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Model to Predict Schedule Variance in Software Application Development Projects

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Abstract

Objectives: 1. To develop a predictive model which measures schedule variance on the basis of multiple independent variables. 2. To describe the skills required for project managers to effectively handle on time delivery of project using factor analysis. 3. To measure the strength of association between the schedule variance and demographic variables of a project manager and project. **Methods:** Data from 70 different projects and additional responses from the project managers managing those projects are collected using mail survey techniques. **Findings:** The output of Multiple Linear Regression (MLR) technique helped to predict change in software application project schedule with a degree of accuracy of R-Value, the coefficient of correlation 90.1%. The research analysis indicates that the relationship between the dependent variable, which is project schedule variance and independent variables, of the developed model is good. The model will fit the real time project environment. Using multivariate factor analysis, sixteen key skills needed for a project manager for efficient on-time delivery has been identified. These are highly loaded into five different factors. Chi-square goodness of fit which is a non-parametric test helped to identify the strength of association between schedule variance and demographic variables. **Conclusion:** The analysis has resulted in a predictive model with eleven independent variables (excluding constant) impacting schedule variance. The five different competencies are the factor labels which are estimate and re-estimate, managing risks, people management, requirement management and time management and control over runs required for project managers, to have a control on the project schedule. It is also inferred that there is no significant association between the project manager's demographic variables and ability to complete the project within the agreed time in Statement of Work (SOW).

Keywords: Application Development Projects, On Time Delivery in Software Projects, Project Manager Competencies, Schedule Variance

1. Introduction

Describe the software application development process as the transformation of client's ideas about his proposed system into the physical, delivered system[1]. Each phase in a product development lifecycle must have a clear start and a clear end. Each phase has a precise and material meaning defined in terms of deliverable items. Organizations engage software developing IT service organizations to design and develop software applications, which will facilitate them to deliver flawless service to its end-customers. In software application development projects, the contract between the customer and service delivery organization is established predominantly through one of the contract types listed. 1. FPP – Fixed price projects, 2. T&M – Time and material 3. RFB – Recurring Fixed Billing. The contract amount will be paid to service delivery organization upon achieving agreed milestones signed off in the Statement of Work (SOW) in case of fixed price project contract type. Fixed price projects are also called as, milestone based deliverable. Upon achieving milestones, service organization bills the customer for the time and effort executed by the delivery team. The deliverable is being tracked by service organization and customer throughout the project lifecycle. A detailed project plan is a master document which helps the customer and delivery organizations to track the agreed, approved scope, schedule and budget.

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Project management is an important part of software development, both for the organization that depends on third party software development and for those whose software is developed primarily in-house[2]. An ideal project scenario expects projects to be delivered on time assigned off in the project plan. The estimated schedule may go wrong due to unforeseen risks, change in customer requirements, customer preferences and several other intrinsic operational factors in a project. The change in schedule variance will either create positive or negative impact on estimated budget and revenue.

The project environment is categorized as application development, post development support, maintenance projects, consulting, transition, migration, etc. The research limits it scope to application development projects which are called as AD projects. The project's schedule variance will have a direct impact on the deliverable committed to the customer. In fixed price as the revenue is tagged to delivery, it is inevitable to adhere to schedule to accomplish revenue. Positive schedule variance will have an adverse impact on projected revenue. In addition to on time deliverable defect prevention is a parameter to enumerate to control the software development project and to ensure that the project meets its targets of quality, cost and time[3].

What is an application development project in IT? A project is a temporary endeavor undertaken to create a unique product or a service. Temporary means that every project has a definite beginning and a definite end[4]. Owing to business requirements, customer wants to either automate the operational process or enhance the existing automated system for efficient service. The contract may inclusive of development of the software application alone or including enhancement, support and maintenance of the application. In the early phase of project lifecycle project managers collect requirements from customer, converts this into a refined technical requirement document. In the role a project manager, a projects manager does requirement elicitation, analyze the requirements, reviews and manage the requirements[3]. The project manager does detailed planning, estimation, analyses budget, time and effort required to develop an application. The requirements of the customers are delivered to them within the schedule and scope. IT service delivery organization uses suitable software languages or package implementation techniques to convert specifications into workable software application software.

Corporate Executive Board report 2015 says "the majority of projects fail to deliver the expected business outcomes, even those delivered within 90% of schedule and budget targets"[5]. The given data alarms all project managers to introspect on quality of business outcomes for those projects which are delivered beyond the estimated schedule.

2. Methodology

2.1 Sampling

The primary data for this research are 1. Project data from 70 software application development projects. 2. Response from project managers in a bipolar scale. The 70 projects were from top 10 listed Indian software development companies with reference to their market cap as on year ending 2014. On an average seven projects were selected from each organization. Snow ball, which is a reference sampling technique, was used to sample the projects needed for study.

Projects which satisfy all the criteria's listed were considered

Criteria-1. Projects revenue worth more than one million USD.

Criteria-2. The contractual relationship with the customer should be 2 and more years.

Criteria-3. Project team size minimum of 20 resources including onshore and offshore.

Criteria-4. Having zero, negative or positive schedule variance then less than 5% of the agreed timeline.

2.2 Instrument

The survey instrument had three sections. Demographic details of the respondents and projects were captured in Section I. Section II had identified variables which has an influence on timely delivery of the project. Section III had a comprehensive list of skills needed for a project manager working on software application projects. 7 point liker scale was used to measure the relevancy of the skills needed for on-time delivery. The scale ranged from not at all important (1) as a lower polar and extremely important (7), which is higher polar.

3. Discussion

3.1 Predictive Model using Multi Linear Regression Technique

Table 1. Model summary

Model	R	R square	Adjusted R Square	Std.Error of the estimate
1	0.901	0.811	0.810	5.69097

R^2 variable (0.811) indicates that proposition of variation in dependent variable "change in project schedule "is being explained by independent variables. It is understood from the Table 1 that the regression equation derived in this analysis is fit.

The output of multiple linear regressions with reference to Table 2 given in appendix is

Schedule variance = 1.329 – (0.007 * time to re-estimate) + (0.037* average time spent to on board resources) + (0.008 * Unpredicted risk cropping up during development and execution of projects) + (0.022 * Number of change requests) – (0.033 * number of SME s) - (0.031 * Sign off delay in project initialization) + (0.152* Dependencies with customer on budget sign off) – (0.020 * legal dependencies) + (0.056 * design delay) + (0.007 *Delay during requirements gathering) –(0.011 * time spent to rectify errors after UAT). The p-value for all the 11 variables the significance value is less than the level of significance 5%. Variables which had p-value > level of significance are truncated in Table 2.

3.2 Descriptive Analytics using Factor Analysis

The list of 55 skills needed for a project manager during project planning and execution phase were identified through literature survey. The pivotal skills which a project manager must possess to have an optimum control on the project schedule were identified through the analysis. The component matrix at Table 3 at appendix gives the Factor analysis output and it has elucidated 16 skills which were highly loaded as five factors. These factors or factor labels represent the meaningful grouping of skills (Variables) which are highly loaded into relevant factor. Ability to select right estimation methodology[6] (0.912), Ability to do effort and schedule estimation (0.821), knowledge on agile estimation (0.712) are highly loaded into factor1. Ability to visualize all risk associated with a project (0.789).

Proper Risk, Contingency plans (0.762), Ability to mitigate risk before any catastrophe (0.618) are the key project risk management variables which are highly loaded into factor 2, which is project risk management. The project manager is expected to foresee all the key variables which influence the project. The project manager has to categorize the expected challenges and prioritize them. Effective manager crafts mitigation, contingency measures to arrest risks before this gets into catastrophe[7]. Project manager to have an absolute

Table 2. Coefficient table

Model	Unstandardized coefficients		Standardized coefficients	t	Sig.	95.0 % confidence interval for B	
	B	Std.Error	Beta			Lower Bound	Upper Bound
(Constant)	1.329	1.866		0.712	.000	1.222	1.911
Time to re-estimate	-0.007	0.021	-0.063	-0.335	.000	-0.091	-0.005
Average time spent to onboard resources	0.037	0.055	0.012	0.675	.001	0.012	0.123
Unpredicted risk cropping up during development & execution of projects	0.008	0.090	0.002	0.086	.000	0.005	0.103
Number of Change requests	0.022	0.062	0.007	0.045	.000	0.002	0.124
Number of SME s	-0.033	0.024	-0.167	-0.149	.001	-0.124	1.234
Sign off delay in project initialisationphase	-0.031	0.089	-0.014	-0.346	.000	-0.072	2.123
Dependencies with customer on budget sign off	0.152	0.384	0.002	-0.049	.000	0.002	1.923
Legal dependencies	-0.020	0.402	-0.006	0.685	0.000	-0.123	0.098
Design Delays	0.056	0.175	0.023	0.317	0.000	0.032	1.235
Delay during requirements gathering	0.007	0.015	0.002	0.477	0.000	0.002	4.325
Time spent to rectify errors after UAT	-0.011	0.057	-0.011	-0.195	0.000	-0.159	0.000

Table 3. Factor analysis component matrix

Skills needed for a project manager	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Ability to select appropriate estimation methodology for the nature of projects	**0.912**	0.021	0.267	0.723	0.215
Ability to do effort and schedule estimation	**0.821**	0.232	-0.103	-0.021	-0.021
Knowledge on agile estimation	**0.712**	0.127	0.222	0.012	-0.198
Ability to visualize all risk associated in a project	0.281	**0.789**	0.121	0.375	0.298
Proper Risk Contingency plans to avoid scope , schedule delays	-0.116	**0.762**	-0.067	0.347	-0.989
Ability to mitigate risk before it impacts schedule and scope	0.214	**0.618**	0.502	-0.129	0.281
Ability to ramp up and ramp down when needed	2.193	0.192	**0.886**	0.231	0.146
Ability to contain attrition in project team	0.372	-0.082	**0.875**	-0.12	0.201
Ability to maintain knowledge repository and critical incidents	0.568	0.568	**0.871**	0.398	-.027
Ability to prioritize and plan the critical activities	0.112	0.565	0.231	**0.827**	0.34
Ability to track and close the deliverables	-0.26	-0.017	0.325	**0.820**	0.512
Ability to use Microsoft project plan , project management techniques	0.167	0.435	0.425	**0.627**	-0.106
Ability to escalate when things go wrong	0.094	0.078	0.184	**0.464**	0.24
Ability to garner project requirements on time	0.200	0.163	0.034	**0.463**	0.231
Ability to control Change requests	0.121	-0.34	0.145	0.032	**0.742**
Ability to control Overruns	-0.787	0.144	0.025	-0.234	**0.728**

control over the attrition of resources which will have an impact on the project schedule. Ability to ramp up and ramp down when needed (0.886)[8], Ability to contain attrition in project team[9] (0.885) and Ability to maintain a knowledge repository and critical incidents (0.871) are the skills which are loaded into a factor 3 and this is named as people management. The risk of subject matter experts leaving the organization is a loss to the project as a contingency plan project managers are expected to design project knowledge repository where the incidents faced, challenges are to be recorded. Project managers are expected to encourage the team members for mentoring sessions. When required reverse – mentoring by the resources. Ability to prioritize and plan the critical activities (0.827), Agile planning (0.820), Ability to use Microsoft project plan, project management techniques, project management tools of the organization (0.627), Ability to elicit requirements (0.464), Ability to refine, validate and documenting requirements[10] (0.463) are loaded into Factor 4, which is requirement management and time management. Though there seems to be a thin layer of difference in business analyst and project manager in requirement management, project manager has the onus on proper elicitation, refining and documenting requirements of the customer. Ability to control fixed price projects overrun[11] (0.742), Ability to convert change requests into business opportunity (0.728). Overruns are common in fixed price projects which has a greater impact on project scoping. In Fixed price projects the requirements are frozen at the planning phase, but due to volatility in market space customers may ask for a change in the existing scope or changes in the modules developed. This will hit project budget, scoping and it will lead to estimation changes. An effective project manager will convert Change requests into billable opportunities to add more revenue. Table 4 provides the factor loadings in which, the 16 variables are categorized into 5 factor components

3.3 The Strength of Association between On-Time Delivery and Demographic Variables using Non-Parametric Test

Hypothesis 1:

H0: There is no significant relationship between certification held by managers and their ability to complete project on-time.

H1: There is a significant relationship between certification held by managers and their ability to complete project on-time.

Project Management Institute (PMI) is a large project management association which assesses the project management knowledge of project managers associated with all domains and industries. Project Management

Table 4. Factor loadings

Component	Factor Name (label)	Variables	Factor Loadings
1	Skill to estimate & re estimate	Ability to select appropriate estimation methodology for the nature of projects	0.912
		Ability to do effort and schedule estimation	0.821
		Knowledge on agile estimation	0.712
2	Managing Risks	Ability to visualize all risk associated in a project	0.789
		Proper Risk Contingency plans to avoid scope , schedule delays	0.762
		Ability to mitigate risk before it impacts schedule and scope	0.618
3	People management	Ability to forecast and ramp up and ramp down when needed	0.886
		Ability to contain attrition in project team	0.875
		Ability to maintain knowledge repository and critical incidents	0.871
4	Requirement management &Project Planning	Ability to prioritize and plan the critical activities	0.827
		Agile planning	0.820
		Ability to use Microsoft project plan , project management techniques , project management tools of the organization	0.627
		Ability to elicit requirements	0.464
		Ability to refine , validate and documenting requirements	0.463
5	Control over runs	Ability to control Fixed price projects overrun	0.742
		Ability to convert change requests into business opportunity.	0.728

Professional (PMP) is the flagship certification offered by the institute. Not only PMI but associations like CAPM, PRINCE 2 offers project management certification. These organizations possess their unique Body of Knowledge (BoK). The output of chi-square test mentioned in Table 5 provides an inference that there is no significant association between adherence to schedule of project delivery and certification possessed by them at 5% level of significance. The research cannot conclude, all certified managers will be able to complete the project on time.

Table 5. Project management certification vs project schedule

Pearson Chi-Square value	P-Value	Inference
1.021	0.821	At 95% confidence level null hypothesis is accepted

Hypothesis 2:

H0: There is no significant relationship between relevant years of experience and ability to complete project on time.

H1: There is a significant relationship between relevant years of experience and ability to complete project on time.

The chi-square test results from Table 6 prove that there is no relationship between years of experience of a project manager and their adherence to schedule. We cannot conclude that only experienced managers will be able to deliver with Zero or minimal deviation from the earmarked schedule during project planning.

Table 6. Project manager relevant years of experience vs project schedule

Pearson Chi-Square value	P-Value	Inference
11.193	0.211	At 95% confidence level null hypothesis is accepted

Hypothesis 3:

H0: There is no significant relationship between onshore, offshore, near-shore mode of delivery and ability to deliver project on-time.

H1: There is a significant relationship between onshore, offshore, near-shore mode of delivery and ability to delivery project on-time.

The place of operation by the project manager either from offshore or on-site at customer location will not have any significant association in the adherence to schedule. Table 7 substantiates the results. It cannot be concluded that projects which are executed by project managers at customer premise or offshore will always be completed within the timeline agreed.

Table 7. Project mode of operation vs on time delivery of project

Pearson Chi-Square value	P-Value	Inference
12.193	0.189	At 95% confidence level null hypothesis is accepted

Hypothesis 4:

H0: There is no significant relationship between qualification of an application development project manager and ability to complete project on time.

H1: There is a significant relationship between qualification of an application development project manager and ability to complete project on time.

The p-value 0.289 from Table 8 helps to prove that academic qualification will not have a significant contribution in the project deliverable. It is difficult to prove that project manager with specific qualification will have the ability to deliver in accordance to the schedule.

Table 8. Project manager's academic qualification vs on time delivery of project

Pearson Chi-Square value	P-Value	Inference
8.193	0.289	At 95% confidence level null hypothesis is accepted

3.4 Measure of Association between the Adherence to Project Schedule and Project Parameters using Non Parametric Test

Hypothesis 5:

H0: There is no significant relationship between methodologies adopted and schedule variance.

H1: There is a significant relationship between methodologies adopted and schedule variance.

Table 9. Project management methodologies vs project schedule

Pearson Chi-Square value	P-Value	Inference
1.329	0.001	At 95% confidence level null hypothesis is rejected.

The test of association at Table 9 proves that there is a significant association between project methodologies applied and schedule deviation. IT projects follow Agile, Waterfall, methods of project development methodology. P-value 0.001 which is mentioned in table 9 helps to reject null hypothesis as it is less than 5% level of significance.

Hypothesis 6:

H0: There is no significant relationship between re-use of software components and time to complete the project.

H1: There is a significant relationship between re-use of software components and time to complete the project.

The analysis concludes that there exists significant association between adopting reusable components and ability to deliver project within schedule. At 5% level of significance, the p-value is found to be 0.002 in the chi-square output Table 10.

Table 10. Re-use of project components vs project schedule

Pearson Chi-Square value	P-Value	Inference
7.129	0.002	At 95% confidence level null hypothesis is rejected

Hypothesis 7:

H0: There is no significant relationship between adherence to schedule and technology used in the project.

H1: There is a significant relationship between adherence to schedule and technology used in the project.

There is no significant relation between technology used in the project and completion of the project on time. Technology used to develop an application need not be a deciding factor for schedule variance. It is concluded from Table 11 that the null hypothesis has to be rejected at 5% level of significance.

Table 11. Technology used in project vs project schedule

Pearson Chi-Square value	P-Value	Inference
8.321	0.192	At 95% confidence level null hypothesis is accepted

4. Conclusion

The research output reveals that there is no significant association between project scheduling and demographic variables. It fails to prove that project managers having years of experience, higher academic qualification, having greater number of international certifications will able to effectively control project scheduling. However, an appropriate selection and use of project management

methodology for the customer requirement, optimum reuse of project components will create a space for a project manager to focus on critical deliverable. It is evident from research that technology used for software designs is not the determining factor of project schedule. Adherence to the project schedule will not depend on the technology used to develop software applications. It is the project manager who has mastery in the relevant required skills will able to control critical path and, deliver projects on time. Proficiency in relevant project management skills is inevitable for effective project scheduling. The factor analysis technique has resulted in sixteen skills which are categorized as five essential competencies. Estimate and re estimate, Managing Risks, People management, Requirement management and Project Planning, Control Change Requests are those five competencies. Multi-linear regression technique was attempted to estimate the dependent variable (Y) which is project schedule variance through 10 different independent variables (X_1 to X_{11}). Time to re-estimate(X_1), Average time spent to on-board resources (X_2), Unpredicted risk cropping up during development and execution of projects (X_3), Number of change requests (X_4), Number of subject matter experts (X_5), Sign off delays in project initialization phase (X_6), Dependencies with customer on budget sign off (X_7), Legal dependencies (X_8), Design delays (X_9), Delay during requirements gathering (X_{10}) and Time spent to rectify errors after UAT (X_{11}). The R-value of the multi linear equation R^2 value 81% defines the fitness of the model.

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