Impact of End User Development Technical and Environmental Factors on Software Cost

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Abstract

Software project manager is confronted with the dilemma of accurate estimation at the very beginning of the project. Quantitative estimates are required at the early stages of development. Software cost estimation is accounted as an important factor while making estimations in Software Engineering. There is no simple way to make an accurate estimate of the effort required to develop software systems incorporating EUD/EUP because of many reasons like unclear user requirements, lack of knowledge on new technology, changing technology requirements and unavailability of solid information. End users were significantly more satisfied with applications they had developed themselves and which possess quality parameters as per their requirements. If the software incorporates End user development features then additional effort may be required in development and designing the EUD features. This paper discusses the impact of end user quality parameters on the overall effort of the software development. It includes a comparative analysis of UCP with my published model AUCP in terms of effort. It also ponders cases where End user development should be positively considered as an additional cost driver for effort estimation.

Keywords: Use Case Point Method (UCP); Advance Use Case Point Method (AUCP); End User Development (EUD), Human Computer Interaction (HCI); End User Computing (EUC); Technical Complexity Factors (TCF); Environmental Complexity Factors (ECF).

1. Introduction

Boehm predicted in 1995 that by 2005, there would be 55 million programmers in United States alone [3]. Christopher Scaffidi, Mary Shaw, Brad Myers of Carnegie Mellon University elaborated the perception of Boehm and estimated that in 2012, there will be 90 million end-user programmers in American workplaces. Of these, they anticipated that over 55 million may use spreadsheets or databases, whereas over 13 million will describe themselves as programmers. Thus, the potential number of end-user programmers throughout the world will significantly surpass the population who assess themselves as programmers [4].

According to Sutcliffe End User Software development EUD essentially outsources development effort to the end user. There is always some effort required to learn a EUD tool, the users’ motivation depends on their confidence that it will empower their work, save time on the job or raise productivity. This study defines costs as the sum of:

- Technical cost: the price of the technology and the effort to install it
- Learning cost: the time taken to understand the technology
- Development cost: the effort to develop applications using the technology
- Test and debugging cost: the time taken to verify the system

The first and second costs are incurred once during acquisition, whereas the third and fourth are incurred every time an application is developed.

Benefits which may be implicit or explicit can be viewed as:

- Functionality delivered by the technology
- Flexibility to respond to new requirements
- Usability of applications produced
- Overall quality of the applications produced

2. Advance use case method (AUCP)

End User Development (EUD) is the demand of today as end user wants to do some level of programming to satisfy their requirements and to customize the software as per their needs. EUD is an overlapping of two concepts, end-user programming (EUP) and end-user software engineering (EUSE) [12]. End-user programming (EUP) enables end users to create their own programs (Ko et al 2011). The difference between EUP and EUD is that EUD methods, techniques, and tools span the entire software development lifecycle, which includes creating, modifying and extending software as per their requirements.

EUSE is a comparatively new subgroup of EUD that began about a decade ago. Its emphasis is on the quality of the software end users create, modify, or extend. Its research focuses on methods, techniques, and tools that promote the quality of such software. End-user software engineering is a highly integrated and incremental concept of software engineering support for end users [13]. To provide quality to the product developed by end users for their own usage also requires some additional cost.

End user takes some effort in programming as to satisfy their requirements. A strong facilitator for end users is their own domain knowledge [11]. Additional Technical and environmental factors...
are provided to the end-user for development cost. This additional EUD costing is provided in AUCP which is an extension of UCP. The additional technical and environmental cost drivers considered while providing end user development features in software are given below in Table 1 and table 2.

3. Steps of UCP method

Use Case Point Method (UCP) is calculated as follows:

a) Unadjusted Use Case Weight (UUCW) calculation.
b) Unadjusted Actor Weight (UAW) calculation.
c) Estimating Technical Complexity Factor (TCF)
d) Estimating Environment Complexity Factor (ECF)
e) Computing Unadjusted Use Case Points (UUCP), where:

\[ UUCP = UAW + UUCW. \]
f) Computing Complexity Factor, where:

\[ TCF = 0.6 + (0.01 \times TF) \]
\[ ECF = 1.4 + (-0.03 \times EF) \]
g) Finding Use Case Point (UCP), where:

\[ UCP = UUCP \times TCF \times ECF \]
h) Identify the End User Development features required by the customers.

4. Steps of AUCP method

Advance Use Case Point Method (AUCP) is an extension of Use Case Point Method (UCP) and is further calculated as follows [5]:

1. The purpose is to study the impact on the development cost as the number and type of quality parameters required in EUD products will decide the actual effort. The quality parameters to be included in EUD include additional effort categorized as EUD_Technical Complexity Factors and EUD_Environmental complexity Factors. Let us take a case study.

This study was based on six government website development project without considering EUD features. The project was given ID from A to H. As the project developed by a small team with a number of personnel with 3 to 5 people [6], UCP was calculated and is given below.

<table>
<thead>
<tr>
<th>No</th>
<th>Project ID</th>
<th>UUCP</th>
<th>TCF</th>
<th>ECF</th>
<th>UCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>480</td>
<td>1.015</td>
<td>0.89</td>
<td>433.61</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>287</td>
<td>1.055</td>
<td>0.65</td>
<td>196.81</td>
</tr>
<tr>
<td>3</td>
<td>C</td>
<td>279</td>
<td>1.005</td>
<td>0.995</td>
<td>278.99</td>
</tr>
<tr>
<td>4</td>
<td>D</td>
<td>292</td>
<td>1.045</td>
<td>0.875</td>
<td>267</td>
</tr>
<tr>
<td>5</td>
<td>E</td>
<td>322</td>
<td>1.025</td>
<td>1.055</td>
<td>348.2</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>307</td>
<td>1.035</td>
<td>0.695</td>
<td>220.83</td>
</tr>
</tbody>
</table>

Let us incorporate varying percentage of EUD features in above six projects. Then we will calculate effort using AUCP method and study the difference between the UCP and AUCP.

The purpose is to study the impact on the development cost as the number of EUD_Technical factors and EUD_Environmental factors required will be different for every project. We will divide the overall end user development requirements in four categories. These categories are:

**Category 1:** When the requirement of end users EUD_TF and EUD_EF is in the range of less than 25%.

**Category 2:** When the requirement of end users EUD_TF and EUD_EF is in the range of 25-50% i.e. greater than 25% and less than 50%.

**Category 3:** When the requirement of end users EUD_TF and EUD_EF is in the range of 50-75% i.e. greater than 50% and less than 75%.

**Category 4:** When the requirement of end users EUD_TF and EUD_EF is in the range of more than 75%.

<table>
<thead>
<tr>
<th>Fi</th>
<th>EUD_ENVIRONMENTAL FACTORS</th>
<th>Weight</th>
<th>Fi</th>
<th>EUD_ENVIRONMENTAL FACTORS</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>Level of EUP</td>
<td>1.4</td>
<td>F5</td>
<td>Training &amp; learning Time</td>
<td>1.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Constraint for end user</td>
<td></td>
</tr>
<tr>
<td>F2</td>
<td>End User Computing Capability</td>
<td>0.25</td>
<td>F6</td>
<td>Reliability of End User</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Code</td>
<td></td>
</tr>
<tr>
<td>F3</td>
<td>Ease of Use &amp; Feedback</td>
<td>1.2</td>
<td>F7</td>
<td>End User Storage Constraint</td>
<td>1.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F4</td>
<td>Inbuilt System Assistance</td>
<td>1.25</td>
<td>F8</td>
<td>Risk Factors</td>
<td>1.12</td>
</tr>
</tbody>
</table>

If EUD_Technical factors (EUD_TF) is applicable for the particular module it will be rated as 1 else 0 and multiply it with weights of EUD_TF. Take the summation of all factors.

c) Calculate EUD Technical Complexity Factor,

\[ EUD_{TCF} = 0.6 + (0.01 \times EUD_{TF}) \]
d) Calculate EUD Environmental Complexity Factor,

\[ EUD_{ECF} = 1.4 + (0.03 \times EUD_{EF}) \]
e) Calculation of AUCP. Advance use case point is equal to the product of Use case point, end user development technical complexity factor and end user development environmental factors.

\[ AUCP = UCP \times (EUD_{TCF} \times EUD_{ECF}) \]
Category 4: When the requirement of end users EUD_TF and EUD_EF is in the range of 75-100% i.e., greater than 75% and less than 100%. We will study the impact of all four categories on the overall development effort one by one.

Table 4: (Varying EUD_TF as per above categories)

<table>
<thead>
<tr>
<th>EUD_TECHNICAL FACTORS</th>
<th>Proj &lt;= 25% EUD_TF</th>
<th>25%&lt;Proj &lt;= 50% EUD_TF</th>
<th>50%&lt;Proj &lt;=75% EUD_TF</th>
<th>75%&lt;Proj &lt;= 100% EUD_TF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weight P1 V1 P2 V2 P3 V3</td>
<td>P4 V4 P5 V5 P6 V6</td>
<td>P7 V7 P8 V8 P9 V9</td>
<td>P10 V10 P11 V11 P12 V12</td>
</tr>
<tr>
<td>T1 Inbuilt system assistance</td>
<td>1.2 1 1.2</td>
<td>0 1.2 0 0 1 1.2</td>
<td>1 1.2 1 1.2 1.2 0</td>
<td>0 1 1.2 1 1.2</td>
</tr>
<tr>
<td>T2 Creating reusable codes</td>
<td>1.4 0 0</td>
<td>0 0 0 0</td>
<td>1.4 0 0 0</td>
<td>1.4 0 0 0 0</td>
</tr>
<tr>
<td>T3 Sharing reusable code</td>
<td>1 0</td>
<td>0 0</td>
<td>0 1.1 1 1</td>
<td>0</td>
</tr>
<tr>
<td>T4 Easy &amp; understandable codes</td>
<td>1.3 1.3</td>
<td>0 0 0</td>
<td>0 0 1 1.3 1.3</td>
<td>1 0 1.3 0</td>
</tr>
<tr>
<td>T5 Security features in codes for more control by end</td>
<td>1.12 1.12</td>
<td>0 0 1.12</td>
<td>1.12 0 0 1.12</td>
<td>0</td>
</tr>
<tr>
<td>T6 Authentication features</td>
<td>1.3</td>
<td>0 0 0</td>
<td>0 0 1.3</td>
<td>0 0 1.3 1.3</td>
</tr>
<tr>
<td>T7 Inbuilt feedback about the correctness</td>
<td>1.2</td>
<td>0 0</td>
<td>0 0 0</td>
<td>0 1.2 0 0</td>
</tr>
<tr>
<td>T8 Testable codes</td>
<td>1.4 1.4</td>
<td>0 0 0</td>
<td>0 0 0 0</td>
<td>0 1.4 1.4 0</td>
</tr>
<tr>
<td>T9 Tools for analyzing by debugging</td>
<td>1.2</td>
<td>0 0 0</td>
<td>0 0 1.2</td>
<td>0 0 0 0</td>
</tr>
<tr>
<td>T10 Error detection tools</td>
<td>1.3</td>
<td>0 0</td>
<td>0 0 1.3</td>
<td>0 0 1.3 1.3</td>
</tr>
<tr>
<td>T11 Online help availability</td>
<td>1.11</td>
<td>0 0 0</td>
<td>0 0 0 0</td>
<td>0 0 0 0</td>
</tr>
<tr>
<td>T12 Self-efficiency</td>
<td>1.20</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>1.2 0 0 1.2</td>
</tr>
<tr>
<td>T13 Perceived ease of use: Apart from extrinsic factors</td>
<td>1</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
</tr>
<tr>
<td>T14 Perceived usefulness</td>
<td>1.2</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 1.2 1.2</td>
</tr>
<tr>
<td>T15 Flexible codes</td>
<td>1.25</td>
<td>0 0 0</td>
<td>0 0</td>
<td>1.25 0</td>
</tr>
<tr>
<td>T16 Scalability features</td>
<td>1.2</td>
<td>0 0 0</td>
<td>0 0</td>
<td>0 0 0 0</td>
</tr>
<tr>
<td>T17 End user training</td>
<td>1.5</td>
<td>0 0</td>
<td>1 1.5 1.5</td>
<td>1.5 0</td>
</tr>
<tr>
<td>T18 Ease of Maintenance</td>
<td>1.14</td>
<td>0 0</td>
<td>0 0 0</td>
<td>0 0 0 0</td>
</tr>
</tbody>
</table>

Summation of EUD_Technical factors

| 4 | 3.8 | 2 | 2.7 | 4 | 4.9 | 9 | 11.1 | 5 | 6.3 | 7 | 7.8 | 11 | 13.8 | 13 | 16.1 | 21 | 22.6 | 24 | 27.5 | 26 | 29.0 |

Table 5: (Varying EUD_EF as Per Varying Requirements)
Applying the following formula for calculating AUCP as per the percentage of EUD requirements we get the values of Table 6. Table 7, Table 8, Table 9. EUD_TCF, EUD_ECF and finally AUCP are calculated using the given formulas:

\[
EUD_{\text{TCF}} = 0.6 + (0.01 \times EUD_{\text{TF}})
\]

\[
EUD_{\text{ECF}} = 1.4 + (0.03 \times EUD_{\text{EF}})
\]

\[
AUCP = UCP \times (EUD_{\text{TCF}} \times EUD_{\text{ECF}})
\]

Analysis of the result of AUCP will be done in comparison of UCP to study the impact on AUCP as the percentage of EUD_TCF and EUD_ECF requirement is varying.

1) Category 1: Analysis of UCP and AUCP when EUD TF <= 25% and EUD EF <= 25%

Table 6: (EUD EF < 25% & EUD TF < 25%)

2) Category 2: Analysis of UCP and AUCP when 25% < EUD TF <= 50% and 25% < EUD EF <= 50%

Table 7: (25% < EUD EF <= 50% & 25% < EUD TF <= 50%)

Fig. 1: (Graph of UCP & AUCP When EUD Requirements <= 25%).

Fig. 2: (Graph of UCP & AUCP When EUD Requirements In Between 25% To 50%).
Percentagewise analysis of EUD technical and environmental factors as per all four above mentioned categories is done in Table 10.

6. Result analysis

It has been observed from Table 6 that if the EUD requirements of the users are in between 25% to 50% then in approximately 30% of cases there may be decrease in development effort by 2.5% and in 70% of cases it may get increased by up to 9%. In such cases it is up to the Strategic Management and Project Manager to decide whether to include EUD factors as an additional cost driver while computing effort. It can be avoided also in case of small projects.

This has been also observed from the computed values of UCP and AUCP from Table 9 that if the EUD requirements of the users is in between 50% to 75% then in 100% of cases the development effort will get increased by 14% to 16%. Hence in such cases EUD factors must be taken as an additional cost driver while calculating development effort.

It has been observed from the computed values of UCP and AUCP from Table 8 that if the EUD requirement of the users is in between 75% to 100% then in 100% of cases the development effort will get increased by up to 9%. In such cases it is up to the Strategic Management and Project Manager to decide whether to include EUD factors as an additional cost driver while calculating development effort.

It has been found from the computed values of UCP and AUCP table 7 that if the EUD requirements of the users are in between 25% to 50% then in approximately 30% of cases there may be decrease in development effort by 2.5% and in 70% of cases it may get increased by up to 9%. In such cases it is up to the Strategic Management and Project Manager to decide whether to include EUD factors as an additional cost driver while computing effort. It can be avoided also in case of small projects.

This has been also observed from the computed values of UCP and AUCP of Table 8 that if the EUD requirement of the users is in between 50% to 75% then in 100% of cases the development effort will get increased by 14% to 16%. Hence in such cases EUD factors must be taken as an additional cost driver while calculating development effort.

It has been observed from the computed values of UCP and AUCP from Table 9 that if the EUD requirement of the users is in between 75% to 100% then in 100% of cases the development effort will get increased by up to 9%. Since the increase in effort is quite high hence in such cases to avoid the uncertainty in estimation it should be mandatory to include it as an additional cost driver.

7. Conclusion

EUD development factors should be considered as an additional cost driver while estimating the overall cost of the software project. From the above analysis it is clear that the percentage of EUD quality features to be incorporated also have an impact on the effort and cost. We can say that if the percentage of EUD_TF and EUD_EF are less than 50% then we do not need to consider...
EUD as an additional cost driver as it also decreases the effort as some development effort is outsourced to the End user. Only in the cases where requirement of EUD_TF and EUD_EF is more than 50% then it becomes compulsory to consider it as an additional cost driver as it may increase the overall project cost by 19 to 33%. Hence it should not be neglected. A detailed analysis of EUD features required to be incorporated within system is essential for more accurate estimation.

References