

# Amplification of the COCOMO II regarding Offshore Software Projects

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**Abstract.** Offshore software development projects comprise of several critical success factors which may jeopardize the success of such a collaborative development project. We therefore require methods that will help in reducing the risk in such offshore outsourcing software development project. This article introduces a Study based on COCOMO II which can be used to estimate the effort of globally distributed projects. This will enable a more accurate estimation than when using the current traditional software development projects methods. It will also help predict the outcome of such collaborative project by reducing the overall risk.

**Keywords:** COCOMO II, risk management, offshoring, cost estimation

## 1 Introduction

Offshoring has become a key software development strategy. Statistics indicate that its impact is inevitable and constantly increasing. This is steered by the need to reduce costs, decrease marketing time and the rigidity of resources. Various studies show that approximately 40 percent of offshore projects fail to deliver the expected benefits. There is a huge gap between targets and realisation. This is caused by the lack of theoretical basics and the ignorance of the risks linked to an outsourcing software development project. An offshore development project comprises of targets and complications that even experienced managers aren't aware of. Our goal is to give them a method that they may use to estimate the additional cost sources and effort of offshore software development so as to be in a position to estimate the effort more realistically. A procedure based on COCOMO II will be introduced with a view to estimating the effort of globally distributed projects. We will therefore be in a position to give a more accurate estimation than when using the traditional software development methods.

The paper is structured as follows. Section 2 gives an overview of the driving force, the state-of-the-art and integrates our approach. Section 3 introduces the existing COCOMO II. Section 4 presents the approach in addition to further details about the additional cost factors arise from offshore outsourcing software development projects. The new approach examines the COCOMO II basing itself on geographically distributed software development and further amplifies this with specific functionalities for cost estimation. Section 5 discusses the benefits and limitations of this approach and presents key questions for future research.

## 2 Motivation

An organization outsources the software development when it wholly or partially contracts out the software development activities to another organization. This is referred to as “offshore outsourcing of a software development project” when one of the companies is remotely located. The “global software development”, also “global software work” or “(geographically) distributed software development”, implies that the development activities are located in various parts of the World. The diverse distribution of the activities all over the world causes a number of unanswered questions about realisation and successful execution.

Companies have progressively been offshoring since the early 21<sup>st</sup> century This trend promises to grow. Project management plays a crucial role in IT-Offshoring, because it helps a company develop and implement its global offshoring strategies so as to eventually become more competitive in the global market. Good project effort estimation is a key factor to the success of each and every IT-Offshoring project. Accurate effort estimation is the main challenge. Estimation of project costs and project duration is an inherent problem of in software engineering business. IT project managers will hardly give estimations because they know that almost every global software development project conceals an array of additional estimation sources, which should be considered when calculating the effort. There are additional risk factors in conjunction with the company’s capabilities. These should be taken considered so as to give a realistic approximation of the project effort. Global software development brings more effort into the software development because communication and coordination effort is considerably larger than in a distributed project [1], [2], [3].

The cost estimation in software development projects is always complex, because the effort of the task is very difficult to quantify. Experts too can’t easily quantify this; there exists more than 500 software metrics that may be used to gauge the quantitative aspect of a software development project [4]. The two well known and most widely used are: the source lines of code (SLOC) [5] and the function points [6]. They are the foundation of cost and effort estimation systems. But the two metrics are seemingly insufficient in the estimation of the effort of software projects .This is because coding is more complex than the number of program lines or program functions. Cost estimation models are thus consequently essential. A lot of these models were developed and published in the seventies and eighties, e.g. the System

of Evaluation and Estimation of Resources - Software Estimating Model (SEER-SEM), a commercial system [7] and the Constructive Cost Model (COCOMO), an open cost model, in which all details are published. COCOMO is used in estimating the number of person months needed to develop software product. Every detail inclusive the time and effort equation with every assumption and every definition has been included.

We decided to use the COCOMO approach as our basis to generate an estimation model of global software development because the COCOMO is “[...] the most established software cost estimation model [...]” [8]. We adopt the model with the *Effort Multipliers (EM)* so as to give more accurate effort estimation than the existing methods that are used in conventional software development projects. This helps us predict the outcome of collaborative project and eventually reduce the overall risk.

### 3 COCOMO

Its theoretical basics were designed in the seventies by Barry Boehm so as to establish better and more realistic estimations for software projects [8]. The first version (COCOMO 81) was introduced in 1981 by Barry Boehm. The purpose of this model was: “[...] to equip you to deal with software engineering problems from the perspective of human economics as well as from the programming perspective.” [5]. Software engineering world has in the meantime changed creating a need to modify the original COCOMO model to the COCOMO II [9], which was published in 2000. This is a widely accepted public cost model [10]. COCOMO II is based on more than 250 projects and is calibrated with 161 actual project data [8]. It can be calibrated from the organization’s historical data. Its factors can be taken as standard values in case there is no data available for the parameter objective impact analysis.

Here is an overview of the model<sup>1</sup>. The basic version of COCOMO estimates the effort of a software development project in person month (PM)<sup>2</sup>. The COCOMO II enables the use of source code lines and function points as reference parameters for the calculation of the projects’ *Size (S)*. It can be used to determine the actual size of the project by algorithmic methods as well as historical data or expert opinions. There are different COCOMO-Models.

Namely,

- Early Prototyping Model
- Early Design Model
- Post-Architecture Mode depending on the project development stage.

We will focus on the post-architecture model which is a detailed widely used..It provides a deep insight into the cost driver, but it depends on a clear definition of the life-cycle and software architecture. The effort equation of COCOMO II is:

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<sup>1</sup> Please refer to [BABC00] for further information

<sup>2</sup> One person month is standard and is set to 152 working hours.

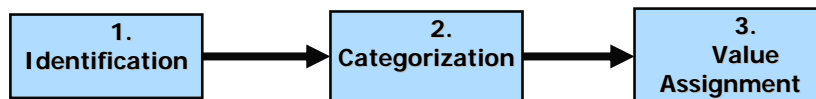
$$PM = A * Size^E * \prod_{i=1}^{17} EM_i \quad (1)$$

*PM*: Person Month  
*A*: Constant (2.94 for COCOMOII.2000)  
*Size*: KSLOC<sub>3</sub> (SLOC, Function Points)  
*E*: Scale Factors  
*EM*: Effort Multipliers

The constant *A* is a calibration factor that portrays the dimension of the productivity. The standard value for COCOMO II is 2.94. But it should be calibrated with the aid of the company's historical project data. The scale factors (*E*) depends on five factors: development flexibility, architecture/ risk resolution, team cohesion, process maturity and precedencedness. Scale factors exponentially influence the effort of a software development project. These factors are cost drivers as well as the effort multipliers (*EM*). Cost drivers are characteristics of the software development. They have an impact on the effort of the software development project. Effort Multipliers are classified into categories ranging from very low to extra high<sup>4</sup>. Numerical values have been assigned to these categories. They are quantified with a numerical value from the COCOMO-tabulations [9]. The nominal value of a cost driver is 1.0., A value higher than the nominal value increases the estimated effort, whereas a value smaller than the nominal value decreases the estimated effort. 17 *EM* exist within the post architecture model (cp. table 1) [9].

## 4 Amplification

The amplification of COCOMO II has been carried out in three steps as illustrated in Figure 1:



**Figure 1.** The amplification of the COCOMO II

The first step identifies the additional cost drivers for distributed development projects. Current literature additionally links Multiple success factors and risks to the software offshore outsourcing [3], [11], [12], [13].

We additionally performed qualitative survey based on semi-structured interviews with some 22 interviewees from renown German software producers. This research

<sup>3</sup>Kilo Source Lines of Code; Kilo = 1.000

<sup>4</sup>The *EM* must not be in all categories.

was explorative and it was designed to gather knowledge about the cost drivers of offshore outsourcing projects. We applied the grounded theory, which was invented by [14] to identify the major risks. These risks are the cost drivers of offshore outsourcing software development projects. We then analyzed the existing cost drivers of the COCOMO II so as to check their relevance to the global software development. We found several factors which are affected by offshore outsourcing software development as depicted in Table 1:

Effort Multipliers	Scale Factors
Product attributes: DOCU	PREC, TEAM, PMAT
Personal attributes: ACAP, PCAP, PCON, APEX, PLEX,	
Project attributes: SITE	

**Table 1.** COCOMO II cost drivers affected by global software engineering [22]

**Scale Factors like** Precedentedness (PREC), Team Cohesion (TEAM) and Process Maturity (PMAT) are affected. Precedentedness portrays the experience of a software developer to the present project context. This factor considerably varies between the offshore provider and the onshore buyer. The same applies to the factors like Team Cohesion and Process Maturity. The first indicates the ability of the team to work as a team. This factor is logically affected by offshore outsourcing development. The latter quantifies the company’s process maturity

The linear **Effort Multipliers** of the existing COCOMO II are also affected by offshore outsourcing software development. Only Documentation Match to Life-Cycle (DOCU) is affected in this the product attributes group.[15] argues that different developer teams have differing documenting effort notwithstanding the fact that the document has the same standard. The effort hence changes if the development teams are distributed. The platform attributes are not affected at all since they are determined by the specific product requirements. All cost drivers in the personal attributes group are affected by the offshore outsourcing software development project. Analyst Capability (ACAP) and Programmer Capability (PCAP) quantify the competence of the analysts, e.g., the software engineers. The employees’ competence definitely varies since they have different experience, education and settings. The Personnel Continuity (PCON) evaluates the staff continuity, and it too varies since fluctuation is a critical factor of offshore outsourcing software development projects. The last factors of this group Application, Platform, Language and Tool Experience (APEX, PLEX, LTEX) may also differ depending on the buyers’ experience. Only the special factor Multi-Site Development (SITE) is affected in the Project attributes group. It is the only factor of the COCOMO II Which is linked with geographical distributed software development. The effort sources of this cost driver are the geographical distance between the development teams and the complexity of the communication channels. Consequently the cost driver SITE is a step in the right direction. There are more effort sources than the two in SITE [3], [11], [12], [13], [16].

The direct use of the COCOMO II for offshore outsourcing software development would be inadequate, as it does not cover the complexity of the topic. We therefore found a need to amplify the model. We used the modular composition of the COCOMO II to integrate the additional cost drivers into the model. Cost drivers suggested in [BABC00] can be kept or excluded by the user. We eventually identified new cost drivers that are typical in offshore outsourcing software development and added them to the model.

We used Effort Multipliers to build up the new costs drivers, because no observations about new scale factors arising through global software development<sup>5</sup> [17]. The current research attempts to reduce the risks and the development effort of offshore outsourcing software development. This indeed results to a lower effort and also lowers costs. Costs can only be saved if the additional effort doesn't become too high.

The new effort equation is:

$$PM = A * Size^E * \prod_{i=1}^{17} EM_i * \prod_{j=1}^{11} EMO \quad (2)$$

We added 11 new Effort Multipliers to the equation and named them Effort Multipliers Outsourcing (*EMO*). These factors are grouped into 4 groups: Outsourcing Factors, Buyers Outsourcing Maturity, Providers Outsourcing Maturity and Coordination Factors (ref. table 2) [22].

Outsourcing Factors	Buyers Outsourcing Maturity	Providers Outsourcing Maturity	Coordination Factors
CULT	BOXP	OOXP	OFIT
BALA	BUPM	OUPM	PMGM
TMZN	CODS	-	TESP

**Table 2.** Effort Multipliers Outsourcing factors for offshore outsourcing software development

- The **Outsourcing Factors** defines three basic and static cost drivers which may arise when collaborating with an international partner. The cost drivers are: Cultural Distance (CULT), Barrier of Language (BALA), and the different Time Zones (TMZN). The capabilities of the employees are not quantified by these factors because they are very abstract.
- The **Buyer's Outsourcing Maturity** defines cost drivers which specify the offshore outsourcing maturity of the buyer. Three factors are critical: Buyer's Outsourcing Experience (BOXP), Buyer's Project Managers (BUPM), and Contract Design (CODS). The BOXP refers to the actual experience of the buyer with offshore outsourcing projects. The BUPM evaluates the capabilities of the buyer's project manager vis-à-vis their offshore qualification. The CODS refers to the complexity of a collaboration contract.

<sup>5</sup> Follow-the-sun approach can possibly be built up with such a factor.

- The **Provider's Outsourcing Maturity** defines cost drivers which specify the offshore outsourcing provider maturity. Two factors can influence the effort: Provider's Outsourcing Experience (POXP) and Provider's Project Managers (PUPM). The POXP refers to the actual experience of the provider with offshore outsourcing projects. The PUPM evaluates the capabilities of the provider's project manager considering their offshore qualification.
- The **Coordination Factors** are cost drivers originating from the interaction between two partners. The additional effort is represented by three factors: Outsourcer's Fit (OFIT), Project Management (PMGM), and Team Spirit (TESP). The OFIT refers to the right selection of a particular partner. The wrong partner increases the effort. The PMGM refers to the increased effort which is inherent in any offshore outsourcing project. The TESP also decreases the possible effort by raising the team spirit through team building meetings, common goals, and a mixture of off- and onshore team members.

We initially identified the additional cost factors of offshore outsourcing software development projects: We further identified eleven additional ones and finally defined them as the starting point for the amplification of the COCOMO II. The Second and third (ref. Figure 1), requires us to categorize these additional factors so as to quantify them with numerical values. This has been done according to the COCOMO II categories and values. We tried to develop our categorization on theoretical thoughts, literature research and especially on expert opinions. We are aware of the lack of validation because of the missing data base of actual offshore outsourcing software development projects. But we are confident that the approach is a step in the right direction and it needs to be further calibrated. The introduction of all the categories and the whole value assessment process will be omitted owing to the limited size of this report<sup>6</sup>. We will therefore explicitly demonstrate step two and three on the additional factor: **Outsourcing Factors**

Categories	Value	Categorization criteria
Very Low	1,00	Both companies are from the same country and the same geographical region
Low	1,08	Both companies are from the same country but from different geographical regions
Nominal	1,15	Both companies are from the same [20]-group, but belong to different countries
High	1,22	The companies belong to different [20]-groups

**Table 3.** Categorization and value assignment of the cost driver CULT

Table 3 illustrates the second and the third step for the cost driver CULT: The criteria for the categorization and the conduction of the value assignment. The cultural

<sup>6</sup> Feel free to contact us for further information e.g. for the complete categorization list and the value assignment.

distance is often used as an instrument for e.g. performance assessment in the international business area [18]. The concept of the cultural distance is based on [20]. We used it as foundation for our categorization. The occurrence “very low” is disregarded if both companies are from the same country and geographical region. In The cultural distance is so small for it to be of any influence. If companies are from the same country but from different geographical regions then a measurable cultural distance exists. This is indicated by the value 1.03. This has been discussed with experts and arises from personal experience. The nominal and high values originate from the Hofstede concept<sup>7</sup>.

Categories	Value	Categorization criteria
Very Low	1.00	Both companies have the same mother tongue
Nominal	1.10	The companies use different mother tongues, but one of them is the project language
Very High	1.21	The companies use different mother tongues, none of them is the project language

**Table 4.** Categorization and value assignment of the cost driver BALA

Table 4 indicates the second and the third step for the cost driver BALA: The criteria for the categorization and the conduction of the value assignment. The first value has no influence. The second and third levels are characterised by a rise in value as well as an increase in communication effort. Some of the characteristics have been omitted because of the extensive difference between these three existing possibilities.

Categories	Value	Categorization criteria
Very Low	1.00	8 hours overlap of the office hours
Low	1.025	5-7 hours overlap of the office hours
Nominal	1.050	3-4 hours overlap of the office hours
High	1.075	1-2 hours overlap of the office hours
Very High	1.10	<1 hours overlap of the office hours

<sup>7</sup> It can be argued that there are differences between the distance of different cultural distances (e.g. ANGLO vs. GERMANIC and JAPAN vs. GERMANIC), so that it can be useful to implement very high as an additional value for the cost driver CULT. But the authors leave that to the user, because the calculation of these distances can be done using equitation [20].



**Table 5.** Categorization and value assignment of the cost driver TMZN

Table 5 illustrates the second and the third step for the cost driver TMZN: The criteria for the categorization and the conduction of the value assignment. Time zones literally do not have such a big impact as the other cost drivers of this factor. We calibrated the factor as shown because this factor is quoted in current literature as less critical; this was done with the support of experts.

We will sum up this section with a simplified and illustrated example of effort estimation in an offshore outsourcing software development project i.e. a company wishes to develop the project X either in-house or offshore. They then identify an Indian provider [21]. So they first calculate the in house (39 PM) effort. The constant A has not been calibrated<sup>8</sup> and the estimated KSLOC are 50. They then calculate the effort still using the original COCOMO II, but with parameters fitted for the Indian provider (110, 66).

	W.E.	Ausprägung	Wert	A.P.	Ausprägung	Wert
$SF_i$	PREC	VH	1,24	PREC	H	2,48
	FLEX	H	2,03	FLEX	H	2,03
	RESL	VH	1,41	RESL	VH	1,41
	TEAM	VH	1,1	TEAM	H	2,19
	PMAT	VH	1,56	PMAT	H	3,12
$EM_i$	RELY	N	1	RELY	N	1
	DATA	N	1	DATA	N	1
	CPLX	N	1	CPLX	N	1
	RUSE	N	1	RUSE	N	1
	DOCU	N	1	DOCU	L	0,91
	TIME	N	1	TIME	N	1
	STORE	N	1	STORE	N	1
	PVOL	N	1	PVOL	N	1
	ACAP	VH	0,71	ACAP	H	0,85
	PCAP	VH	0,76	PCAP	H	0,88
	AEXP	H	0,88	AEXP	H	0,88
	PEXP	H	0,91	PEXP	H	0,91
	LTEX	H	0,91	LTEX	H	0,91
	PCON	H	0,9	PCON	N	1
	TOOL	N	1	TOOL	N	1
	SITE	XH	0,8	SITE	VL	1,22
	SCED	N	1	SCED	L	1,14
	Size=50		PM(on)= 39			PM(off)= 110,66

**Table 6.** Example of the COCOMO II in distributed environment [22]

The amplified model is then used to estimate the effort. The additional cost drivers have been added to the second (distributed) estimation in this model. This was further simplified because only the minimum and the maximum values of the  $EMO$  were used.

COCOMO II	COCOMO II	Amplification	Amplification
in house	distributed	best case	worst case
39	110,66	161,93	828,39

**Table 7.** Effort estimations (PM): Just COCOMO II coupled with the amplified model

The data of table 7 shows that the effort of offshore outsourcing software development projects increases at least by 50 % and by as much as eight times in the worst case scenarios not true There is still a cost advantage under the presumption

<sup>8</sup> A=2.94 according to COCOMO II.

that the wage level in Germany is eight times as high as that in India and that the worst case scenario is not realised.

## 5 Summary and future prospects

The report addressed effort estimation of offshore outsourcing software development projects. It demonstrated an approach of effort estimation of offshore outsourcing software development based on COCOMO II. Cost drivers were added as **Effort Multipliers**. It should be noted that this is still work in progress. The model eventually needs more calibration and validation. An exact estimation on the effort remains complex and hardly realizable. Traditional methods can also not live up to that. The proposed model provides an estimation of the range but not the precise figure. It nonetheless helps predict the outcome of a global software development project by reducing the overall risk.

Multi-sourcing is indeed an interesting research topic. We have simplified it by reducing the number of collaborative companies into two. It would be much more interesting to carry out a differentiated examination to the effect of software development processes on the effort. More calibration based on expertise opinion needs to be done. Further interaction between Experts is needed so as to unveil any unidentified or overlapping cost drivers.

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