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Understanding software development productivity and its enhancing way with 'Software development efficiency calculation system'

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Abstract: In the information technologies era, the software development industry is become one of the 'Leading and Prominent Sector', that continuously aided the progressive path for society by various aspects like the technological developments and software sophistications but, itself strive for the productivity enhancements. Uncertainty is basic hurdles in enhancing way of software development productivity. To resolve uncertainties problem "Software Development Practitioner" needs to comprehend uncertainty aspect and demarcate its impact on software development productivity.The objective of this study is to plot a landscape on current knowledge, in the terms of productivity and find out its impact on the software development process. The goal of this paper is to rectify the present hurdles and hassles in development approaches by representing "software development efficiency calculation system".

Key Words: Software development productivity, Software development productivities measure and metrics, factor affecting productivity, Interlink factors of software development productivity, software development efficiency calculation system.

Introduction

Every software development industries prominent focus on successfully deliver very high quality software product. To achieve the success for any software development industries, there are multiple software development processes and models are available. We have many successful software development models and process even though availability of plenty of software development models and processes, many software projects got failed [46].

To overcome software projects failure problem, there is need to understand the software development productivity, its metrics,its measures, its impacting factor.

The researcher has made workaholic ardent efforts by way of distinctive permutations and combinations of variables in the Technological factors. Researcher has reviewed the relevant literature of the "software development productivity and analyze its affecting and interlink factor on basis of "Software development process efficiency calculation system".

This paper is organized in V sections. Section I deals with introduction of title of this paper. Section II deals with Software Development Productivity, its metric and measurement. In section III, it deals with methodology and observation. The section IV is lead with discussion supported by Implication, Evolution. The summary of study is depicted in section V.

Section II:

2.1. Software Development Productivity overview

Software Development Productivity is a most debatable concept science 1960. It comprised with three different things: Software, Development and Productivity. Productivity itself has its own definition. It is defined as "Productivity is activity to produce a product efficiently or successfully" [1,3,4,5,11,12, 25,29, 32, 34,35,37,40,43,44,45,46,47,48,49]. Victor L. Winter, Steve Roach and Greg Wickstrom defined Productivity as output divided by the effort required to produce that output [46].

In Economics perspective, the 'productivity' is defined as: "The rate of output per unit of input used especially in measuring capital growth and in assessing the effective use of labor materials and equipment." [11, 44, 45, 49]

Mostly, productivity is calculated in terms of 'efficiency' in which the production process transforms input into output. And efficiency can be expressed based on the utilization of technology to enhance its firm size and to reduce manufacturing cost along with other changes happened at organization level[1,2,3,4,5,6,11,12,14,19,24,25,29,33,34,35,37,40,43,44,45].

2.2. Software Metrics

2.2.1. Metrics:

- The IEEE [19] glossary defines: A **metric** as "a quantitative measure of the degree to which a system, component, or process possesses a given attribute."

2.2.2. Software Metrics:

Software metric is a measurement scale of 'software products, process, and resources with its results by various aspects like Size, Complexity, Quality, which is classify by Organization orientation [2, 18, 23, 25, and 29].

2.2.3. Types of Software Metrics:

Many software metrics now exist, the most common of these are as Size oriented metrics measures,Function-Oriented Metrics,Reconciling LOC and FP MetricsProcess Metrics: (Private, Public and Statistical software development process). Resource Metrics,Object-oriented Metrics,Project Metrics Use Case-Oriented Metrics, Webapp Project Metrics, Complexity Metrics, Software Quality Metrics[18, 23, 25, 29,30,32, 43,45,47,48].

2.3. Software development Productivity measurement

Measurement is the process by which numbers or symbols are assigned to attributes of entities in the real world in such a way as to describe them according to clearly defined unambiguous rules [18, 25, 29, 32, 45, and 47].

2.3.1. Principles of Software productivity Measurement:

With the consideration of published literatures [18, 25, 29, 32, 45, 49] the objectives or principles of measurement should beEstablished at the initial stage of development and before data collection begins. Each metric should be defined very clearly. Metrics should be measured on the basis of the valid concepts and principles for the estimated project.The defined metrics should be suitable for the project and its development processes.

2.3.2. Types and scales of Softwareproductivitymeasurement

There are three types of Software development productivity Measurement: Direct Measurement, Indirect Measurement, and Predictable Measurement [25, 29, 32, 42, 45, and 47]. The software productivity measurements scales are as Nominal Scale,Ordinal Scale,Interval Scale, Ratio Scale,Absolute Scale [25, 29]:

2.4. How to Measure Software development productivity:

Software development productivity measurement process should be the appropriate formulation of software measures and metrics for the estimated project under development. It should be used with mechanism that collects the data required to measure the formulated metrics with the help of mathematical tools. It should be helped to analysis, interpret the recommendation.

Along with software metrics, we can use software measurement toolsto measure the software productivity. As we have seen in software measurement section, Direct and Indirect Measurements can be significant tools for software productivity measurement (As per Wikipedia [48]). Using direct measures we can measure software internal attributes like Cost, efforts, LOC, speed and memory utilized by software product. And using Indirect Measure we can check Functionality, complexity and quality of any software product. These models are nothing but Indirect measures of software product and combination of various software metrics and complexity functions. Following table listed various Functionality, Complexity, and Quality models. (As per Wikipedia) [44].

Table 2.1: Functionality, Complexity, and Quality model

Functionality	Quality Model	Complexity
Suitability metrics	McCall's Model (1977)	Cyclomatic Complexity Measures
Accuracy metrics	Boehm's Quality Model (1978)	Halstead's Complexity Measures
Interoperability metrics	ISO 9126 Standard Quality Model (1986)	Function Point complexity measure: • Function point analysis • Mark II Function points analysis (MKIIFPA) • Use Case function Point analysis
Security metrics	FURPS (1987) /FURPS+ (2000)	System Complexity Measures
Functionality compliance metrics	Capability Maturity Model (CMM 1991)	
Other Quality module: (Ghezzi Model (1991), IEEE Model (1993), Dromey's Quality Model (1995), SATC's Quality Model (1996), Bansiya's QMOOD Model (2002) Kazman Model (2003), Aspect –Oriented Software Quality Model (2006), Component based Software development Quality Model (2008), DEQUALITE Model (2009), UML Conceptual Model (2010), Sehra S. K Model (2011), SQuaRE's Model (2011))		

2.5 Model used in Software development Productivity

We know that traditionally, software development productivity is calculated based on measurement of thousands of lines of code (kloc) written by software developers per week in hours [1,3,4,5,6,7,8,10, 15,20,21,25,29,30,31,32,36,39,41] and these number of lines of code is ultimately defines the size of software. So to calculate Software development productivity, size of the software as the output is mostly getting measured.

But how can we measure the number of screens used by Software product? Or the number of data elements? Even customer of software product can't have any concern 'how many line of code having by the software'. The customers are concern with cost and quality of the software. So productivity is not only line of code, so we must comprehend productivity with itsintrinsically linked with five factors in estimating software development projects: Schedule, Productivity, Cost, Resources, and Quality [27].

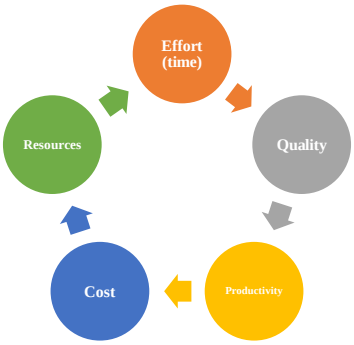


Figure: 2.1 Software development Productivity and it's interlink aspect

Likewise any other model, Software Development Productivity model also deals with input and output based on internal black box processing. On same line Aleixandre Bern and David N. Card recommended the Model of Software development productivity in terms of Project success and failure [7]. For the present research work, Model of Software development is customized and extended with three different modules and these modules are:

- **Input Module** : Cost & Client/User Requirements.
- **Processing Module** : Resource Efforts & Software Development Process
- **Output Module** : Software Product

Figure: 2.2 Model of Software development Productivity

Using this model, success or failure of any software product can be measured very easily but as

2.6 What are the factors affecting software development productivity (Project Success)?

In this contingency, there are numerous fruitful publications available till today. These publications explore the causes behind software development productivity trip down.By considering theses publication, software development process productivity is a direct function of individual ability, efforts, development type, its method and many more in list, which is influenced by various factors [15, 6, 9,10,11,12,18, 26,28,31,32,34,49]

These publications, most commonly pointed out 17th the factors that influence productivity, which in following table

Table 2.2: Factors that influence productivity		
Individual Ability	Appropriate Notation	Resigning Expectation
Management skill	Level of Technology	Systematic Approach
Required skill	Product complexity	Appropriate goal
Facility & resources	Available time	Require Reliability
Team Communication	Problem Understanding	Change control
Adequacy of Training	Stability Of requirement	

Last few years numerous studies reported many 'software development productivity influence factors identification frameworks' [5, 12, 15,34]. These frameworks usually focus on the 'project parameter management ability and 'development method's ability' aspects. With these frameworks, we are able to understand the role of 'software development method' and 'project parameters'to produce effectively 'the software development process productivity' and its interlinking factor.

Moreover, the level of project parametervariations at every occurrence and its management may be different according to the organization to organization. In that concern, it is very critical and crucial, but essential to comprehend the individual or the collective influence of the Software project, its development method and its management ability aspect.

Furthermore, in this contingency literate Chow, T., & Cao, D. (2008) [10] focuses five classifications of productivity influences twelve factors. These classifications are Organization, People, Project, Technical and Development process with factors [10]. If we club the classification with above factor 16 factor (except 'level of technology' because level of technology is pre-determined at the initial state of development) then it is very easy to understand its individual or collective influence over the productivity. Following figure shows factor and its individual or collective influence over the productivity.

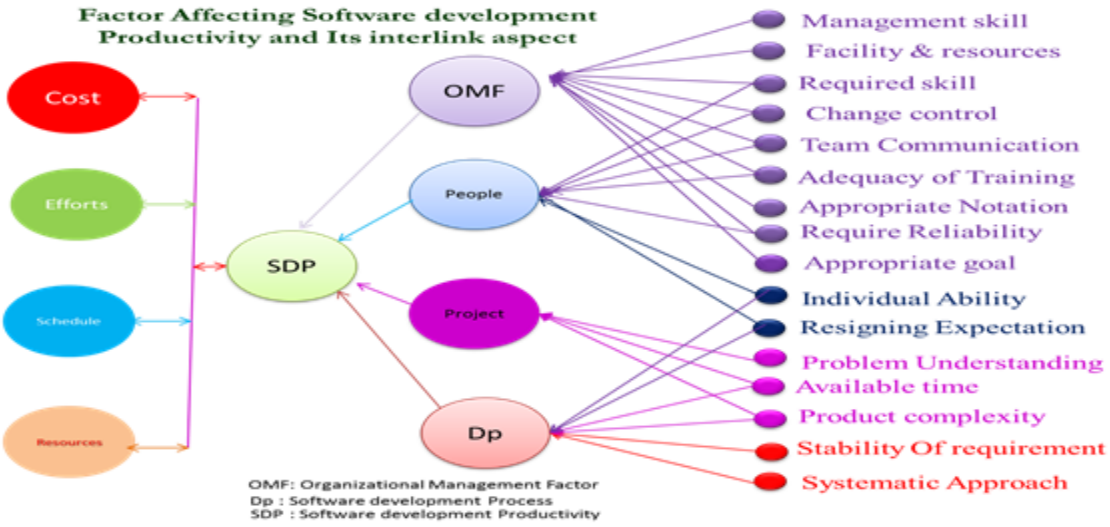


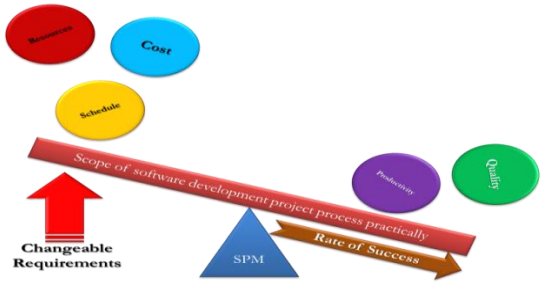
Figure 2.3: Factors that influence productivity

2.5 Constrain of software development productivity

As we know that there are several capable and very successive ways to measure software productivity, including 'Function Point Analysis', 'Cost Component Modeling', 'Cyclomatic Complexity', and 'Program performance metrics' that take into account the costs of executing and maintaining the software. Using these tools we are able to measure the productivity but, At the initial stage 'Development team' is responsible to set the 'Goal of project' and estimate these five factors as a target for a project to document as expected to reach the goal [27].

But as we know that software development process is nothing but research and development activity and which cannot escape innovation and creativity throughout the entire development process. As a result uncertainty may drop by various reasons at any time and this may not match to the predictions or estimation of several parameters made in the early software development phase. So it would hamper software development process productivity.

Table 2.3: Scope of software development process[Mike Dunham the 5 Variables of Project Estimation » http://sciodev.com/blog/the-5-variables-of-project-estimation/ by Mike Dunham | Aug 17, 2015 | Agile Methodology, Project Management Lase access 19 march 2017] [17]

Theoretically scope graphical representation	Practically scope graphical representation
	

We have great tool to develop and estimate software project in the scene of available development method or model and estimation or calculation productivity model but, achieving predictability is not so easy in changeable environment, it can be confirmed from the various variables of the software crisis experienced as on date.

To tackle such changeable environment is big constrain for software development practitioner. Though we have great tool in the sense of agile practice driven methods for embrace the change but, with consideration of the various survey reports, software development industry is still facing the problem of failure.

2.6 Challenges of software development productivity

Globalization and technical revaluation raises several challenges for software development productivity in various aspects like (Business sector, requirements volatility, application language, hardware platform, tool use, quality requirements,…etc.) For the present work different failure factors are considered which are discussed in NATO conference till today by various blog, publication and survey report [6,10,32,33,35,38,39], It is presented similar failure aspect and factors like over run, budget and low acceptance with common reasons that can be classified into 'Hardware' and 'Software failures'. In this study, we especially concentrate on 'Software failures' in software development productivity perspective.

Moreover Literate "Walt Scacchi 1994" [47] and literate "Boehm 1987" [5] suggested strategies for reducing the influence of these factors for improving software productivity. To implement such strategies there **is need to comprehend accurate scope of project and software development method's effectiveness in software development process for produce productivity effectively by reducing wasteful steps and eliminating rigid activity**

So it is necessity to utilize in suitable opportune for enhance software development productivity. But, in that concern, there is not much more attention reported or received so far

Opportunity to enhance productivity on the basis of Literate "Walt Scacchi 1994" [47] and literate "Boehm 1987" [5] suggested strategies.

As knowledge cannot be seen, but one can be observe its effects. Software development is itself a very complex process which requires knowledge of software development as well as knowledge of the domain for which the software is developed. Hence knowledge is defined as 'a capacity to act'. To resolve problem of failure, in this work we try to attempt a solution by reviewing uncertainties impact on software development productivity with following aspect.

a) Software development methodologies effectiveness in uncertainty
b) Uncertainty Impact on development productivity
c) Rate of Change in environment impact on productivity
d) Duration impact on Project
e) Project Planning cost impact on Project

Section III: Methodology

In this work, we consider over quantitative solution by prototype model "Software development methodologies process efficiency calculation system" on the basis of literature review and publish literature "An Economic Model of Software Development Approaches" (by Honorable Literate Dr. Li Liu, Dr. Xiaoying Kong, Dr. Jing Chen) with inspiration of "The Analytical Theory of Project Investment" (by Honorable Literate "Jing Chen &TsviVinig" in Sprouts ISSN1535-6078) [7, 8]. Based on this model, a prototype module is constructed by using platform: Visual Basic 6.0, Ms Access 7, Fusion Chart (Trial version). This module is implemented only for projected study purpose.

Field specification of the Software development methodologies process efficiency calculation system

Table 2.4 Field specification Table

Field Specification			
ono	Observation Number	Rate Change	Change rate (Team , development environment, Market Position)
Commodity	Project estimated Cost	Uncertainty	Project Aspect
Duration	Project Development time	PPc	Project Planning cost
pdc	Project development cost	Popceff	Process Effectiveness

Test parameter:a) Software development methodologieseffectiveness

b) Projects requirement Uncertainty Impact on development productivity

c) Rate of Change in Development environment impact on productivity

d) Duration impact on Project

e) Project Planning cost impact on Project

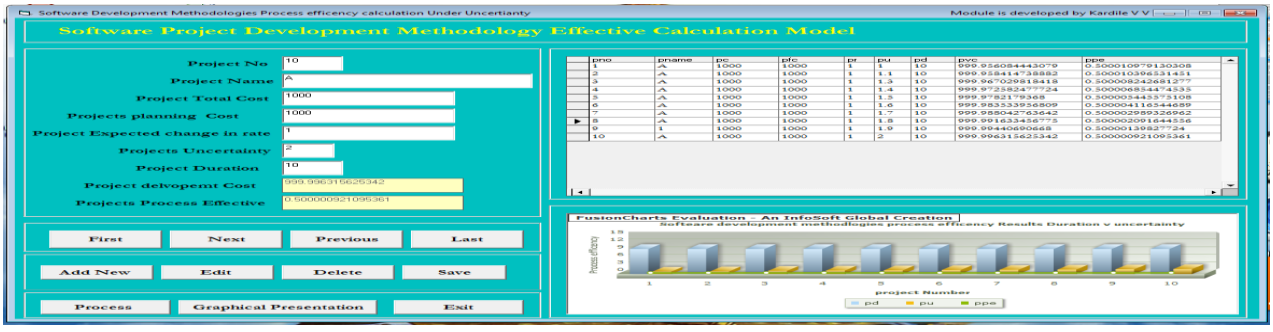


Figure 2.4: Output screen of Software development methodologies Process efficiency calculation system

Assumption

- Plan driven method life cycle following development process is having max project planning cost then agile driven method life cycle.

- Uncertainty is consider as uncertainty in requirement specification of project
- Rate in change is consider as change in Development environment

Note:Unfortunately, we are not able to collect and produce actual Software Development Organisations Data. So here we take dummy data for show impact of Productivity influence aspects describe the above mention reference.

Observation

Software development efficiency calculation system's results as per test parameter

a) Software development methods effectiveness in uncertainty

Table 2.5 :Project Planning cost impact on Project calculation table for hypothesis 2

Ono	commodity	Rate change	uncertainty	duration	pfc	d1	d2	Ke^{-rt}	pvc	Proceff
1	1000	1	1	10	1000	4.74341649	1.58113883	0.04539993	999.9561337	0.50001097
2	1000	1	1.1	10	900	4.6443396	1.165834178	0.040859937	999.9624126	0.52632620
3	1000	1	1.2	10	800	4.59140147	0.796668276	0.036319944	999.9692083	0.55556506
4	1000	1	1.3	10	700	4.5747637	0.463802737	0.031779951	999.9760502	0.58824358
5	1000	1	1.4	10	600	4.58774787	0.160559142	0.027239958	999.9824024	0.62500687
6	1000	1	1.5	10	500	4.62602161	-0.117394882	0.022699965	999.9878469	0.66667207
7	1000	1	1.6	10	400	4.68734352	-0.372300734	0.018159972	999.9921723	0.71428971
8	1000	1	1.7	10	300	4.77205795	-0.603814076	0.013619979	999.9953702	0.76923351
9	1000	1	1.8	10	200	4.88562024	-0.806479552	0.009079986	999.9975778	0.83333502
10	1000	1	1.9	10	100	5.05175272	-0.95657483	0.004539993	999.9990121	0.90909173
11	1000	1	2	10	50	5.21708335	-1.107471968	0.002269996	999.9996048	0.95238131
12	1000	1	2.1	10	25	5.38172667	-1.259056415	0.001134998	999.9998451	0.97560990
13	1000	1	2.2	10	10	5.57785104	-1.379159817	0.000453999	999.9999497	0.99009906
15	1000	1	2.3	10	5	5.73999006	-1.533248559	0.000227	999.9999811	0.99502489
16	1000	1	2.4	10	1	6.02252556	-1.566940825	4.53999E-05	999.9999965	0.99900100
17	1000	1	2.5	10	0.5	6.1792047	-1.726489449	2.27E-05	999.9999987	0.99950025
18	1000	1	2.6	10	0.25	6.33599421	-1.885927709	1.135E-05	999.9999995	0.99975006

b)Uncertainty Impact on development productivity

Table 2.6.: Uncertainty Impact on Project calculation table

ono	commodity	Rate change	uncertainty	duration	PPc	d1	d2	Ke^{-rt}	pdc	Proceff
1	1000	1	1	10	1000	4.74341649	1.58113883	0.04539993	999.9561337	0.50001097
2	1000	1	1.1	10	1000	4.61405059	1.13554516	0.04539993	999.9584401	0.50001039
3	1000	1	1.2	10	1000	4.53259798	0.737864787	0.04539993	999.9621425	0.50000946
4	1000	1	1.3	10	1000	4.48800176	0.377040798	0.04539993	999.9670348	0.50000824
5	1000	1	1.4	10	1000	4.47236412	0.045175395	0.04539993	999.9726141	0.50000685
6	1000	1	1.5	10	1000	4.47989335	-0.263523138	0.04539993	999.9782843	0.50000543
7	1000	1	1.6	10	1000	4.50624567	-0.553398591	0.04539993	999.983535	0.50000412
8	1000	1	1.7	10	1000	4.54809934	-0.827772682	0.04539993	999.9880363	0.50000299
9	1000	1	1.8	10	1000	4.60287082	-1.089228972	0.04539993	999.9916501	0.50000209
10	1000	1	1.9	10	1000	4.66852044	-1.339807114	0.04539993	999.9943901	0.50000140

c) Rate of Change in development environment impact on productivity

Table2.7 :Rate of Change in environment Impact on Project calculation table										
ono	commodity	Rate change	uncertainty	duration	PPc	d1	d2	Ke^{-rt}	pdc	Proceff
1	1000	1	1	10	1000	4.74341649	1.58113883	0.04539993	999.9561337	0.50001097
2	1000	1.1	1	10	1000	5.05964426	1.897366596	0.016701701	999.9835708	0.50000411
3	1000	1.2	1	10	1000	5.37587202	2.213594362	0.006144212	999.9939002	0.50000152
4	1000	1.3	1	10	1000	5.69209979	2.529822128	0.002260329	999.9977463	0.50000056
5	1000	1.4	1	10	1000	6.00832755	2.846049894	0.000831529	999.9991694	0.50000021
6	1000	1.5	1	10	1000	6.32455532	3.16227766	0.000305902	999.9996942	0.50000008
7	1000	1.6	1	10	1000	6.64078309	3.478505426	0.000112535	999.9998875	0.50000003
8	1000	1.7	1	10	1000	6.95701085	3.794733192	4.13994E-05	999.9999586	0.50000001
9	1000	1.8	1	10	1000	7.27323862	4.110960958	1.523E-05	999.9999848	0.50000000
10	1000	1.9	1	10	1000	7.58946638	4.427188724	5.6028E-06	999.9999944	0.50000000

d) Duration impact on Project

Table2.8:Duration impact on Project calculation table										
pno	commodity	Rate change	uncertainty	duration	PPc	d1	d2	Ke^{-rt}	pdc	Proceff
1	1000	1	1	10	1000	4.74341649	1.58113883	0.04539993	999.9561337	0.50001097
2	1000	1	1	9	1000	4.5	1.5	0.123409804	999.8814372	0.50002964
3	1000	1	1	8	1000	4.24264069	1.414213562	0.335462628	999.6798761	0.50008004
4	1000	1	1	7	1000	3.96862697	1.322875656	0.911881966	999.1367229	0.50021591
5	1000	1	1	6	1000	3.67423461	1.224744871	2.478752177	997.6754609	0.50058181
6	1000	1	1	5	1000	3.35410197	1.118033989	6.737946999	993.7518392	0.50156694
7	1000	1	1	4	1000	3	1	18.31563889	983.2403354	0.50422532
8	1000	1	1	3	1000	2.59807621	0.866025404	49.78706837	955.1463067	0.51147067
9	1000	1	1	2	1000	2.12132034	0.707106781	135.3352832	880.1639324	0.53186852
10	1000	1	1	1	1000	1.5	0.5	367.8794412	678.8179749	0.59565719

e) Project Planning cost impact on Project

Table2.9: Project Planning cost impact on Project calculation table										
ono	commodity	Rate change	uncertainty	duration	PCc	d1	d2	Ke^{-rt}	pdc	Proceff
1	1000	1	1	10	1000	4.74341649	1.58113883	0.04539993	999.9561337	0.50001097
2	1000	1	1	10	900	4.77673441	1.614456751	0.040859937	999.9604236	0.52632675
3	1000	1	1	10	800	4.81398068	1.651703017	0.036319944	999.9647308	0.55556644
4	1000	1	1	10	700	4.85620701	1.693929351	0.031779951	999.9690563	0.58824600
5	1000	1	1	10	600	4.90495374	1.742676076	0.027239958	999.9734013	0.62501039
6	1000	1	1	10	500	4.96260887	1.800331215	0.022699965	999.9777673	0.66667655
7	1000	1	1	10	400	5.03317306	1.870895401	0.018159972	999.982156	0.71429482
8	1000	1	1	10	300	5.12414612	1.96186846	0.013619979	999.9865696	0.76923872
9	1000	1	1	10	200	5.25236545	2.090087786	0.009079986	999.9910111	0.83333958
10	1000	1	1	10	100	5.47155783	2.30928017	0.004539993	999.9954852	0.90909464

Section IV

Evaluation: Result by exploiting above "Software development methodologies efficiency calculation system" specifies that 'level of uncertainty','duration or development time', 'and change rate development environment' and the 'level of planned cost of projected project or module'have a playing vital role at process effectiveness. Process effectiveness directly impact over project Success or Productivity.

Implications: 'Uncertainty level', 'development time', 'change rate' and 'project or module planned cost level'are sketch line of control for process efficiency. It is directly indicated to "There is relationship between the above mention factor and the process efficiency significantly".With this consideration to enhance software development productivity software development practitioner need to utilize suitable development approach as per projects requirement specification uncertainty and development environments change rate level .

Section V

Summary

Software Development productivity defined as an output of 'development process' and 'human efforts' required to produce that output within time , cost and with customer acceptable format. Software productivity rates are always varies across the software development industry.With this work we focus on to copperhead software development productivity with its metrics and measures, along with we try to explore how and which factors are affecting software project to be failed and successful.

This work summarizes with 'Success and Failure is not accident'. Failure and Success provide different perspectives on improvement. Failure teach us 'what will not to do in future', whereas success explore us 'what should be done again'. So, to get the success there is need to study the success story of these approaches and explore the way through that development practitioner able to enhance success rate or productivity that should directly positive impact on enhancement of social and economical aspect of society.

This work recommended there is a need to systematic review the other consulting published publication for more comprehends root causes of software development productivities failures.

This work conveys to software development practitioners to comprehend uncertainty and its sources before allocation of software development method for development to enhance productivity.

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