and 98% respondents have admitted that their organizations have seen the power of agile projects success. The most used agile methodologies were Scrum and Hybrid Scrum/XP, 58% of respondents have supported this fact in [2]. Project management survey 2017 by KPMG have stated that there is 43% increase in usage of agile methods as compared to the survey done in 2013 [3]. The most important research question that arises is 'Why there is an increase in usage or demand of agile methodologies in software projects?' To answer this question, there is dire need to find and validate the critical factors which are directly or indirectly contributing to agile software projects success. From the literature, a theoretical framework has been developed and validated which consists of agile software development (ASD) critical success factors and perceived level of success dimensions.
The structure of this paper will be as follows: Section 2 proposes a theoretical framework, Section 3 explains the details of the research methodology, Section 4 describes the results of the measurement model, Section 5 discusses results of the structural model, and Section 6 provides the conclusion.

2. Theoretical framework

The framework consists of five CSFs and one perceived level of success factor for software projects in ASD. The framework established intrarelationship of various factors in terms of representing a CSF and individual effect of various CSFs towards the success factor which in turn combines the overall impact towards the perceived level of success. The total variance explained by all factors in the framework is 69.515. The success factor includes technical, organization, people, process and project factors.
Technical factor: This factor consists of the technical complexity of the project like working software delivered within a short period of time, simple design, upfront coding standards, correct integration testing, and the right amount of documentation, training and education to employees' aspects. This factor consisted of seven variables and the total variance explained by this factor is 34.487%.
Organization factor: This factor is related to organization vision, team vision, and coherent self-organizing teamwork, agile style working environment, cooperative culture, reward system and acceptability of agile methods in the organization. This factor consisted of eight variables with a total variance of 11.762%.
People factor: This factor will be measured by seven variables. This factor comprises of variables such as cross-functional teams, knowledge sharing and learning in teams, motivated team mem-

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bers, team co-location, customer satisfaction, customer participation and reintroduces specific roles of employees. The total variance explained by people factor is 9.84%.

Process factor: This factor is related to project planning and control, project realistic schedule, agile requirement process agile configuration management and stresses on oral communication aspects which are required for the success of a project. The variance explained by this is 6.027%.

Project factor: This factor has the least variance explained among all the factors variance explained. This factor is measured by four variables namely projects with upfront cost evaluation, upfront risk evaluation, small team size and project manager act as a facilitator and knowledgeable.

Perceived level of success: The project success is measured on the four bases. These are time, cost & efforts, quality and scope & requirements of the project. The project can be treated as a success if it is completed all user requirements within time, cost, and quality.

3. Research methodology

Various studies related to ASD has been conducted in various parts of the world but the scenario in Indian perspective is in a nascent stage. To confirm the theoretical framework in Indian scenario, a survey based approach was used. The survey consists of the questionnaire related to 35 variables (listed in fig 2) which were set on a five-point Likert scale (5 signifies 'strongly agree'; 4 signifies 'agree'; 3 signifies 'neither disagree nor agree'; 2 signifies 'disagree'; 1 signifies 'strongly disagree'). The respondents' of the survey were from the Indian software industries which were using agile practices and methods for the project development and are registered with NASSCOM (National Association of software and service companies). The data analysis was performed with the help of tools like 'The Statistical Package for the Social Sciences' (SPSS) and 'Analysis of moment structure' (AMOS). The following steps [4], [5] were applied to confirm the pooled measurement model:

1) Measurement or hypothetical model was confirmed using Confirmatory Factor Analysis (CFA).
2) Inspect the fitness indexes values which confirm the fitness of measurement model into the data.
3) If minimum values of fitness indexes have not been achieved then observe the factor loadings of the variables.
4) Identify the variable with the lowest factor loading and it should be less than 0.6
5) Delete the variable and run the new measurement model.
6) Inspect the fitness indexes values and repeat the steps (d to f) till the fitness indexes achieve the acceptance level.
7) If still, the measurement model has not achieved the acceptance level, look at the Modification Indices (MI) values.
8) The MI values greater than 10 indicates that the redundant variables are there in the model. It means correlated error between variables exists.
9) To solve the problem of redundant variables in the model, set the redundant variables as 'free parameter estimate' or delete the variable with lowest factor loading.
10) Run the measurement model and repeat steps (h) and (i) till fitness indexes values will not be achieved.
11) After measurement model acceptance, the structural model was validated by achieving the minimum acceptable value of fitness indexes.

The survey consists of three sections. Section 1 consists of demographics and has total six questions. Section 2 measures agile projects 'success factors' and has total 31 questions and section 3 had four questions related to the 'perceived level of success dimension' of agile projects. The respondents from 31 companies' participated in the survey but total companies contacted were 59. The sampling frame was displayed in table 1. The response rate is 52.54% which is well above the minimum norm of 40% as suggested by the author [6].

Table 1: Sampling Frame

Total companies contacted	59
Companies agreed for survey	38
Response rate of companies agreed to participate	64.40
Companies actually participated in the survey	31
Response rate of companies actually participated	52.54

Table 2: Sample Size

Number of employees	Sample size in terms of companies
1-500	15
501-5000	10
5001-above	6

Table 3: Level of Respondents

Level A or I (Strategic Managers)	Level B or II (Tactic Managers)	Level C or III (Operational Managers)
Director, CEO (Chief Executive Officer), President, Vice President, Project Manager, Chief Agilest, Senior consultants.	Analysts, Team lead, Consultants, Agile Coach, Senior software engineer, Senior software developer, senior tester, Team manager, Scrum Master.	Software Developer, Architect, Engineer, Programmer, Designers, Testers, Trainee.

The sample size in terms of companies and the respondents were also categorized into three levels [7] as shown in table 2 and table 3. The respondents were divided into three levels. Level A were those who take strategic decisions i.e. set long-term objectives for an organization as a whole. Level B were who take tactical decisions and these decisions do not come from top management and will not affect whole organization and were concerned with the fiscal year and level C were those who take operational decisions which are concerned with the day to day operations and these decision focus on immediate future, tomorrow, and the next day or week [8]. The number of respondents collectively participated at the level I, level II and level III in the survey were 215 and out of which 201 samples were selected which were complete and correct. The selection of respondents was based on stratified random sampling.

4. Measurement model

Measurement model determines the relation between observed or measured variables with latent variables/factors [9]. Factors such as organization, process, project, technical, process and perceived level of success which cannot measure directly are known as unobserved variables or latent factors. Information about these latent factors can be achieved through observed variables. A total of 35 observed variables are identified and factor analysis technique was used to reduce these identified variables into a small set of latent factors by considering covariation among variables property [10]. Factor analysis is of two type's namely exploratory factor analysis (EFA) and CFA. EFA is an exploratory technique and works for theory building in our study whereas CFA is a confirmatory technique and works for theory testing of the measurement model,

CFA compares the population covariance of the measurement model with the observed covariance of data in light of various fitness indexes. The model will fit the data if there is a minimum difference between these two [11]. CFA is further defined by two types, one is performing individual CFA on each measurement models whereas pooled CFA was performed at once on the combined measurement models. Pooled CFA is more preferred than individual CFA for latent factors since it addresses the issue of identification problem. While performing pooled CFA, three variables were deleted as their factor loadings were less than 0.6. The variables were deleted one by one. The deleted variables were 'organization have clear vision', 'management support' and 'reintroduce specific roles'. After deleting these variables, measurement model has been confirmed. The reliability and validity of the measurement model have also been achieved as shown in Section 4.1. Before addressing structural model, unidimensionality, validity, and reliability need to be addressed [12]. The measurement model is shown in fig 1.

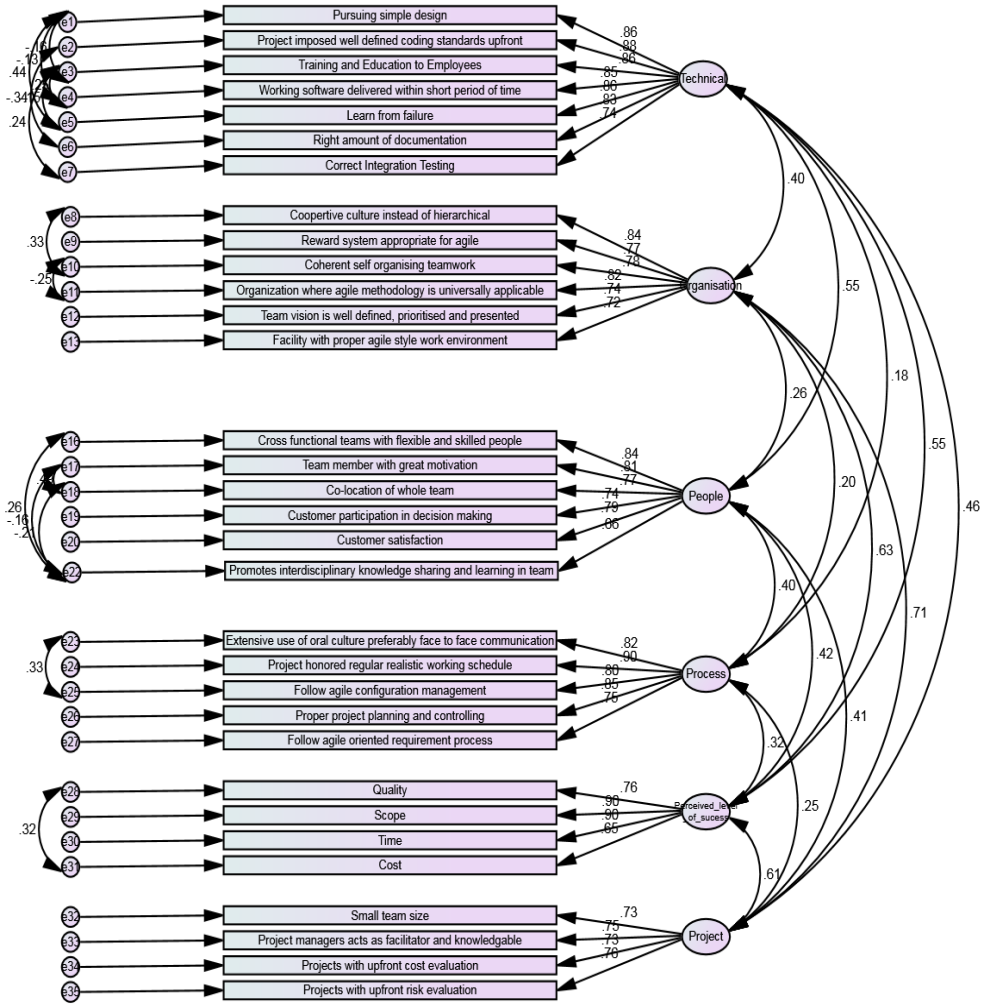


Fig. 1: Measurement Model

4.1. Unidimensionality, validation and reliability

CFA measures the unidimensionality, validity, and reliability of the latent factors. First of all unidimensionality of latent factors should be done before performing reliability and validity.

(1) Unidimensionality: It is attained when all variables of their respective latent factor have factor loadings greater than 0.6. If any variable has low factor loading than this variable must be deleted to ensure unidimensionality for the measurement model. If there is more than one variable having factor loading less than or equal to 0.6 then delete the variable with the lowest factor loading and run the measurement model for all remaining variables. If still, unidimensionality not achieved then repeat the whole process till all variables have appropriate factor loadings of greater than 0.6 [4]. Unidimensionality has been for all latent factors as shown in fig 2.

	Factor Name	Variables included in the factor	Factor Loadings	Cronbach's alpha	Average Variance Extracted	Composite Reliability
1	Technical factor	Correct Integration Testing	0.74	0.943	0.7075	0.9441
		Training and Education to Employees	0.86			
		Right amount of documentation	0.83			
		Working software delivered within short period of time	0.85			
		Project imposed well defined coding standards upfront	0.88			
		Learn from failure	0.86			
		Pursuing simple design	0.86			
2	Organization factor	Team vision is well defined, prioritized and presented	0.74	0.897	0.6076	0.9026
		Coherent self-organizing teamwork	0.78			
		Cooperative culture instead of hierarchical	0.84			
		Reward system appropriate for agile	0.77			
		Organization where agile methodology is universally applicable	0.82			
		Management support	DELETED			
		Facility with proper agile style work environment	0.72			
		Organization have clear vision	DELETED			
3	People factor	Promotes interdisciplinary knowledge sharing and learning in team	0.66	0.905	0.5937	0.8971
		Cross functional teams with flexible and skilled people	0.84			
		Customer participation in decision making	0.74			
		Customer satisfaction	0.79			
		Co-location of whole team	0.77			
		Team member with great motivation	0.81			
		Reintroduce specific roles	DELETED			
4	Process factor	Follow agile oriented requirement process	0.76	0.916	0.6845	0.9153
		Proper project planning and controlling	0.85			
		Project honored regular realistic working schedule	0.90			
		Follow agile configuration management	0.80			
		Extensive use of oral culture preferably face to face communication	0.82			
5	Perceived level of success	Cost & Efforts	0.65	0.887	0.6550	0.8819
		Time	0.90			
		Quality	0.76			
		Scope & Requirements	0.90			
6	Project factor	Project managers acts as facilitator and knowledgeable	0.75	0.830	0.5515	0.8310
		Small team size	0.73			
		Projects with upfront cost evaluation	0.73			
		Projects with upfront risk evaluation	0.76			

Fig 2: Factors with Their Loadings, Cronbach's Alpha, AVE and CR

(2) Validity: It is an ability of an instrument to measure the supposed metric. Following are the types of validity should be satisfied for any measurement model.

a) Convergent validity: It is attained when average variance extracted (AVE) of each factor is greater than or equal to 0.5 [13], [14], [15]. This validity can be failed if variables with lower factor loadings are retained in the measurement model. The present study has achieved convergent validity. For reference see fig 2.

b) Discriminant validity: This validity will be achieved when the square root of AVE is greater than inter-construct correlations [15]. All diagonal values mentioned in table 4 are the square root of AVE and non-diagonal values are inter-construct correlations.

Table 4: Diagonal Values Are AVE and Off-Diagonal Values are Squared Inter-Construct Correlations

Construct/Factor	Technical	Organization	People	Process	Perceived level of success	Project
Technical	0.7075					
Organization	0.1624	0.6076				
People	0.3058	0.0697	0.5937			
Process	0.0309	0.0392	0.1600	0.6845		
Perceived level of success	0.3047	0.3919	0.1739	0.1030	0.6550	
Project	0.2134	0.5055	0.1714	0.0620	0.3782	0.5515

(3) Reliability: It checks the reliability of measurement instrument while measuring latent constructs. The following reliability can be assessed:

a) Internal reliability: It indicates that how much strongly variables are grouped together to measure their respective factor. The internal reliability is attained when Cronbach's alpha value is greater 0.7 [15]. The combined Cronbach's alpha is 0.941 and Cronbach's alpha for each factor is greater than 0.7 as can be seen in fig 2.

b) Composite reliability: It tells the internal consistency of the latent factor. It should be equal or exceeds 0.6 [16]. This has also been achieved see fig 2.

4.2. Fitness of indices for measurement model

Fitness indexes are used to know about how fit the model is in reference to the data. Many researchers, argued about different fitness indexes to use and there was no agreement found among researchers for using which fitness indexes while reporting the results. The model fit is classified into 3 categories namely (i) Absolute Fit (II) Incremental Fit (iii) Parsimonious Fit. The authors [5], [17] showed the model fit by satisfying the minimum level of acceptance condition of anyone fitness index from each category as mentioned in table 5. The measurement model of this study satisfied the minimum level of acceptance condition as guided by above-mentioned authors. Table 5 showed the category, name of the index, level of acceptance of each index, results, and references.

Table 5: Fitness Indices of Measurement Model

Name of category	Name of index	Level of acceptance	Results	Reference
Absolute fit	Chi-Square	** p > 0.05 means significant	0.000 but sample size is greater than 200	[18]
	RMSEA	RMSEA < 0.08	0.051	[18], [19]
	GFI	Satisfactory model fit if greater than 0.9 Acceptable model fit between 0.8 and 0.9	0.838	[20], [21], [22], [23], [24]
	SRMR	SRMR < 0.08 means acceptable fit	0.0467	[25]
	AGFI	Satisfactory model fit if greater than 0.9 Acceptable model fit between 0.8 and 0.9	0.802	[22],[23], [24]
Incremental fit	CFI	Satisfactory model fit if greater than 0.9	0.952	[18], [26]
	TLI	Satisfactory model fit if greater than 0.9	0.945	[18]
	NFI	Acceptable model fit if greater than 0.8	0.873	[27]
Parsimonious fit	Normed Cmin	1.0<Cmin/df<3.0	1.521	[18]

** For sample size above 200, Chi-square absolute index could be ignored [18].

Some researchers have used two-index formats to show model is fit. The author [25] have given the two index format for the model to be fit. The RMSEA and SRMR were used as a fit index combination and their values should be less than or equal to 0.06 and less than or equal to 0.09 respectively. The results of this study have shown RMSEA 0.051 and SRMR 0.467 which satisfies the criteria of [25] and model fit is achieved.

This article [28] strongly advocated Chi-Square test, RMSEA, CFI and SRMR usage for checking model fitness. The present study has also achieved the model fitness for all the above-mentioned indexes.

5. Structural equation modeling (SEM) results and analysis

SEM is called casual modeling or path analysis. It consists of CFA and regression. SEM proves to be a better approach for establishing the relationship between latent factors by validating the structural model. The fitness indices for structural model are shown in table 6 and the structural model is shown in fig 3. The steps involved in SEM are:-

1) Make the hypothetical or theoretical model based on the theory.
2) Collect the data of observed variables for measuring the latent factor.
3) Perform the pooled CFA for measurement model of latent factors as discussed in Section 4.
4) Convert the hypothetical or theoretical model into AMOS structural model.
5) Execute the model and verify the relationship between latent factors to confirm the theory.

The steps (d) and (e) are discussed in this section and a hypothesis has emerged to show the relationship between latent factors.

Hypothesis: ASD success factors have a positive impact on the perceived level of success dimension in software projects.

The results confirmed the positive impact of success factors on the perceived level of success dimension as the standard estimate value is 0.947, the standard error value is 0.136, the critical ratio is 6.956 and p-value is <0.001, so the hypothesis is accepted.

Table 6: Fitness Indices for Structural Model

Name of category	Name of index	Level of acceptance	Results	Reference
Absolute fit	Chi-Square	** p > 0.05 means significant	0.000 but sample size is greater than 200	[18]
	RMSEA	RMSEA < 0.08	0.055	[18], [19]
	GFI	Satisfactory model fit if greater than 0.9 Acceptable model fit between 0.8 and 0.9	0.826	[20], [21], [22], [23], [24]
	SRMR	SRMR < 0.08 means acceptable fit	0.077	[25]
	AGFI	Satisfactory model fit if greater than 0.9 Acceptable model fit between 0.8 and 0.9	0.801	[22], [23], [29], [24]
Incremental fit	CFI	Satisfactory model fit if greater than 0.9	0.942	[18], [26]
	TLI	Satisfactory model fit if greater than 0.9	0.935	[18]
	NFI	Acceptable model fit if greater than 0.8	0.863	[27]
Parsimonious fit	Normed Cmin	1.0<Cmin/df<3.0	1.615	[18]

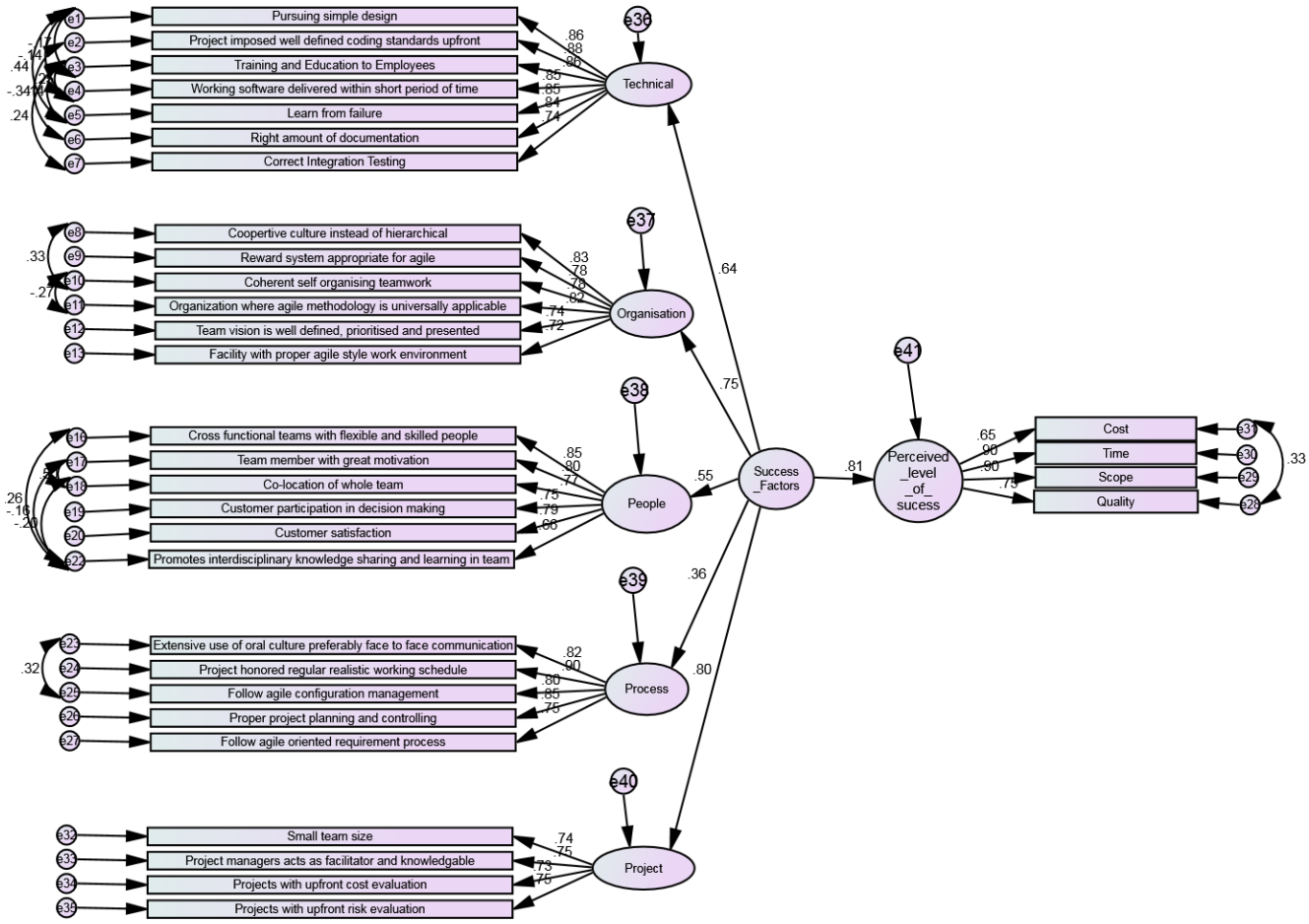


Fig 3: Structural Model

6. Conclusion

A survey based research methodology was adopted to confirm the success factors and perceived level of success dimension. The total number of respondents was 201 and all respondents are agile practitioners and working in software companies. After collecting the data, CFA was performed to confirm the factors and fitness indexed were checked to confirm that data is fit for measurement model. After measurement model, the structural model based on the theoretical framework was confirmed by finding the suitability of fitness indexes. The study has also assessed the high causal relationship between critical success factors of agile software development and the perceived level of success dimension. The project, organization, technical, people and process factors showed a direct effect on the critical success factor as the factors have the p-value less than 0.001 and project factor is highly influencing success factor as its standard beta coefficient was 0.80 as compared to other values 0.75, 0.64, 0.55 and 0.36 respectively. These findings will help the agile practitioners, researchers and agile management to concentrate on the most significant activities which can be beneficial to the project success.

The findings can be concisely represented as follows:-

- The present study has taken 35 variables, out of these, 32 variables have been found unidimensional as their factor loadings were greater than 0.6.
- The internal reliability and the composite reliability have also been achieved for all six latent factors as Cronbach's alpha value for all factors greater than 0.7 and CR value greater than 0.6 respectively.
- The measurement model and structural model have also been validated.

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