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Standardized Cost Estimation in Thai Government's Software Development Projects

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***Abstract*—Software features and costs are often unquantifiable due to the abstract nature of software. In many cases, this results in the estimated costs of software development projects to be potentially highly biased, highly inaccurate, or highly unjustified. Hence, current software estimation methodologies can open up areas for corruption as estimated budgets and costs are difficult to verify and validate. The Thai COCOMO Framework and cost estimation model were developed in order to overcome this problem in software development projects for Thai government by providing standard and transparency to the software estimation process with justification to the associated costs. This paper discusses the areas in software project estimation that are prone to corruption and ways that the COCOMO model and framework can be used to address them.**

Keywords: COCOMO II, cost estimation, software engineering

I. Introduction

Corruption is one of the major problems that significantly impair economic growth especially in developing countries. Thailand, being one of the developing countries, was ranked 85th out of 175 countries surveyed in the 2014 Corruption Perceptions Index [15]. The Thailand Development Research Institute (TDRI) reported that corruptions in Thailand are usually conducted in three different forms: (1) exploiting political positions to benefit one's own group of people, (2) bribing with gifts or money, and (3) corruption at policy level. The corruptions are mostly found in the public sector's procurement, permissions and licensing and the government's bidding process respectively, which often result in causing the private sectors to spend at least an additional 10 percent of the project cost [14].

There are various methods that can be implemented in attempt to prevent or reduce corruptions in Thailand. Introducing new laws and enforcing good governance is one of the methods. In 2011, the Thai government passed the law requiring all government agencies to make the detailed cost breakdown of government projects along with the criteria used for those costs publicly available [13]. This law was initiated by the Office of the National Anti-Corruption Commission to ensure public accountability.

The Ministry of Information and Communication Technology (MICT) was assigned to formulate the standard process and criteria to estimate costs of software development project in order to reduce the variance of estimated software development costs during procurement process and increase transparency to the estimated costs [12]. The COnstructive COst MOdel (COCOMO) [5] was chosen as suitable method for software cost estimation due to the following reasons.

- COCOMO is the most widely used and calibrated over historical data.
- COCOMO is thoroughly documented which will can be used as guidance to explain how the estimated costs are obtained.
- COCOMO is parametric model which allow users to adjust the parameters based on their project attributes.
- COCOMO has flexibility in size input such as SLOCs, function points and application points.
- COCOMO is multi-model coverage of different development sectors.

Since 2012, MICT has funded the project, titled Thai Software Costing Process and Model, to create standard guidance, criteria, and methodology for software estimation using COCOMO in collaboration with the Department of Computer Science from Thammasat University and the Center for Systems and Software Engineering from University of Southern California. The initial guideline and standards were released in 2013 and later refined in 2014 along with the release of the Thai Cost Estimation System [11].

The original COCOMO II model will be discussed in the next section and the Thai Software Costing Process and Model in section III. Three sample projects were selected for case study and the outcome will be presented in section IV. The lessons learned from the case studies will be discussed in section V and concluded in VI.

II. COCOMO II Model

The COCOMO model is a well-known parametric cost and schedule estimation model [4], [5]. Since its establishment in 1980, COCOMO has been used intensively by software managers and software engineers to support their software cost and estimation process due to the ability to perform estimations

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with little expert knowledge and experience. The model has also helped software managers and software engineers in making critical development decisions such as negotiations on requirement changes, making architectural decisions, perform risk management decisions or process improvement decisions [7]. Figure 1 shows COCOMO II model. The COCOMO takes project size, cost factors (product, platform, personnel and project attributes) and organization project data as an input to calculated the estimated development efforts. The COCOMO model allows any organization to recalibrate the model using organization project data to create a specific model for an organization.

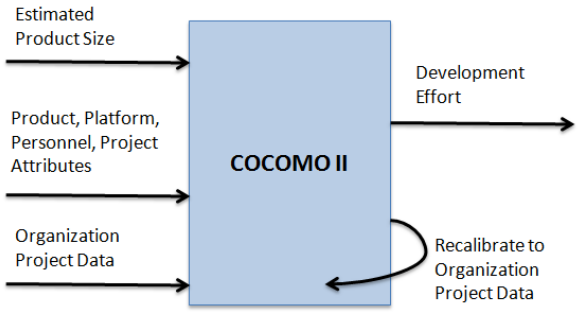

Fig. 1. The COCOMO II Model

The original COCOMO model is known as COCOMO81 [3]. The model is established from the analysis of 63 projects from different domains during the 1970s and the early 1980s. In 2002, the model went through major revisions to cope with the growth of scope and complexity of software systems. One of the major changes is the update of the set of parameters in form of Scale Factors and Cost Drivers [6]. COCOMO 81 has 1 Scale Factor and 15 Cost Drivers while COCOMO II has 5 Scale Factors and 17 Cost Drivers as shown in Table I. COCOMO II is a highly reliable model as it has been calibrated using the Bayesian analysis from over 200 project data as well as expert data via Delphi surveys [8], [9].

Scale Factors are sources of exponential effort variation. 5 Scale Factors in COCOMO II are precedentedness, development flexibility, architecture/risk resolution, team cohesion and process maturity. Cost Drivers are source of linear effort variation. In COCOMO II, 17 Cost Drivers can be grouped into 4 categories that impact product, platform, personnel and project attributes of a module within software project. All 22 factors can be rated between very low and extra high. COCOMO II provides rating guidance to make the scale as objective as possible. Table II shows example of reliability (RELY) rating scores and rating guideline provided by COCOMO II.

The guideline shown in Table II is one of key components to provide justification and transparency how the software requirement specification is converted to the estimated costs.

III. Thai Software Costing Process and Model

The COCOMO II model cannot be used directly to perform software cost estimation for Thai government agencies since the COCOMO II has been calibrated from the US data only. Initially, the calibration of the model using software development data could not be accomplished due to incomplete data and project documentations. Expert surveys and judgment were used to adjust the COCOMO model instead.

TABLE I. Comparison between COCOMO 81 and COCOMO II Scale Factors and Cost Drivers

Model	Scale Factors	Cost Drivers
COCOMO 81	B (exponential constant)	**PRODUCT** - Required Reliability - Database Size - Product Complexity **COMPUTER** - Execution Time Constraint - Main Storage Constraint - Virtual Machine Volatility - Computer Turnaround Time **PERSONNEL** - Analyst Capability - Applications Experience - Programmer Capability - Virtual Machine Experience - Programming Language Experience **PROJECT** - Modern Programming Practices - Use of Software Tools - Required Development Schedule
COCOMO II	- Precedentedness - Development Flexibility - Architecture / Risk Resolution - Team Cohesion - Process Maturity	**PRODUCT** - Reliability - Database Size - Product Complexity - Developed for Reusability - Documentation Match to Life-Cycle Needs **PLATFORM** - Execution Time Constraint - Main Storage Constraint - Platform Volatility **PERSONNEL** - Analyst Capability - Programmer Capability - Personnel Continuity - Applications Experience - Platform Experience - Language and Tool Experience **PROJECT** - Use of Software Tools - Multisite Development - Required Development Schedule

TABLE II. Example of COCOMO II rating scores and rating guideline for reliability (RELY)

RELY	Measure the extent to which the software must perform its intended function over a period of time.				
Question to ask	What is the effect of a software failure?				
Very Low	Low	Nominal	High	Very High	Extra High
Slight Inconvenience	Low, easily recoverable losses	Moderate, easily recoverable losses	High financial loss	Risk to human life	-
0.75	0.88	1.00	1.15	1.39	-

The objective of the survey was to refine the cost factors that significantly impact software development in Thai government context. The surveys were distributed in 2 rounds each followed by a focus group of 20 experts. The first round was distributed to 17 experts from the private sectors who have been working as vendors for Thai government agencies. 9 surveys were returned and only 7 surveys were valid. The second round was distributed to over 500 experts from both government and private sectors. About 200 surveys were returned and less than 100 surveys were valid. The results

of the survey suggested reducing of 2 scale factors and 7 cost drivers, adding 1 product cost driver, and combining 5 personnel cost drivers into 2 drivers. Details of the cost factor adjustments as well as the definition of the cost factors are out of the scope of this paper and can be found in [11]. Table III shows scale factors and cost drivers of Thai COCOMO.

TABLE III. THAI COCOMO SCALE FACTORS AND COST DRIVERS

Model	Scale Factors	Cost Drivers
Thai COCOMO	- Precedentedness - Architecture / Risk Resolution - Stakeholder Cohesion	**PRODUCT** - Reliability - Product Complexity - Documentation Match to Life-Cycle Needs **PERSONNEL** - Team Capability - Personnel Continuity - Team Experience **PROJECT** - Required Development Schedule

Scale factors and cost drivers that had been removed from COCOMO II model were considered to have low and insignificant impact to the software development projects for Thai government agencies. For example development flexibility for Thai government agency is always be very low to low because on the governance level that the private sector needs to comply.

Team cohesion is refined to stakeholder cohesion to ensure that all stakeholders are take into account when rating this factor. Personnel capability and experience for different role is combined to team capability and team experience due to the roles within Thai team are ambiguously defined.

Security is suggested to be added to the model due to the importance of security in the current software especially for government sector. Different level of security can impact the software development costs significantly. For example, the implementation of software that required authentication requirements has less costs than the same software that required both authentication requirements and integrity requirements.

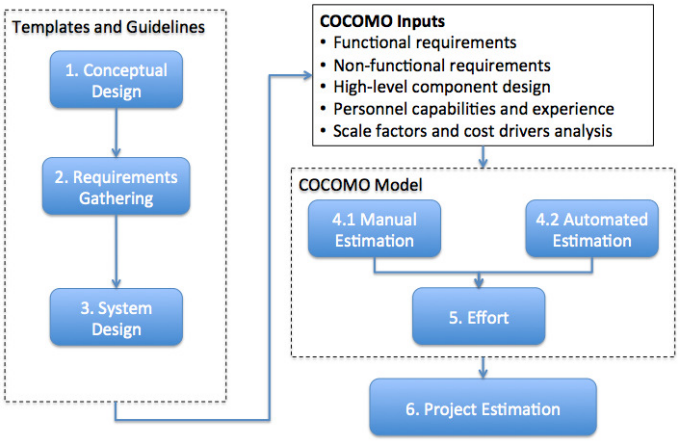

Fig. 2. The COCOMO Framework

Furthermore, a Thai COCOMO Framework was also developed as part of costing process and model in order to provide a standardized process and capture criteria for software cost estimation. Figure 2 shows the components of the Thai COCOMO Framework, which consists of templates and guidelines in addition to the estimation model itself. The templates and guidelines serve to provide best practices for writing the Terms of Reference (TOR) document and guidance on how to convert those information into COCOMO compatible inputs.

For Thai COCOMO, function point technique is used as a standard method for estimating software sizes. Function point is selected due to ability to provide explanation and justifications on how software functionalities are converted to their relative sizes and complexities [1][2][16]. The COCOMO factors are analyzed based on project attributes with clearly defined guidance on how to rate the scale of each COCOMO factors (scale factors and cost drivers)as mention in above section. The size and ratings for COCOMO cost factors are input into Thai COCOMO Model to calculate the effort required to implement the project. The effort is then convert to monetary costs based on the Thailand's base salary published by the Ministry of Finance.

The Thai COCOMO Framework ensures that the estimated project costs are justifiable with proper traceability for requirement complexity and costs. This is achieved by enforcing strict analysis process for sizing features and functions as well as project attributes and cost factors. All of these bring transparency to the TOR document and cost being estimated for procurement process.

IV. CASE STUDIES

As initial step to review and validate the process of applying Thai COCOMO framework, we studied 3 government projects sampled from very small, small, and medium size groups. The projects chosen have been through the procurement process. The vendor was selected and contract were signed. This allows us to apply the Thai COCOMO framework and compare the results with the actual estimated budget. However, the projects are under-development making the actual project costs are not available for comparison.

The main focus of the studies was to review the accuracy of the budgets based on the project scopes and requirements written in the Terms of Reference (TOR) documents. Note that at the time of writing the TOR document, only the high-level requirements of the system are required for project scoping and budgeting purposes. The detailed requirements are usually not known at this point of the project life cycle and are gathered during the first phase of the project implementation.

The focus of the case study was to observe the critical weak points in the TOR document that significantly impacted the outcome of the project budgets and how the Thai COCOMO framework can overcomes these weak points. Due to limited space, detailed breakdown of the sizing and costing process for each case study is out of the scope of this paper.

The project costs can be broken down into the following categories:

1) Hardware
2) Software
3) Personnel
4) Experts and Consultants
5) Recurring Costs
6) Other

TABLE IV. CASE STUDY ESTIMATION SUMMARY

Project	Size	Budget	Contract	COCOMO Est.	% Error
Government Website	Very Small	THB 800,000	THB 792,000	THB 2,301,136.81	190%
Content Management	Small	THB 4,750,000	THB 4,730,000	THB 10,369,444.10	119%
Back Office System	Medium	THB 14,250,000	THB 14,250,000	THB 32,949,204.60	131%

Table IV shows the summary of the estimation results of the case study projects. Notice that by applying the Thai COCOMO framework to the estimation process, all the projects in this case study result in high deviation from the actual expert estimation. We discovered later during the interview sessions with the project owners that it was due to various reasons that can open up the area of corruptions during the procurement process. We will discuss these reasons in the next sections.

A. Government Website Project

The first case study project was a very small project to create a website for a government organization. The structure of the website is partially a static site for displaying information and content and partially a content management system for managing the contents to display.

In this project, the TOR document was very well detailed with all the high-level requirements, or capability goals, clearly specified. The TOR document specifically listed out all the web sections as well as the minimum core capabilities required for each section. This allowed us to performed very specific sizing of the project using function point sizing method.

Table V shows the cost breakdown of the government website project resulting from Thai COCOMO framework. Although, the result of total cost estimation by Thai COCOMO model yields high deviation, when we look at the estimated effort resulting from Thai COCOMO model the results are close to the actual effort and schedule estimated in the TOR document.

TABLE V. THAI COCOMO ESTIMATION FOR GOVERNMENT WEBSITE

Category	Cost
Hardware	THB 0.00
Software Licenses	THB 0.00
Total Development Effort	6,635.44 hrs
Personnel	THB 2,027,965.59
Experts and Consultants	THB 412,340.00
Recurring Costs	THB 0.00
Other	THB 0.00
Total	**THB 2,440,296.59**

With this fact, we discussed with the project owners regarding this phenomenon. We discovered that, in actuality the project was under budgeted due to budget cut. They were required to force this project to be implemented by another government agency in order to stay within the allotted budget. The project could not be feasibly implemented by any of the private software vendors.

Although the project contract was signed within the estimated budget, the government agency implementing this project had to absorb additional development costs to stay within allotted budget. In this case, the Thai COCOMO framework can provide detail justification of cost for each features or capabilities being specified in the TOR document to provide fareness of doing business between two government agencies.

B. Content Management Project

The purpose of the second project in this case study was to implement a web-based knowledge center for a government organization with capabilities ranging from providing data of available experts to business matching opportunities. It was designed to be a content management system and the use of third-party content management software was not allowed. It is important to note that this was a continuation of the project (second phase); however, the project was very poorly implemented in the first phase and nearly all the core capabilities were required to be implemented again.

Table VI shows the cost breakdown of the content management project resulting from the Thai COCOMO framework. In this second project, Thai COCOMO estimate again yields high deviation from the actual cost estimation defined in the TOR document. It is due to the fact that the project was inappropriately scoped. The TOR document was written in an ambiguous way and hardly to perform the cost estimation. Moreover, the TOR document was written to be the maintenance of features and capabilities implemented in the previous phase.

TABLE VI. THAI COCOMO ESTIMATION FOR CONTENT MANAGEMENT

Category	Cost
Hardware	THB 0.00
Software Licenses	THB 0.00
Total Development Effort	35,307 hrs
Personnel	THB 9,747,044.10
Experts and Consultants	THB 622,400.00
Recurring Costs	THB 0.00
Other	THB 0.00
Total	**THB 10,369,444.10**

In our study, we could not perform the estimation using Thai COCOMO based on only the TOR document. The interviews with project owner and stakeholders were conducted to understand the scope of work. During the interviews, we discovered that majority of the features and capabilities need to reimplement for system to perform as described in the TOR document. Although, Thai COCOMO estimation result in 119% higher than the actual budget estimate for phase 2, the result is actually 30% less than the actual budget estimation for phase 1 and 2 combined.

Observe that, vaguely written TOR document can lead to unsuccessful project implementation. The project delivered with poor quality causing the project with higher costs than it need to. The government did not get the value out of the invested money. The Thai COCOMO framework overcomes this issue by providing the TOR document template and guideline how to write the TOR document to support the estimation using Thai COCOMO. The template enforces the project owners to have well understanding of the high-level features and system capabilities in order to perform the estimation. The estimation is done at features or capabilities level hence it can be used as justification and specification of what features or capabilities can be implemented within a specified budget. The

TOR document written from the Thai COCOMO framework also provides enough detail to the vendor to understand scope of work during the procurement process. This helps reduce the risks to both government agency who is the owner of a project and the vendor who implementing the project.

C. Back Office System Project

The scope of the Back Office System project was to implement a system that interfaces with 7 different systems with capabilities ranging from project management to content management web portals.

Table VII shows the cost breakdown of the Back Office System project which is the third case study project. The TOR document for the Back Office System project does not provide enough detail of system requirements to perform Thai COCOMO estimation. We again conducted the interviews with the project owner to understand the scope of work to perform the estimation using Thai COCOMO. The main budgeted costs for this project came from the 22 experts and consultants specified in the TOR document. The TOR document only specified 1 person in the development team, which was a project manager. The rest of the development team for the project consisted of experts and consultants with no development roles specified.

TABLE VII. THAI COCOMO ESTIMATION FOR BACK OFFICE SYSTEM

Category	**Cost**
Hardware	THB 627,300.00
Software Licenses	THB 0.00
Total Development Effort	20,452.31 hrs
Personnel	THB 5,240,904.60
Experts and Consultants	THB 26,533,000.00
Recurring Costs	THB 0.00
Other	THB 528,000.00
Total	**THB 32,949,204.60**

Because of this fact, the total costs of experts and consultants do not change in relation to the development effort in the Thai COCOMO estimate. This causes the estimation using Thai COCOMO deviated from the actual estimation by 131% as showed in Table IV. It is very difficult to justify the costs of 22 experts and consultants in a software project where the majority of effort should be in development. It also opens number of questions to this project. For example who will be the person implementing this project and what are 22 experts and consultants for, why there are no development resources required, and etc.

V. LESSONS LEARNED

From the case study, we have learned the factors which could contribute to corruptions in the original estimation process and method implementing within the Thai government agencies. Spending too much money or too little money for a given project scope can both be considered as some form of corruption as the budget can be inappropriately or inadequately allotted and abused. Spending too much money is obvious; however, spending too little can significantly increase the risk of failure for projects resulting in zero return on investments. Additionally, increasing the risk of failure can encourage the continuation of projects they can end up requiring multiple phases to maintain and complete.

A. Inappropriate Budget Allotment

Software projects often do not go through proper budgeting process with good understanding of the requirements. Without rigorous estimations in the budgeting process or utilization of standardized method, projects are not carefully estimated for required development effort and costs. Furthermore, without good understanding of the requirements, projects can never properly scoped. Proceeding with poorly allotted budgets can either end in cost underruns or overruns.

The Thai COCOMO Framework should be utilized starting from the very beginning of the project life cycle (budgeting). However, this is currently not the case as the COCOMO framework is used after the budget has been allocated. The COCOMO framework can help with scoping of the project to stay within the budget, but we suggest that the framework should be used earlier.

B. Inadequate Details in TOR Document

From our studies, two out of three TOR documents did not have sufficient detail of system requirements in order to properly scope the project and deliverables to perform project cost estimation. Based only on the TOR document, the deliverables can be varied which can be a high potential channel for corruptions. In this case the corruptions can be exercised in many ways such as

- Vendor attempts to deliver the minimal set of features possible while complying with the scope in the TOR document.
- TOR document can easily be highly over or under estimated.

The Thai COCOMO framework provides the necessary guidelines for project owners to give enough detail in the TOR document in order to create proper estimates. The estimation of project sizing (function point) cannot be done without the good understanding of project requirements. Moreover, while performing scale and cost factors for COCOMO estimation, it enforces the project owner to think and rethink what are the real impact factors to their system.

C. Ball-park Estimation by Experts

Expert judgment has typically been the most common estimation method used for estimating software projects in Thailand, which can be performed with a single or a group of experts. The method can result in estimates with critically high deviation or estimates that are highly biased. This opens up potential leads for corruptions because expert's judgments are considered acceptable and justifiable method of estimation; however, the estimation process itself does not ensure accuracy or traceability in the estimate.

The Thai COCOMO framework allows non-experts and experts to perform the estimate in a standardized way that provide transparency to the public. It allows the estimators to provide justifications to the estimated costs as well as traceability to the complexity of each estimated feature.

D. Costs Irrelevant to Development Effort

In some projects, the estimated costs may not be derived directly from the overall development effort required to implement the project, but from other independent costs. These costs are not always justifiable based on the project scope alone. For example, in the estimation for the Back Office System project, over 80% of the total project cost came from the hiring of 22 experts and consultants, while only 16% were related to the system development and project implementation effort.

The COCOMO model and framework estimations are based purely on the required effort to implement the project. While the total cost may consist of other factors such as hardware and software required, the majority of monetary costs must be derived from the development effort. This enforces justification to the estimates as the framework requires detailed analysis of sizing and project attributes.

VI. Conclusion

From our study, the Thai COCOMO framework provides transparency to the costs estimation process and method during the procurement of software development project which can help reducing the opportunities to open the area of corruptions. The guideline and template empower the TOR document to be written in well form with enough project requirements to support the cost estimations. The project sizing using standard function point method and COCOMO model offer the necessary justifications to the cost calculations. Moreover, the Thai COCOMO framework as a standardized estimation methodology helps reduce the variation in the estimation of software development project. However, we have not yet be able to quantitatively validate the accuracy of the COCOMO estimations. From empirical observations, the estimated effort seems to be appropriate. The future study needs to be done to validate the accuracy and further calibrate the model for Thai government software projects. Note also that inaccuracy of the software cost estimation can due to number of reasons such as project uncertainty, software sizing errors and inexperience project manager. All of these impacts to accuracy of software cost estimation will need to be investigated further in the future studies.

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