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Research paper

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 there 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 comfort. 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:
a) TCF = 0.6 + (0.01* TF)
b) ECF = 1.4 + (-0.03 * EF)
g) Finding Use Case Point (UCP), where:
a) UCP = UUCP * TCF * ECF [1]
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]: T1 to T18 EUD_Technical factors (EUD_TF) are identified and weights are assigned to all the factors as displayed in table.1 after thorough analysis of its impact on the overall development effort [14]. These 18 EUD_TF are related with technical aspect of End User development.

Table 1: (EUD_TF with Associated Weights)

EUD_Ti	EUD_TECHNICAL FACTORS	Weight	EUD_Ti	EUD_TECHNICAL FACTORS	Weight
T1	Inbuilt system assistance	1.2	T10	Error detection tools	1.3
T2	Creating reusable codes	1.4	T11	online help availability	1.11
T3	Sharing reusable code	1	T12	Self – efficiency	1.2
T4	Easy & understandable codes	1.3	T13	Perceived ease of use: Apart from extrinsic motivation	1
T5	Security features in codes for more control by end users	1.12	T14	Perceived usefulness	1.2
T6	Authentication features	1.3	T15	Flexible codes	1.25
T7	Inbuilt feedback about the correctness	1.2	T16	Scalability features	1.2
T8	Testable codes	1.4	T17	End user training	**1.5**
T9	Tools for analyzing by debugging	1.2	T18	Ease of Maintenance	**1.14**

a) 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.
b) F1 to F8 EUD_ENVIRONMENTAL FACTORS are identified and weights are assigned to them as in table 2 after thorough analysis of its impact on the development.

Table 2: (EUD_TF with Associated Weights)

Fi	EUD_ENVIRONMENTAL FACTORS	Weight	Fi	EUD_ENVIRONMENTAL FACTORS	Weight
F1	Content Level of EUP	1.4	F5	Training & learning Time Constraint for end user	1.12
F2	End User Computing Capability	0.25	F6	Reliability of End User Code	1.2
F3	Ease of Use & Feedback	1.2	F7	End User Storage Constraint	1.02
F4	Inbuilt System Assistance for EUP	1.25	F8	Risk Factors	1.12

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 * EUD_TF)
d) Calculate EUD Environmental Complexity Factor, EUD_ECF = 1.4 + (0.03 * 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 X (EUD_TCF X EUD_ECF)

5. Impact of end user development factors UCP vs AUCP

EUD definitely increases the effort and 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 3: (UCP of 6 Websites)

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

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 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)

EUD_TECHNICAL FACTORS																												
			Proj <= 25% EUD_TF						25%<Proj <= 50% EUD_TF						50%<Proj <=75% EUD_TF						75%<Proj <= 100% EUD_TF					
EUD_TF	EUD_TECHNICAL FACTORS	Weight	P1	V1	P2	V2	P3	V3	P4	V4	P5	V5	P6	V6	P7	V7	P8	V8	P9	V9	P10	V10	P11	V11	P12	V12
T1	Inbuilt system assistance	1.2	1	1.2	1	1.2	0	0	1	1.2	0	0	1	1.2	1	1.2	1	1.2	1	1.2	0	0	1	1.2	1	1.2
T2	Creating reusable codes	1.4	0	0	0	0	0	0	1	1.4	0	0	0	0	1	1.4	0	0	0	0	1	1.4	1	1.4	1	1.4
T3	Sharing reusable code	1	0	0	0	0	1	1	1	1	1	1	0	0	1	1	0	0	0	0	1	1	1	1	1	1
T4	Easy & understandable codes	1.3	1	1.3	0	0	0	0	0	0	1	1.3	1	1.3	0	0	1	1.3	0	0	1	1.3	1	1.3	1	1.3
T5	Security features in codes for more control by end	1.12	1	1.12	0	0	1	1.12	1	1.12	0	0	1	1.12	0	0	1	1.12	1	1.12	0	0	1	1.12	1	1.12
T6	Authentication features	1.3	0	0	0	0	0	0	1	1.3	0	0	1	1.3	1	1.3	1	1.3	1	1.3	1	1.3	1	1.3	1	1.3
T7	Inbuilt feedback about the correctness	1.2	0	0	0	0	0	0	0	0	1	1.2	0	0	0	0	1	1.2	1	1.2	1	1.2	1	1.2	1	1.2
T8	Testable codes	1.4	1	1.4	0	0	0	0	0	0	0	0	0	0	1	1.4	1	1.4	0	0	1	1.4	0	0	1	1.4
T9	Tools for analyzing by debugging	1.2	0	0	0	0	0	0	1	1.2	0	0	0	0	0	0	1	1.2	1	1.2	1	1.2	1	1.2	1	1.2
T10	Error detection tools	1.3	0	0	0	0	1	1.3	0	0	1	1.3	0	0	1	1.3	1	1.3	0	0	1	1.3	0	0	1	1.3
T11	online help availability	1.11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1.11	1	1.11	1	1.11	1	1.11
T12	Self – efficiency	1.20	0	0	0	0	0	0	1	1.2	0	0	1	1.2	1	1.2	0	0	0	0	0	0	1	1.2	1	1.2
T13	Perceived ease of use: Apart from extrinsic	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
T14	Perceived usefulness	1.2	0	0	0	0	0	0	0	0	1	1.2	1	1.2	1	1.2	1	1.2	1	1.2	1	1.2	1	1.2	1	1.2
T15	Flexible codes	1.25	0	0	0	0	0	0	1	1.25	0	0	0	0	1	1.25	0	0	1	1.25	1	1.25	1	1.25	1	1.25
T16	Scalability features	1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1.2	1	1.2	1	1.2	1	1.2	1	1.2
T17	End user training	**1.5**	0	0	1	1.5	1	1.5	1	1.5	0	0	1	1.5	1	1.5	1	1.5	0	0	0	0	1	1.5	1	1.5
T18	Ease of Maintenance	**1.14**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1.14	1	1.14	1	1.14	1	1.14	1	1.14
Summation of EUD_Technical factor			4	5.0	2	2.7	4	4.9	9	11.2	5	6.0	7	8.8	11	13.8	13	16.1	11	12.9	14	17.0	16	19.3	18	22.0

Table 5: (Varying EUD_EF as Per Varying Requirements)

EUD_ENVIRONMENTAL FACTORS																									
			Proj <= 25% EUD_EF						25%<Proj <= 50% EUD_EF						50%<Proj <=75% EUD_EF						75%<Proj <= 100% EUD_EF					
Fi	EUD_Environmental factors	Weight	P1	V1	P2	V2	P3	V3	P4	V4	P5	V5	P6	V6	P7	V7	P8	V8	P9	V9	P10	V10	P11	V11	P12	V12
F1	Content Level of EUP	1.4	1	1.4	0	0.0	0	0.0	1	1.4	0	0.0	0	0.0	1	1.4	0	0.0	1	1.4	1	1.4	1	1.4	1	1.4
F2	End User Computing Capability	0.25	0	0.0	0	0.0	1	0.3	0	0.0	1	0.3	1	0.3	0	0.0	1	0.3	0	0.0	1	0.3	1	0.3	1	0.3
F3	Ease of Use & Feedback	1.2	1	1.2	0	0.0	0	0.0	1	1.2	0	0.0	0	0.0	1	1.2	0	0.0	1	1.2	1	1.2	1	1.2	1	1.2
F4	Inbuilt System Assistance for EUP	1.25	0	0.0	1	1.3	0	0.0	0	0.0	1	1.3	1	1.3	1	1.3	1	1.3	0	0.0	1	1.3	1	1.3	1	1.3
F5	Training & learning Time Constraint for end user	1.12	0	0.0	0	0.0	0	0.0	1	1.1	0	0.0	1	1.1	1	1.1	1	1.1	1	1.1	1	1.1	0	0.0	1	1.1
F6	Reliability of End User Code	1.2	0	0.0	1	1.2	0	0.0	0	0.0	1	1.2	1	1.2	0	0.0	1	1.2	1	1.2	1	1.2	1	1.2	1	1.2
F7	End User Storage Constraint	1.02	0	0.0	0	0.0	0	0.0	1	1.0	0	0.0	0	0.0	1	1.0	1	1.0	1	1.0	0	0.0	1	1.0	1	1.0
F8	Risk Factors	1.12	0	0.0	0	0.0	1	1.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	1.1	0	0.0	1	1.1	1	1.1
Summation of EUD_Environmental factors			2	2.6	2	2.5	2	1.4	4	4.7	3	2.7	4	3.8	5	6.0	5	4.8	6	7.1	6	6.4	7	7.4	8	8.6

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_TCF = 0.6 + (0.01 * EUD_TF)

EUD_ECF = 1.4 + (0.03 * EUD_EF)

AUCP = UCP X (EUD_TCF X EUD_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%)

No	Project ID	UUCP	TCF	ECF	UCP	Project ID	EUD_TF	EUD_TCF	EUD_EF	EUD_ECF	AUCP	AUCP-UCP	% INCREASE
1	A	480	1.02	0.89	433.61	P1	5.00	0.65	2.60	1.48	416.57	-17.04	-3.93
2	B	287	1.06	0.65	196.81	P2	3.00	0.63	2.50	1.48	182.89	-13.92	-7.08
3	C	279	1.01	1.00	278.99	P3	5.20	0.65	1.40	1.44	262.30	-16.69	-5.98
4	D	292	1.05	0.88	267.00	P1	5.00	0.65	2.60	1.48	256.51	-10.49	-3.93
5	E	322	1.03	1.06	348.20	P2	3.00	0.63	2.50	1.48	323.56	-24.64	-7.08
6	F	307	1.04	0.70	220.83	P3	5.20	0.65	1.40	1.44	207.62	-13.21	-5.98

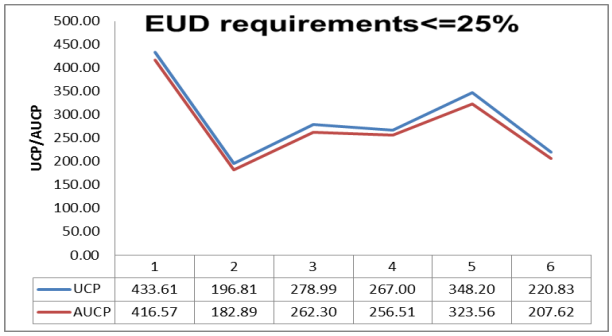

Fig. 1: (Graph of UCP & AUCP When EUD Requirements<=25%).

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%)

No	Project ID	UUCP	TCF	ECF	UCP	Project ID	EUD_TF	EUD_TCF	EUD_EF	EUD_ECF	AUCP	AUCP-UCP	% INCREASE
1	A	480	1.02	0.89	433.6	P1	10.60	0.71	4.70	1.54	471.74	38.1	8.79
2	B	287	1.06	0.65	196.8	P2	5.80	0.66	2.70	1.48	191.79	-5.0	-2.55
3	C	279	1.01	1	279	P3	8.60	0.69	3.80	1.51	289.76	10.8	3.86
4	D	292	1.05	0.88	267	P1	10.60	0.71	4.70	1.54	290.48	23.5	8.79
5	E	322	1.03	1.06	348.2	P2	5.80	0.66	2.70	1.48	339.32	-8.9	-2.55
6	F	307	1.04	0.7	220.8	P3	8.60	0.69	3.80	1.51	229.35	8.5	3.86

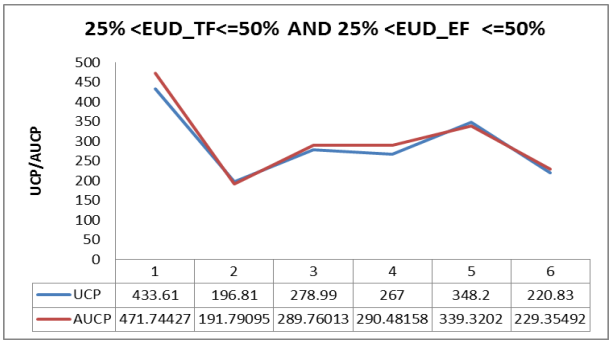

Fig. 2: (Graph of UCP & AUCP When EUD Requirements In Between 25% To 50%).

3) Category 3: ANALYSIS OF UCP AND AUCP WHEN 50% <EUD_TF<=75% AND 50% <EUD_EF <=75%

Table 8: (50 %< EUD_EF<=75% & 50 %< EUD_TF<=75%)

No	Project ID	UUCP	TCF	ECF	UCP	Project ID	EUD_TF	EUD_TCF	EUD_EF	EUD_ECF	AUCP	AUCP-UCP	% INCREASE
1	A	480	1.02	0.89	433.61	P1	12.40	0.72	6.00	1.58	496.02	62.41	14.39
2	B	287	1.06	0.65	196.81	P2	15.30	0.75	4.80	1.54	228.82	32.01	16.26
3	C	279	1.01	1.00	278.99	P3	12.00	0.72	7.10	1.61	324.01	45.02	16.14
4	D	292	1.05	0.88	267.00	P1	12.40	0.72	6.00	1.58	305.43	38.43	14.39
5	E	322	1.03	1.06	348.20	P2	15.30	0.75	4.80	1.54	404.83	56.63	16.26
6	F	307	1.04	0.70	220.83	P3	12.00	0.72	7.10	1.61	256.46	35.63	16.14

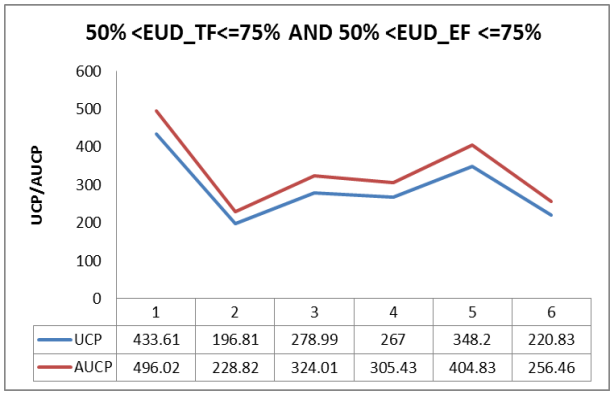

Fig. 3: (Graph of UCP & AUCP when EUD Requirements In Between 50% To 75%).

4) Category 4: ANALYSIS OF UCP AND AUCP WHEN 75% <EUD_TF<=100% AND 75% <EUD_EF <=100%

Table 9: (25 %< EUD_EF<=50% & 25 %< EUD_TF<=50%)

No	Project ID	UUCP	TCF	ECF	UCP	Project ID	EUD_TF	EUD_TCF	EUD_EF	EUD_ECF	AUCP	AUCP-UCP	% INCREASE
1	A	480	1.02	0.89	433.61	P1	14.70	0.75	6.40	1.59	515.66	82.0	18.92
2	B	287	1.06	0.65	196.81	P2	17.70	0.78	7.40	1.62	248.04	51.2	26.03
3	C	279	1.01	1.00	278.99	P3	20.10	0.80	8.60	1.66	370.51	91.5	32.81
4	D	292	1.05	0.88	267.00	P1	14.70	0.75	6.40	1.59	317.52	50.5	18.92
5	E	322	1.03	1.06	348.20	P2	17.70	0.78	7.40	1.62	438.83	90.6	26.03
6	F	307	1.04	0.70	220.83	P3	20.10	0.80	8.60	1.66	293.28	72.4	32.81

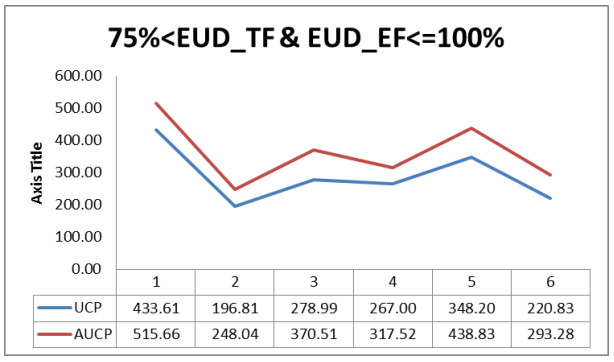

Fig. 4: (Graph of UCP & AUCP when EUD Requirements in between 75% to 100%).

6. Result analysis

Percentagewise analysis of EUD technical and environmental factors as per all four above mentioned categories is done in table.10.

Table 10: (Comparative % Wise Analysis of EUD Factors)

Required EUD factors			EUD factors<25%			25%<EUD factors<=50%			50%<EUD factors<=75%			50%<EUD factors<=100%		
No	Project ID	UCP	AUCP 25%	AUCP-UCP	% INCREASE	AUCP 50%	AUCP-UCP	% INCREASE	AUCP 75%	AUCP-UCP	% INCREASE	AUCP100%	AUCP-UCP	% INCREASE
1	A	433.61	416.57	-17.04	-3.93	471.74	38.13	8.79	496.02	62.41	14.39	515.66	82.05	18.92
2	B	196.81	182.89	-13.92	-7.08	191.79	-5.02	-2.55	228.82	32.01	16.26	248.04	51.23	26.03
3	C	278.99	262.30	-16.69	-5.98	289.76	10.77	3.86	324.01	45.02	16.14	370.51	91.52	32.81
4	D	267.00	256.51	-10.49	-3.93	290.48	23.48	8.79	305.43	38.43	14.39	317.52	50.52	18.92
5	E	348.20	323.56	-24.64	-7.08	339.32	-8.88	-2.55	404.83	56.63	16.26	438.83	90.63	26.03
6	F	220.83	207.62	-13.21	-5.98	229.35	8.52	3.86	256.46	35.63	16.14	293.28	72.45	32.81

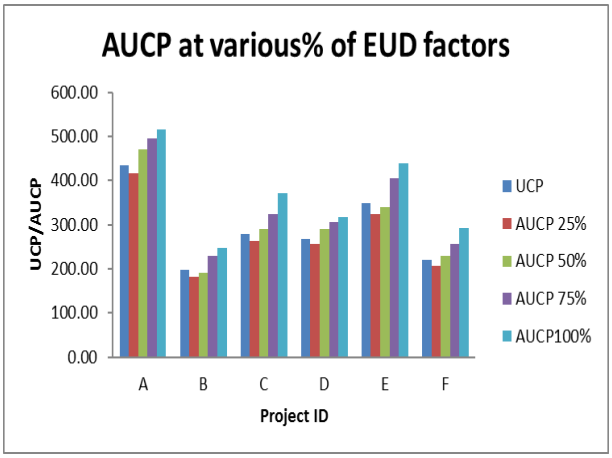

Fig. 5: (Graph of Comparative percentage Wise Analysis of EUD Factors).

It has been observed from table 6 that if the EUD requirements of the users are very less i.e. less than or equal to 25% the computed values of UCP and AUCP shows that as the computational ability is given to end users it is actually decreasing the overall development effort from 3% to up to 7%. In such cases we can easily ignore the EUD factors while costing. As at times it might decrease the overall cost by 3% to 5% which can be considered as negligible.

It has been found from the computed values of UCP and AUCP from 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 19% to 33%. 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.

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