Productivity Improvement Measures in Engineering Services Industry: An analysis using DMAIC tools

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Abstract—This paper presents usage of DMAIC approach of Six Sigma process & its tools to identify various root causes which influences Productivity in Engineering Services Industry. Difference of actual and estimated effort was studied for variety of tasks over specified period to identify root cause for the benefit of revisiting of estimated effort for the future tasks. The improvement was to contain effort variance of around 5% for repeated tasks and of around 15% for new kind of tasks. The paper further studied about productivity and learning curve enumeration of effort after implementation of selected Six Sigma tools. Prioritized root causes which affect effort variation are considered for Design of Experiments with two levels each. Analysis of results yielded basic outcomes which needed further attention in Engineering Service Industry.

Keywords—Productivity, Learning curve, Six Sigma, DMAIC, Effort variation.

I. Introduction

Productivity is commonly defined as a ratio of a volume measure of output to a volume measure of input use [1]. In other words: “Productivity is a gauge of the relationship between production of goods and services and the factors of production used (labour, machinery, raw materials and so on). It is the current hot word in service industries to tackle cost & quality pressure in Globalized environment. Over the period, every consumers/customers demand either reduction in cost or value added services in commoditized service industry, like knowledge-based service industries. If we cannot measure performance, we cannot manage and improve it. But measuring performance, especially in the service industry, is far from easy. Despite this, we should measure what is measurable; if something is not measurable, we should try to make it so. Efficiency measures based on the output/input ratio can be supplemented with effectiveness measures in index form.

Bascially, there are two main approaches to productivity measurement: partial factor productivity measurement and multifactor productivity measurement. The former is a ratio of the output to one of the factor inputs, such as labour productivity or capital productivity. However, partial productivity measures are not comprehensive and, if used alone, can be misleading. Multifactor productivity measurement, on the other hand, considers output in relation to multifactor inputs. A good example is total factor productivity, which measures the synergy and efficiency of utilizing both labour and capital inputs.

According to Drucker [2], “Quality in a product or service is not what the supplier puts in. It is what the customer gets out and is willing to pay for”. Costs on Training & Orientation are spent by the organizations in order to achieve maximum quality output from human resource. In spite of effort spent to improve productivity, there are certain cases where measurement of productivity is in subjective manner like most of service industry. Tracking of Estimation & Actual effort spent out of human knowledge on processes are tried usually.

II. Problem Statement

In a typical knowledge-based service industry, customer inputs are processed for pre-defined outputs by following defined realization process. Customer is directly ready to pay for actual value added services. Knowledge improvement of Human resources is part of strategy of the industry. It is obvious that customers expectation on reduction of cycle time or cost over the period irrespective economic situation. So, Productivity and Learning capability demonstrated by resources are important to monitor on regular basis. Customer will be satisfied as long as the outputs are delivered on or before agreed deadline with required quality. It is essential to estimate the effort required before start of the activity in order to control execution. It includes the impact of cost also.

Effort variance is defined as difference between Actual effort spent on the task and Estimated effort of the task. For the sake of quick analysis, Effort variance is assumed to be absolute values.

An analysis of typical “Project-A” of knowledge-based industry for a year is shown in Fig. 1.

Objectives of the study are,

• To find various causes for effort variance in knowledge-based industry systematically,
• To quantify and prioritize root causes for effort variance,
• To suggest possible solutions for improvement concerning the nature of work.

Fig. 1. Polar plot of Effort variance of Project-A
III. Methodology

In spite of limited implementation of Six sigma approach to services industry than manufacturing, Ayon [4] highlights three major factors for its success.

Namely, 1) Critical success factors, 2) Critical to quality characteristics & 3) Key performance indicators. Effective utilization and control of Effort variance in service industry is equally important for above three. Above approach is planned in the current research based on literature review [5].

Process Understanding- DMAIC variant of Six sigma approach suggests usage of following tools “Project charter, Thought process mapping, SIPOC & CTQ’s”.

Relationship matrix SIPOC => Suppliers > Inputs > Detailed process > Outputs > Customers are analyzed as shown below to understand different processes, inputs and outputs involved in a typical task covered under “Project-A”.

While a plan is to start some process management or improvement activity, high-level understanding of the scope of the process is important. A SIPOC Process Definition helps the Process Owner and those working on the process to agree the boundaries of what they will be working on. It provides a structured way to discuss the process and get consensus on what it involves before rushing off and drawing process maps. Based on the information from SIPOC and Voice-of-Customer, CTQ > Critical-to-Quality parameters are defined as below.

<table>
<thead>
<tr>
<th>Need</th>
<th>Driver</th>
<th>CTQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction of Effort Deviation</td>
<td>Optimum utilization of Resources</td>
<td>Productivity-Utilization</td>
</tr>
<tr>
<td>Actual Reporting hours needed for costing</td>
<td>Billable cost</td>
<td></td>
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<tr>
<td>Delay in Delivery</td>
<td>Customer Satisfaction</td>
<td>On-Time Delivery</td>
</tr>
<tr>
<td>Realistic estimation for future projects</td>
<td>Cost estimation to new customers</td>
<td></td>
</tr>
</tbody>
</table>

EV-L = abs( Estimation effort – Execution effort – Review effort ) 

--- Eqn. (1)

Raw Data Analysis - Process capability compares the output of an in-control process to the specification limits by using capability indices. A process where almost all the measurements fall inside the specification limits is a capable process.

From measurements, Current sigma level is 2.6

From Fig. 8, Cpk=0.14 meaning that process is not mature enough to identify and control. Sample Standard deviation is higher than Sample Mean. Immediate plan is to improve Sigma level to 4. The aim is to satisfy most of the customers by having Cpk=1.33 [4 sigma] or higher.

Root Cause Analysis - Root cause analysis (RCA) is a process [7] designed for use in investigating and categorizing the root causes of events with safety, health, environmental, quality, reliability and production impacts.

Following data are extracted from measurement to understand current “Effort variance” of each tasks: “Task name, Owner, Estimated effort, Execution effort, Reviewer, Review effort”

Fig. 2. Planned methodology

Fig. 3. Identified CTQ’s

Fig. 4. Process capability chart

Fig. 5. Pareto analysis of Root causes
Development of Experiments - Although above identified factors are influencing “Effort variance” of each of the task, their relationship of “Effort variance” is important to quantify the impact. Based on quantum and direction of impact, further steps can be planned for improvement. Development of Experiments (DoE) is used with above 4 factors and 2 levels (i.e low & high variations) to ascertain the output of the process “Effort variance”.

Besides, a full factorial DoE is chosen. A “full factorial” DoE studies the response of every combination of factors and its levels, and an attempt to zone in on a region of values where the process is close to optimization.

No. of experiments for Full factorial DoE is decided by,

\[ \# \text{experiments} = \text{Levels}^{\text{Factor}} \]

--- Eqn. (2)

So, 16 experiments are conducted on same Project-A with defined levels on each factor.

Based on collected information “Effort variance” of each experiment, Main effects plots are plotted to understand direction and quantum of its relations on output.

Fig. 6. Main effects plot on Response

IV. Results Discussion

The research concentrated on reduction of effort variation, in order to define and evolve a suitable methodology for knowledge based industries. Either positive or negative effort variation affects profitability, reputation to customer, exploitation of resources. All of them are recognized as bad. However, Effort variation is directly depending on two different factors viz. estimated effort and actual effort. Interpretation of RCA and DoE used in above research revealed the controllability of actual effort, but not on estimated effort. Current research only concentrated on factors influencing on actual effort, not on estimated effort. So, it is equally important to factor in all influencing parameters for estimation for complete understanding of effort variation.

Main effects plot of full factorial DoE (Fig. 12) reveals that,

1. Importance of experience gained over knowledge processing, Maturity of knowledge acquired for next level are not properly documented and not reused at later stage for similar activities. So, there were several re-inventions of wheels over period.

2. Knowledge arouse out of repeated nature of tasks are well preserved and reused, may be by same engineer. Whilst repeated nature of tasks, good control over effort variation is evident.

3. No influence of hardware used to save planned effort, which is another important investigation area for effort estimation.

Productivity measurement in knowledge based industries is not straight forward unlike production industries. Aggregate productivity calculation will not lead to identification of improvement measures. Competency based productivity measures are un-avoidable.

Learning curves [8] enable managers to project the production effort / cost per unit for any cumulative production quantity. In knowledge based industries, production quantity can be equated to delivered tasks. Ratio of estimation effort to actual effort can be compared between consecutive tasks and plotted in learning curves. Learning curve will become a leading indicator than lagging indicator by productivity calculation.

V. Conclusion

Productivity improvement, its calculations are subjective matter in knowledge based industries unless all possible influencing factors for effort estimation and actual effort tracking are systematically and statistically quantified. Six sigma tools provide overall insight about various quality tools that could be used promptly in quantification of effort estimation and actual effort tracking. Re-usability of gained knowledge, extensive usage of communication & knowledge repositories will improve productivity in knowledge based industries. Current research opened some insights on process output and its influencing factors. Further deep researches with wide range of levels on each factor which affect estimated effort are recommended. Well planned and tested mechanism on actual effort tracking is also required in order to ascertain quantum of effort variance. Each kind of activities like CAD conversion, CAE simulation, Product benchmarking, Reliability analysis require individual productivity measure.

References


ii. Drucker, Peter, “Innovation and entrepreneurship”.


