

The State of Practice of Software Cost Estimation: Evidence From Thai Software Firms

Tharwon Arnuphaptrairong

Abstract—Software cost and effort estimation is crucial for software project management success. It is used for project planning and control of project resources. Parametric software cost estimation models have been introduced for decades since 1960 [1], [2]. Today, researchers are still introducing new software estimation models [3]. The practice of software cost estimation model is, therefore, one of the interest area for researchers [2], [4-9]. The objective of this study was to explore how the software estimation was actually practiced in Thai software firms. This paper presents the findings from the returned 26 the questionnaires from a survey of Thai software firms. The findings indicate the discrepancy between theory and practice. The companies studied have not applied software cost estimation models found in the literature. Expert judgment and analogy method are the most employed instead. The companies also indicate that they cannot find appropriate software cost estimation models or tools that are accurate, easy to learn and use.

Index Terms— software cost and effort estimation, software cost estimation practice, software cost and effort estimation practice, Thai software cost estimation practice, software estimation practice evidence.

I. INTRODUCTION

Software cost and effort estimation is crucial for software project management success. It is used for project planning and control of project resources. Parametric software cost estimation models have been introduced for decades since 1960 [1], [2]. Today, researchers are still introducing new software estimation models [3]. The practice of software cost estimation model is, therefore, one of the interest area for researchers [2], [4-9].

The objective of this research was to study the state of the practice of software cost and effort estimation in Thai software firm.

Understanding the state of the software cost and effort estimation practice will give incitements which hopefully will help closing the gap between theory and practice, and lead to the software project management success.

This paper is organized as follows. Section II gives the review of the empirical study in software cost and effort estimation practice. Section III discusses the research questions and the research methodology is given in section

IV. Section V discusses the findings of the survey and the conclusion and discussion are presented in section VI.

II. OVERVIEW OF RELATED LITERATURE

This section reviews the literature related to the proposed research objectives i.e., the empirical study in software cost and effort estimation practice. The following surveys are listed in chronological order based on the year of their publication as shown in table I.

TABLE I
SOFTWARE COST AND EFFORT ESTIMATION PRACTICE SURVEY

Year	Author	Country	Number of Respondents
1991	Hihn and Habib-agahi [4]	USA.	83
1999	Verner and Evanco [5]	USA.	21
2003	Molokken and Jorgensen [6]	Literature survey	--
2004	Molokken, Jorgensen and Tanilkan [7]	Norway	18
2008	Yang, Wang, Li, Yang, Ye, and Du [2]	China	116
2011	Trendowiz, Munch, and Feffery [8]	Australia	10
2011	Mansor, Kasirun, Yahya. and Arshad [9]	Malaysia	13

Survey 1: Hihn and Habib-agahi.

In 1991, Hihn and Habib-agahi [4] conducted a survey of the 185 staff at Jet Propulsion Laboratory (JPL) in the United State of America. 83 completed the questionnaires. The respondents were asked to describe the techniques used in software cost estimation. An experiment was also conducted for the respondent to estimate the size and cost of a specific piece of software provided by the researchers.

Survey 2: Verner and Evanco

Verner and Evanco [5], in 1999, investigated the state of practice of effort estimation of the USA business organization. 21 senior software developer were structured discussed with and a questionnaire was also filled out by each of the developers. The questions are for example, what estimation method used, how good the estimates were. It is found that undocumented analogy is the most used effort estimation method. The authors also concluded that there is still a large gap between research and practice. The software community is not getting the message about the effort estimation method.

Survey 3: Molokken and Jorgensen

In 2003, Molokken and Jorgensen [6] did a literature survey to find the answer for four research questions including “Which method are used to estimate software effort, and do these systematically differ in accuracy?” The

T. Arnuphaptrairong is with the Department of Statistics, Chulalongkorn Business School, Chulalongkorn University, Bangkok 10250 Thailand (e-mail: Tharwon@acc.chula.ac.th).

authors reported 4 surveys found in the literature regarding this question. They are McAulay [10] in 1987, Heenstra and Kuster [11] in 1992, Wydenbach and Paynter [12] in 1995, and Bergeron and St.-Arnaud [13] in 1992.

Survey 4: Molokken, Jorgensen and Tanilkan

In 2004, Molokken *et al.* [7] conducted a structured interview with 18 senior managers from 18 companies in Norwegian industry on 50 projects. The main objective is to find out that to what extent different estimation methods used in the industry are. 13 out of 18 companies relied 100% on expert judgment estimation method.

Survey 5: Yang et al.

In 2008, with the objective to collect evidence and to identify the area of improvement in software cost estimation, Yang *et al.* [2] used a questionnaire to survey 116 organizations in China. The questions are for example, to what extent the estimation methods are used in the industry, for what purpose cost estimations are used, and how important people think estimation is, in comparison with other aspects of development.

Survey 6: Trendowiz, Munch, and Feffery

Trendowiz *et al.* [8], in 2011, presented the results of their industrial survey in Australia. One of the objectives of the survey was to study if effort estimation method actually applied at the Australian software companies. The data from 10 software companies were analyzed. 9 out of 10 companies reported that they use expert judgment for software effort estimation.

Survey 7: Mansor et al.

In 2011, Mansor *et al.* [9] conducted a survey research on 30 software companies around Kuala Lumpur and Selangor in Malaysia. 13 questionnaires were collected. 8 of the respondents are project managers and the other 5 are developers. It is reported that expert judgment is the most commonly used method while price to win and algorithmic models are the second and third most commonly used respectively.

III. RESEARCH QUESTIONS

From the literature reviewed, seven research questions were derived. The objective of the study was to investigate the software cost and effort estimation practice in the Thai software industry with comparable questions posed in previous surveys. The seven research questions (RQ) are:

RQ1: How important is the software estimation accuracy perceived?

RQ2. To what extent are different cost estimation methods used in the industry?

RQ3. What are the purposes of cost estimation used for?

RQ4. On what basis is a cost estimation method selected?

RQ5. To what extent are different software size estimation models used in the industry?

RQ6. What are the causes of inaccurate estimation?

RQ7. What are the barriers and difficulties in the application of software cost estimation models?

Table II shows the research questions and the research the questions were derived from. Except for research question 3 (RQ3), there is no previous research found.

TABLE II
 RESEARCH QUESTIONS AND PREVIOUS RESEARCH DERIVED FROM

No.	Research Question (RQ)	Appeared in
1	How important is the software estimation accuracy perceived?	-- Molokken and Jorgensen [6] -- Molokken, Jorgensen and Tanilkan [7] -- Yang, Wang, Li, Yang, Ye, and Du [2]
2	To what extent are different estimation methods used in the industry?	-- Hihn and Habib-agahi [4] -- Verner and Evanco [5] -- Molokken and Jorgensen [6] -- Molokken, Jorgensen and Tanilkan [7] ---Yang, Wang, Li, Yang, Ye, and Du [2] --Trendowiz, Munch, and Feffery [8] -- Mansor, Kasirun, Yahya. and Arshad [9]
3	What are the purposes of cost estimation used for?	-- Yang, Wang, Li, Yang, Ye, and Du [2] --Trendowiz, Munch, and Feffery [8]
4	On what basis is an estimation method selected?	-- Molokken, Jorgensen and Tanilkan [7]
5	To what extent are different software size estimation methods used in the industry?	---
6	What are the causes of inaccurate estimation?	-- Molokken, Jorgensen and Tanilkan [7] ---Yang, Wang, Li, Yang, Ye, and Du [2]
7	What are the barriers and difficulties in the application of software cost estimation models?	---Yang, Wang, Li, Yang, Ye, and Du [2]

IV. RESEARCH METHODOLOGY

A. Survey Design

The survey method was used to obtain the information of the software cost and effort estimation practice from the Thai software firms. About 200 software companies that joined Software industry club of The Federation of Thai Industries (FTI) were used for the survey frame. In the data collection process, names, addresses and contacts of software firms were obtained from FTI. An officer at The Federation of Thai Industries (FTI) was asked to help in contacting and solicitation in order to increase the response rates. The software firms will first be contacted by e-mail and asked to participate in the research. If the software company agreed to participate, the questionnaire was sent for the software cost and effort estimation practice information needed. Finally, 26 completed questionnaires were obtained.

B. Questionnaire Design

The questionnaire consists of three parts. General information about the software firms and the respondents were obtained from the first part of the questionnaire. The second part of the questionnaire was designed to obtain the information regarding the software cost estimation practice of the software firms. The third part asked about problems and barriers of the software cost estimation practice. 10 questions included in the questionnaire are shown in Table III.

TABLE III
 QUESTIONS IN THE QUESTIONNAIRE

Part 1: General information
1. Organization Name:
Organizational Size (Number of employee)
(Number of developers)
2. Respondent Position
Experience (number of years) in project management
Part 2: Software Cost Estimation Practice
3. Does your organization follow/ use/ have a software cost estimation process?
4. How important is the software estimation accuracy perceived?
5. What are the cost estimation methods used in your organization?
6. What are the purposes of cost estimation used for?
7. On what basis is a cost estimation method selected?
8. Does your organization utilize software size estimation incorporation with cost estimation? If yes, which models are used?
Part 3: Problems and barriers
9. What are the causes of inaccurate estimation?
10. What are the barriers and difficulties in the application of software cost estimation models?

C. The Profile of the Respondents

As shown in Table IV, of the 26 questionnaires returned, 25 companies (96.2%) answered that their organizations have a software cost estimation process. Therefore the organizations that answered that they do not have software cost estimation process will be excluded from further analysis.

TABLE IV
 THE NUMBER OF FIRMS WITH SOFTWARE COST ESTIMATION PRACTICE

Software Cost Estimation Practice	Frequency	Percentage
Software cost estimation is embedded in the project management process	6	23.1
Software cost estimation process is maintained as a separate process	19	73.1
Do not have Software cost estimation process	1	3.8
Total	26	100.0

Profile of the 26 companies and respondents are given in Table V. Most of the companies are either of small or large size. 50.0 percent of the companies have the number of employees of 1 to 38 and 38.4 percent of the companies has the number of employees of more than 77. The average number of employee is 96.5.

50 percent of the companies have the number of developers: 1-13, 30.80 percent of the companies have the number of developers of 14-27 and 15.40 percent of the

companies has the number of developers more than 27. The average number of the developer is 19.10.

Most of the respondents are project managers (50%) and staff (34.6%). 30.80 percent have more than 2 years of experience in project management and 23.10% less than 1 year of project management experience. The average years of work experience are 4.3 years.

TABLE V
 THE COMPANIES' AND RESPONDENTS' PROFILE

	Frequency	Percentage
Number of Employees		
1 - 38	13	50.0
39 - 77	3	11.5
more than 77	10	38.4
Number of Developers		
1 - 13	13	50.0
14 - 27	8	30.8
more than 27	4	15.4
missing	1	3.8
Position		
Owner	1	3.8
Management	2	7.7
Manager	13	50.0
Employee	9	34.6
missing	1	3.8
Work Experience (Years)		
Less than 1	6	23.1
1 - 2	5	19.2
More than 2	8	30.8
missing	7	26.9

V. FINDINGS

This section presents the findings of the state of practice of software cost and effort estimation in the order of the research questions posed.

RQ1: How important is the software estimation accuracy perceived?

Table VI shows the perceived importance the software estimation accuracy of all of the 25 companies.

TABLE VI
 THE PERCEIVED IMPORTANCE OF THE SOFTWARE ESTIMATION ACCURACY

Software Cost Estimation Practice	Frequency	Percentage
Unimportant	-	-
Of Little Important	-	-
Moderately Important	-	-
Important	7	28.0
Very Important	18	72.0

Most of the software companies in Thailand perceive software estimation accuracy as very important (72%) or important (28%)

RQ2: To what extent are different estimation methods used in the industry?

Table VII and Figure 1 show that the most estimation method used is expert judgment (68%) and the second most is analogy method (56%) while software cost model ranked third with only 8 of 25 companies (32%). Of the 8 companies, six are from the large companies and only one each from small and medium size company.

TABLE VII
 THE COST ESTIMATION METHODS USED IN THE SOFTWARE INDUSTRY

Estimation method	Frequency	Percentage
Expert judgment	17	68.0
Intuition experience	3	12.0
Analogy	14	56.0
Software Cost Models [COCOMO, Used Case-based models, other algorithms driven method]	8	32.0
Price to win	5	20.0
Capacity related (Parkinson)	4	16.0
Top-down	5	20.0
Bottom-up	3	12.0
Machine learning	-	-
other (specify)	2	8.0

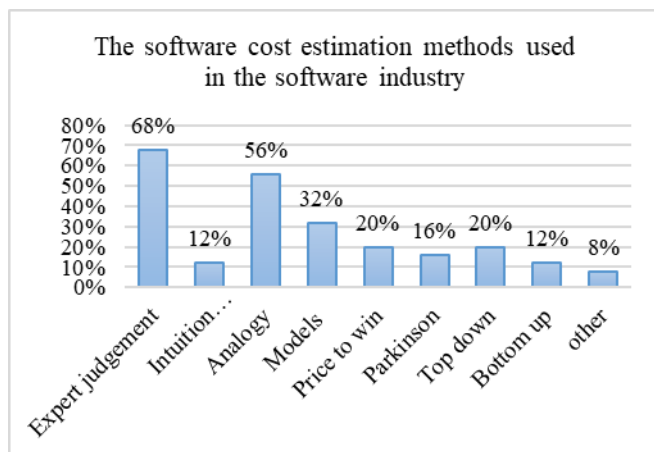


Figure 1. The estimation methods used in the software industry

RQ3. What are the purposes of cost estimation used for?

Table VIII indicates that most of the software companies reported that the purpose of cost estimation is used for project planning and control (88%). The second most is for software process improvement, e.g. assess new process, improve productivity (80%).

TABLE VIII
 THE PURPOSED OF THE COST ESTIMATION USED FOR

The purposes	Frequency	Percentage
• Project proposal evaluation	19	76.0
• Contract negotiation	6	24.0
• Making budget	6	24.0
• Project level planning and control, e.g. effort or schedule distribution among development phrases	22	88.0
• Short-term planning and control, e.g. weekly or monthly team work plan	11	44.0
• Software process improvement, e.g. assess new process, improve productivity	20	80.0
• Others	1	4.0

RQ4. On what basis is an estimation method selected?

Concerning the basis the estimation method selected, structured analysis has the most frequency while the second most is the reason that estimator has had success with the method as shown in Table XI.

TABLE XI
 THE BASIS AN ESTIMATION METHOD SELECTED

The basis an estimation method selected	Frequency	Percentage
Estimator has had success with the method	14	56.0
Consultant advice	7	28.0
Thorough testing	5	20.0
Structured analysis	18	72.0
Lectures at universities/ colleges/ courses	-	-
Review of other companies experiences	1	4.0
Market popularity	4	16.0
Others	2	8.0

RQ5. To what extent are different software size estimation models used in the industry?

Regarding the software size estimation models, only a few companies utilize software size models. Table X reveals that the most software size estimation method used is Use Case Points (24%) and the second most is Feature Points (20%) while Function Points and Object Oriented Function Points ranked third with 4 of 25 companies (16%).

TABLE X
 SOFTWARE SIZE MODELS USED IN THE SOFTWARE INDUSTRY

Software Size Model	Frequency	Percentage
▪ Function Points	4	16.0
▪ Feature Points	5	20.0
▪ Early Function Points	-	-
▪ FP with DFD	-	-
▪ Predictive Object Points	-	-
▪ Object-Oriented Function Points (PDPs)	4	16.0
▪ OOmFP	1	4.0
▪ UML Points	3	12.0
▪ 3D FP	-	-
▪ Full Function Points หรือ COSMIC FFP	3	12.0
▪ Use Case Points	6	24.0
▪ Class Points	1	4.0
▪ Object-Oriented Design Function Points	4	16.0
▪ Web Points	1	4.0
▪ Pattern Points	1	4.0
▪ others	-	-

RQ6. What are the causes of inaccurate estimation?

“Frequent request for changes by users” and “User’s lack of understanding of their own requirements” are the most and the second most causes of inaccuracy reported by the software companies (76% and 60% respectively) as shown in Table XI.

RQ7. What are the barriers and difficulties in the application of software cost estimation models?

“Haven’t found appropriate software cost estimation models or tools” is portrayed by the companies to be the most mentioned barriers and difficulties in the application of software cost estimation models (44%). The second most are “Lack corresponding tools which are easy to use” and “Software cost estimation models are hard to learn and use” (both with 28%) as shown in Table XII.

TABLE XI
 THE CAUSES OF INACCURATE ESTIMATION

The causes of inaccurate estimation	Frequency	Percentage
• Frequent request for changes by users	19	76.0
• User’s lack of understanding of their own requirements	15	60.0
• Overlooked tasks	12	48.0
• Insufficient user-analyst communication and understanding	13	52.0
• Poor or imprecise problem definition	11	44.0
• Insufficient analysis when developing estimate	10	40.0
• Lack of an adequate methodology or guidelines for estimation	2	8.0
• Lack of coordination of systems development, technical services, operation, data administration, etc. functions during development	8	32.0
• Changes in Information Systems Department personnel	9	36.0
• Insufficient time for testing	8	32.0
• Lack of historical data regarding past estimates and actuals	6	24.0
• Lack of setting and review of standard durations for use in estimate	2	8.0
• Pressure from managers, users and others to increase or reduced the estimate	6	24.0
• Inability to anticipate skill of project team members	7	28.0
• Red tape	3	12.0
• Users’ lack of data processing understanding	2	8.0
• Lack of project control comparing estimates and actuals	5	20.0
• Reduction of project scope or quality to stay with estimate resulting in extra work later	4	16.0
• Inability to tell where past estimates failed	3	12.0
• Lack of careful examination of the estimates by Information System Department management	3	12.0
• Lack of participation in estimating by the system analysts and programmers who ultimately develop the system	5	20.0
• Performance reviews don’t consider whether estimates were met	1	4.0
• Lack of diligence by system analysts and programmers	2	8.0
• Removal of padding from the estimate by management	3	12.0

TABLE XII
 THE BARRIERS AND DIFFICULTY IN THE APPLICATION OF SOFTWARE COST ESTIMATION MODELS

The barriers and difficulties	Frequency	Percentage
Software cost estimation models cost a lot of effort to collect data, configure parameters, calibrate models, etc.	5	20.0
Organization do not have sufficient investment for improving software estimate	4	16.0
The software cost estimation models cannot bring significant benefits	4	16.0
Lack corresponding tools which are easy to use	7	28.0
Haven’t found appropriate software cost estimation models or tools	11	44.0
Software cost estimation models are hard to learn and use	7	28.0

V. CONCLUSION AND DISCUSSION

From the data analysis above, the general picture of the software cost estimation practice of Thai software companies can be concluded as the followings:

1. Most of the software companies in Thailand understand and realize the importance of software estimation accuracy.

2. Expert judgment is the most estimation method and the second most is analogy method. There are only 8 of 25 (32%) companies reported that they used software cost model. Of the 8 companies, six are from the large companies and only one each from small and medium size company.

3. Most of the software companies reported that the purposes of cost estimation are used for is for project planning and control.

4. Concerning the basis the estimation method selected, structured analysis has the most frequency while the second most is the reason that estimator has had success with the method.

5. Regarding the software size estimation models, the most size estimation method used is Use Case Points (24%), following by Feature Points, Function Points, and Object Oriented Function Points.

6. “Frequent request for changes by users” and “User’s lack of understanding of their own requirements” are the most and the second most causes of inaccuracy estimation reported by the software companies.

7. The most reported barriers and difficulties in the application of software cost estimation models is “Haven’t found appropriate software cost estimation models or tools”. The second most are “Lack corresponding tools which are easy to use” and “Software cost estimation models are hard to learn and use”.

This indicates the discrepancy between theory and practice. The companies studied have not applied software cost estimation models found in the literature but expert judgment is the most employed instead. This is consistent with the findings, in the literature, of Hihn and Habib-agahi [4], Verner and Evanco [5], Molokken and Jorgensen [6], Molokken *et al.* [7], Yang *et al.* [2], Trendowiz *et al.* [8], Mansor *et al.* [9]

To explain this phenomenon, it is hypothesized because they have not found yet the appropriate software cost estimation models or tools that are accurate, easy to learn and use as described in the finding of research question 7 (RQ 7). The implication is that academic community may need to response by improving the accuracy estimation models or should the academic community discard estimation models and improve the accuracy of expert judgment and analogy method instead as deliberately discussed in Jorgensen and Boehm [14].

REFERENCES.

- [1] R.D. Stutzke, "Software Estimation Technology: A Survey," *CROSSTALK*, May 1996, pp.218-229.
- [2] D. Yang, Q. Wang, M. Li, Y. Yang, K. Ye, and J. Du, "A Survey on Software Cost Estimation in the Chinese Software Industry," in *ESEM '08 Proceedings of the Second ACM-IEEE international symposium on Empirical software engineering and measurement*, 2008, pp. 253-262.
- [3] T. Arnuphaptrairong, "The Development and Achievements of Software Size Measurement," in *Proceedings of the International MultiConference of Engineers and Computer Scientists 2012 (IMECS 2012)*, Hong Kong, March 14-16, 2012, pp.786-794.
- [4] J. Hihn, and H. Habib-agahi. "Cost Estimation of Software Intensive Projects: A Survey of Current Practices," in *ICSE '91 Proceedings of the 13th international conference on Software engineering*", 1991, pp. 276-287.
- [5] J. M. Verner, and W. M. Evanco, "State of the Practice of Effort Estimation in Business Environment," in *Proceedings of the ESCOM-SCOPE*, 2000, pp. 229-238.
- [6] K. Molokken-Ostfold and M. Jorgensen, "A Review of Surveys on Software Effort Estimation," in *Proceeding of the 2003 International Symposium on Empirical Software Engineering (ISESE'03)*, 2003.
- [7] K. Molokken-Ostfold, M. Jorgensen, and S.S. Tanilkan, "A Survey on Software Estimation in the Norwegian Industry," in *Proceeding of the 10th International Symposium on Software Metrics (METRICS'04)*, 2004.
- [8] A. Trendowicz, J. Munch, and R. Jeffery, "State of the Practice in Software Effort Estimation: A Survey and Literature Review," in *IFIP International Federation for Information Processing*, 2011, pp. 232-245.
- [9] Z. Mansor, Z. M. Kasirun, S. Yahya, and N. H. Arshad, "Current Practices of Software Cost Estimation Technique in Malaysia Context," in *ICIEIS 2011: Informatics Engineering and Information Science*, 2011, pp. 566-574.
- [10] K. McAulay, "Information Systems Development and the Changing Role of MIS in the Organization," in *First New Zealand MIS Management Conference*, 1987.
- [11] F.J. Heenstra and R.J. Kuster, "Controlling Software Development Costs: A Field Study," in *International Conference on Organization and Information Systems*, in 1989.
- [12] G. Wydenbach and J. Paynter, "Software Project Estimation: A Survey of Practices in New Zealand," *New Zealand Journal of Computing*, vol. 6, 1B, pp.317-327, 1995.
- [13] F. Bergeron and J.Y. St.-Arnaud, "Estimation of Information Systems Development Effort: A Pilot Study," *Information and Management*, vol. 22, Number 4, pp. 239-354, 1992.
- [14] M. Jorgensen and B. Boehm, "Software Development Effort Estimation: Formal Models or Expert Judgment?" *IEEE Software*, vol. 26, Number 02, March/April, pp. 14-19, 2009.

Tharwon Arnuphaptrairong is an Associate Professor in Business Information Technology at the Department of Statistics, Faculty of Commerce and Accountancy, Chulalongkorn University, Thailand. He received a B.Sc. Degree in Statistics from Chulalongkorn University, A M.Sc. in Computer Applications from Asian Institute of Technology, Bangkok, Thailand, and a Ph.D. Degree in Management Sciences from University of Waterloo, Canada. His research interests include Software Project Management, Software Risk Management, Software Cost Estimation and Empirical Software Engineering.