International Journal on Advanced Science Engineering Information Technology
Vol.8 (2018) No. 5
ISSN: 2088-5334

Validated Software Cost Estimation Factors for Government Projects using Rasch Measurement Model

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***Abstract*— Software cost estimation (SCE) in software management can be a complicated task, as it could yield inaccurate results. Based on new empirical evidence, Public sectors more often face estimation failure, which causes projects to over shoot budgets, get delayed, face termination or the project scope or requirement to remain incomplete. Hence, the main aim of this paper is to identify the critical factors that significantly impact SCE in the context of software development in the Indonesian regional government. This research employs a quantitative approach, in which a questionnaire is used as the data collection instrument. The data is analysed using a RASCH model. This study is conducted in the regional government of West Sumatera Province, Indonesia. The result of the study reveals that there are six critical factors that significantly impact SCE results in a government project. These critical factors are programmer capability, top management support, the understanding of top management regarding the objectives of the project, risk management, knowledge, competency of the project manager, and top management involvement in the project.**

***Keywords*— software cost estimation; critical factors, government projects; rasch; Indonesia.**

I. INTRODUCTION

The essential part of software project development is the prediction of the project costs required to complete the project effectively. Software cost estimation is a complicated task in software management due to inaccuracies that can occur in estimation [1], [2]. According to Ramesh and Reddy [1], the result obtained from software cost estimation can be over- or underestimated and thus inaccurate. Overestimation might waste resources, while underestimation can incur additional costs or project cancellation.

Thus, accuracy in software cost estimation is important, as this determines the success of a project. According to Leena [3], the accuracy of software cost estimation is vital due to the following reasons:

- It could be used to identify and manage the resources of the project wisely.
- The customer expectation of the actual cost should be in line with the estimation cost.
- It could be used to evaluate the effect of changes to be made and to guide re-planning of the project.
- Project control and management could be made easier by using resources wisely.
- It could assist project development to meet the overall business plan.

Furthermore, getting the exact result for software cost estimation continues to be problematic for the Government and the Private sector. Nevertheless, based on new empirical evidence, Public sectors more often face estimation failure, which causes projects to shoot over budgets, become delayed and all the project requirements undelivered [4], [5]. Haslindah, Azizah & Othman [5] identified the cost estimation failures that could influence project sustainability. Due to ineffective cost estimates, there have been many instances of government ICT project failures in Malaysia. Consequently, 16% of projects would be cancelled before they ever accomplished their objectives, 53% of projects would be over budget by as much as twice the original estimates, and less than 31% of projects would be successful [5]. According to Zulkefli et al. [6], more than half of all large and complex projects overshoot estimated costs, 15% of projects become delayed, and 25% of projects are terminated before the projects are completed. As a result, this does not only cause cost overruns, but also time wastage.

Likewise, as mentioned in the Chaos report [7], American companies and government agencies have spent $81 billion to cancel projects; if they had wanted to complete the project, an extra cost of $59 billion would have been incurred. As a result, the project would be overrun and over-budget. Based on the Standish Group research in the Chaos report [7], 52.7 of projects would cost 189% more than the original cost estimation. This shows that cost estimates are usually inaccurate.

In addition, based on research conducted in Indonesian companies in 2013, the number one problem occurring in software development is that the actual cost required to accomplish a project is more than the estimated cost [8]. In fact, according to the Presidential Regulation no. 70 of 2012, only software that can estimate owner cost is considered good (Subsection 66 number (5) item a). Before estimating the Owner Estimate Cost (OEC), the Committing Officer (CO) must first identify the associated requirements and specifications. Unfortunately, it is challenging to calculate OEC as part of software cost estimation due to there being no standard techniques for reference and guidance [9]. The critical factor for software cost estimation in government projects is the inability of a project to prepare its scope and requirements. The scope and requirements have to be identified in the first stage of the project. As a result, there are several cases of software development projects putting in unreasonable cost [8]. The scope and requirements determine the cost of the project, primarily if it encompasses all activities of software development [10].

II. MATERIAL AND METHOD

A. *The Components of Software Cost Estimation*

Software cost estimation is a process of estimating the cost, effort, and productivity required to develop a software project [2][11]. The processes involved in software cost estimation include determining software size, estimating the needed effort, deriving the schedule, and calculating the software cost [2]. The essential aspects of software project estimation are to balance the "magic" triangle, which comprises effort, schedule, and quality [11]. So, software cost estimation comprises elements that determine the success or failure of a project.

As stated by Potdar et al. [12], accurate cost estimation is significant to ensure the project is completed within the specified period and budget. Therefore, estimators have to consider all the factors that influence the estimation because inaccurate estimation results may lead to project cost overruns and an overview of software development that is too optimistic. There are five significant critical measurements of software cost estimation, which are an effort, hours, time, resource requirements, and risk occurrence. Ramesh & Reddy [1] stated that software cost estimation consists of one or more determinations such as effort (usually in person-months), a project duration (in calendar time), and cost (in dollars).

Moreover, Sommerville [13] stated that the determinations below are required in estimating software cost:

- Hardware cost, software cost, and maintenance.
- Travel and training costs.
- Effort costs to pay the software engineers.

B. *Factors Influencing Software Cost Estimation*

Many factors influence software cost estimation. These include data availability, data quantity, unrealistic assumptions, fewer detail design specifications, project complexity, product size, available time, and level of technology. Other factors are lack of cost estimator experience, historical data quality, lack of user involvement, insufficient requirements, lack of executive support, developer incompetence, and software development method [3], [14], [15]. These factors affect estimation accuracy results [1],[3]. As stated by Zulkefli et al. [14], [16], if the factors influencing software cost estimation are appropriately managed, more accurate estimation results could be achieved. Otherwise, the cost of the project might increase.

Likewise, according to Rajkumar & Alagarsamy [9], the major factors influencing software cost estimation are management based on the experience, knowledge, skills, and commitment of staff. These factors also play an important role in the software development process, as shown in Fig. 1. Besides that, project design is associated with project planning and project variables, which are significant in identifying the requirements and outcome of a project. Therefore, data and information gathering is important to determine the resources of a project. Financial issues also contribute towards project completion because budget constraints can delay a project. User responses indicate how users react to a new system because most end-users do not have the training to use a new system and find it difficult to adapt to using the system. Likewise, user involvement in the development process is also significant. Project pricing does not involve management only, but also the customer that will be involved in project development. Thus, many factors influence the success of software cost estimation.

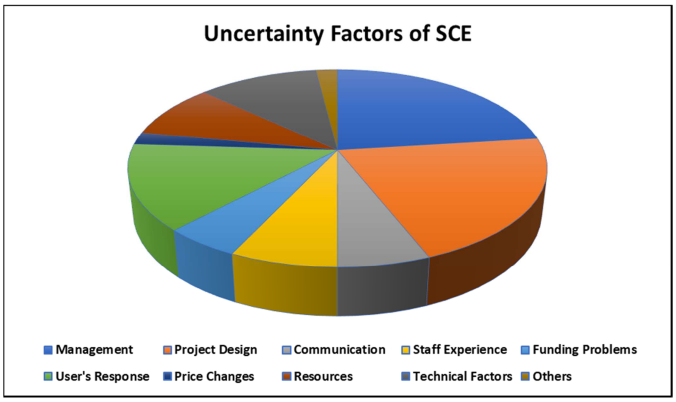

Fig. 1 The major uncertainty factors affecting SCE

Ubani et al. [4] found that the possibility of Public sector projects becoming overrun is higher than that of Private sector projects because many factors influence the software cost estimation process such as project complexity and the inexperience of the cost estimator. Besides that, some project costs are purposely understated to ensure acceptance of the project and to gain funding commitments. Therefore, software cost estimation should be investigated in more depth, mainly because previous research has shown poor records of software cost estimations. According to Flyvberjerg et al. (2002) [4], the noble principle has slowly been adopted into project management, especially in the Public sector, where people are using the noble principle as a foundation when it comes to miscalculating expenses of Public projects. The latter could be a situation where a particular project would be in the interest of the people. On the other hand, the total cost to be invested in the project always tends to frighten off the public due to the huge cost of money to be invested.

As stated by Phongpaibul and Aroonvatanaporn [17], the cost estimation of software development projects in the government tends to be biased, inaccurate, and exceedingly unjustified. Hence, corruption could happen, which would greatly impact a country, especially its economic growth. Furthermore, lack of historical government project records also impacts data availability, making the quantity and quality of data ineffective and inefficient. This, in turn, results in non-centralised data that is not collected and maintained consistently. In the end, it will not be effective to use historical data for estimating cost. So, the better the data quality, the better the estimation quality would be.

Besides the factors above, people who lack experience in estimating costs are often involved in the estimating process. For instance, the United States Government Accountability Office (GAO) found that NASA lacked good cost analyst skills. The person who performs the estimation should be a budget specialist that has the responsibility of managing funds. Cost analysts are the ones that are supposed to make the cost prediction because they are responsible for facilitating financial services to control the project so that the project would be on track [15]. Moreover, Haslinda, Azizah & Othman [5] investigated government ICT project failure in Malaysia. The failure was due to ineffective cost estimation and because the project did not fit project requirements. The leading cause was organizational factors, in which the agencies or project champions did not correctly conduct the cost estimation process, as the government had reduced the project cost because of the economic downturn.

Likewise, good cost estimation also represents the project manager's capability [11]. Singh and Dwivedi [15] also stated that the most significant factor influencing the success of a project is management ability and the people involved in the project. As stated by Renny et al. [16], the number of failures in IT projects is high due to several factors including less support from top management, lack of user involvement, unclear project objectives, and organizational immaturity.

Mansor et al. [14] stated that most project managers use manual methods to perform calculations due to unavailability of computerized tools. The tools usually selected for performing calculations are EVM, cash flow statements, WBS statements, burndown charts, and Gantt charts that are drafted with the help of Microsoft Excel. They also use HP quality center, which is an automated method. Unfortunately, this does not have all the functionalities to support cost estimation.

Quality requirements can also influence the amount of effort required to complete a project. Thus, this factor also affects the expenditures required to finish a project. For instance, if the requirement of a security system level were changed, the project would require more cost, effort, and resources [20].

Therefore, many factors influence software cost estimation, and these are outlined in Table 1.

TABLE I
FACTORS INFLUENCING SCE ACCURACY

No.	SCE Factors	No.	SCE Factors
1	Data availability	8	Time availability
2	Data Quantity	9	Technology
3	Assumptions	10	Historical data of the project
4	Project complexity	11	User involvement
5	Project Size	12	Project Requirements
6	Level of Technology	13	Executive support
7	Cost estimator ability	14	Competency of the project team

The data were analyzed using the Rasch model. Georg Rasch introduced the Rasch model in 1960. The model is prevalent because it is based on the item response theory (IRT), which describes the relationship between persons and test items. Furthermore, the Rasch model has also been used to analyze dichotomous data; the model was further evolved by Andrich to analyze rating-scale data. Masters also improved the Rasch model so that it could be used to evaluate a partial model. Lastly, Linacre introduced the facets model. Also, the Rasch model can analyze data from science and social science fields such as education, psychology, marketing, communication, and so forth [21]. According to Engelhard & Stefanie [22], the Rasch model is used to measure the items, respondents, and the relationship between the item and the respondent. As a result, it can explain a specific person's capability and item difficulties. The results can be used to identify respondent competency and the difficulty level of the items.

TABLE II
INSTRUMENT DETAILS

Dimension	**Total Factors**	**Description**	**Samples**
Technology	3	To measure the impact of proper tool availability and usability in estimating software cost.	Software cost estimation is done using a proper tool.
Process	31	To examine the effect of people involved in the project on SCE.	Previous project data is important to estimate the software cost of a new project.
Stakeholders	12	To measure the SCE in the Public sector and its influence on SCE.	The project manager is knowledgeable and competent in ICT.
Organisational Factors	4	To examine the effect of the environment on the SCE.	The hierarchical structure influences the decision-making process.

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     SUMMARY OF 96 MEASURED Person
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT    |
|          SCORE      COUNT     MEASURE   ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN      201.4      50.0       1.79     .23      1.08    -.1   1.05    -.2 |
| S.D.       16.1        .1        .85     .03       .78    2.7    .76    2.6 |
| MAX.      233.0      50.0       3.76     .30      5.44    9.9   5.48    9.9 |
| MIN.      157.0      49.0       -.04     .17       .25   -4.7    .23   -5.0 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .27 TRUE SD     .81  SEPARATION  3.05  Person RELIABILITY  .90 |
|MODEL RMSE    .23 TRUE SD     .82  SEPARATION  3.55  Person RELIABILITY  .93 |
| S.E. OF Person MEAN = .09                                                   |
-------------------------------------------------------------------------------
Person RAW SCORE-TO-MEASURE CORRELATION = .99
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .92

     SUMMARY OF 50 MEASURED Item
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT    |
|          SCORE      COUNT     MEASURE   ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN      386.8      96.0        .00     .17      1.01     .0   1.05     .1 |
| S.D.       26.8        .1        .71     .02       .32    2.0    .36    2.2 |
| MAX.      444.0      96.0       1.57     .21      1.86    4.8   1.98    5.1 |
| MIN.      315.0      95.0      -1.86     .13       .41   -4.6    .42   -4.7 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .18 TRUE SD     .69  SEPARATION  3.91  Item   RELIABILITY  .94 |
|MODEL RMSE    .17 TRUE SD     .69  SEPARATION  4.16  Item   RELIABILITY  .95 |
| S.E. OF Item MEAN = .10                                                     |
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Fig. 2 Instrument validation

The instrument used in this study is the questionnaire, which consists of 50 questions. The scale measurements of data are as follows: strongly disagree, disagree, neutral, agree, and strongly agree. The questionnaire contains four dimensions, as shown in Table 2.

The participants in this study are government employees involved in software cost estimation projects in West Sumatera Province, Indonesia. The most dominant gender in this study is the male population, making up 57.30%, while the female respondents make up 42.70%.

III. Results and Discussion

Software cost estimation factors for government projects was validated using the following value: Cronbach's alpha, person reliability, item reliability, infit and outfit MNSQ, infit and outfit ZSTD, person mean, and item mean, as shown in Fig. 2. Moreover, the critical factors affecting software cost estimation were identified based on the pearson item distribution map.

1) Cronbach's Alpha

The Cronbach's alpha value identifies the reliability of an instrument. The value of Cronbach's alpha for this study is 0.92, which shows that the correlation between item and person are very good. Furthermore, the result indicates that it has high reliability and a high consistency for the raw score (instrument).

2) Person Reliability

The person reliability value is 0.90, indicating that the respondents are qualified to respond to this study. Therefore, the ability spread of the sample involved in this study is very good. Likewise, the person mean value is 1.79, which is greater than the item mean value of 0.00. The mean logit indicates that overall the respondents agree that these factors affect the software cost estimation results in the Public Sector. Besides that, if the person mean is higher than the item means, then the entire test meets the expectation of this study. So, the person reliability value and the comparison between the person mean and item mean can be used for personability measures in this study.

3) Item Reliability

The item reliability in this study is very good because the value is high, which is 0.94. This reveals that the item difficulties among the items are spread well. Hence, it also indicates that if the test were given to a different respondent group, the possibility of the item difficulties would still be the same.

4) Infit and Outfit MNSQ

The infit is used to identify the unexpected response given by the respondents near the capability level of the respondent. The outfit is used to consider the expected answer and the actual answer given by the respondent, which shows how far away the item is agreed from personability. Furthermore, the infit and outfit MNSQ person are 1.08 and 1.05, respectively. Also, the infit and outfit MNSQ items are 1.01 and 1.03, respectively, which have a good value since the mean-square fit statistic value should be between 0.50 and 1.50. Therefore, the items do not easily guess or predict the answer. The ideal value of MNSQ is 1, so the value of the result above is close to the ideal value. This also indicates that it can be used for measurement [23].

5) Infit and Outfit ZSTD

According to Bambang and Wahyu [24], the ideal value of infit and outfit should be 0. The data has a reasonable logic if the value of the infit and outfit of ZSTD falls between $-1.90<y<1.90$. Based on the result above (see

Figure 1), the infit and outfit items are 0.00 and 0.10, respectively, which indicates that the items fit the model and can measure what is supposed to be measured.

6) Item Separation

The separation value indicates the quality of the separation between person and item. The separation is good when the value of separation is high, which means the quality instruments are better as well. The value of the separation (see Figure 1) is 3.05, which shows that the instrument quality is good.

show ideal results since they are not more than 15%. The value is 11.1% and the other values are below 10% [23].

9) Scalogram

The scalogram result reveals the consistency of answers given by the respondents. As shown in Fig. 5, respondents 66 and 43 should answered four and five instead of two and three. Although they are competent respondents, they might have simply ticked their answers. The scalogram can be used to identify the item from the easiest item to the most difficult items to be endorsed and the most competent respondent to

Table of STANDARDIZED RESIDUAL variance (in Eigenvalue units)

		-- Empirical --			Modeled
Total raw variance in observations	=	70.8	100.0%		100.0%
Raw variance explained by measures	=	20.8	29.4%		32.1%
Raw variance explained by persons	=	7.3	10.3%		11.2%
Raw Variance explained by items	=	13.5	19.1%		20.8%
Raw unexplained variance (total)	=	50.0	70.6%	100.0%	67.9%
Unexplned variance in 1st contrast	=	5.5	7.8%	11.1%	
Unexplned variance in 2nd contrast	=	4.4	6.2%	8.8%	
Unexplned variance in 3rd contrast	=	3.4	4.9%	6.9%	
Unexplned variance in 4th contrast	=	3.0	4.2%	5.9%	
Unexplned variance in 5th contrast	=	2.7	3.8%	5.4%	

Fig. 4 Item Dimensionality

7) Local Independence

Local independence means every response has to be determined only by the person's ability. Therefore, it must be independent, which means that one item does not overlap with other items. The value is less than 0.70, indicating that the items are independent of each other [24]. Hence, as shown in Fig. 3, the result shows that no item overlaps with another.

LARGEST STANDARDIZED RESIDUAL CORRELATIONS
USED TO IDENTIFY DEPENDENT Item

CORREL-ATION	ENTRY NUMBER	Item	ENTRY NUMBER	Item
.65	38	I0038	39	I0039
.61	4	I0004	5	I0005
.58	19	I0019	20	I0020
.58	16	I0016	17	I0017
.57	4	I0004	6	I0006
.56	14	I0014	15	I0015
.53	5	I0005	6	I0006
.51	42	I0042	43	I0043
.44	20	I0020	21	I0021
-.47	26	I0026	27	I0027

Fig. 3 Local Independence Result

8) Item Dimensionality

The item dimensionality, as shown in Fig. 4, is 29.4%, which is higher than 20%. This shows that the instruments are able to measure what they are supposed to measure. Hence, the items fulfil the item dimensionality requirement. Moreover, there are also unexplained variance values, which

the least competent respondent, as illustrated in Fig. 5. It can also check for any careless answers given by the respondents, even if they fall in the most competent category.

10) Person Item Distribution Map

The person item distribution map (as shown in Fig. 6) is used to identify the critical factors that significantly impact software cost estimation accuracy. As a result, six critical factors have a significant impact on the accurate result of SCE (as shown in Table 3).

The first critical factor is programmer capability significance towards the success of a project. The programmer plays a vital role in software development because the progress and accomplishment of the project depend on the programmer, who is responsible for developing the software. The project manager must have competent skills, knowledge, and experience so that the project can be completed within the time and cost estimate.

Moreover, other critical factors include top management. Top management support is essential for the project to be successful. Besides that, the top management should understand the objectives of the project, so that the top management sees the necessity of particular software to increase the efficiency of agency activities. Additionally, the top management should also be involved and committed to the project. As a result, this will assist the top management to understand the project and to be aware of the progress of the project.

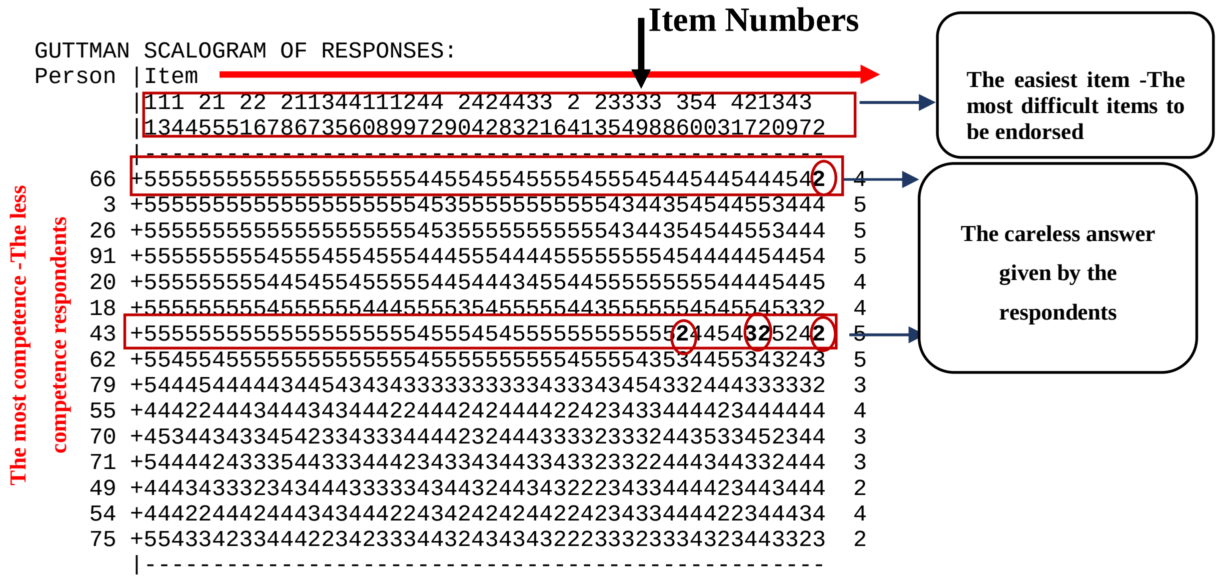

Fig. 5 Guttman Scalogram

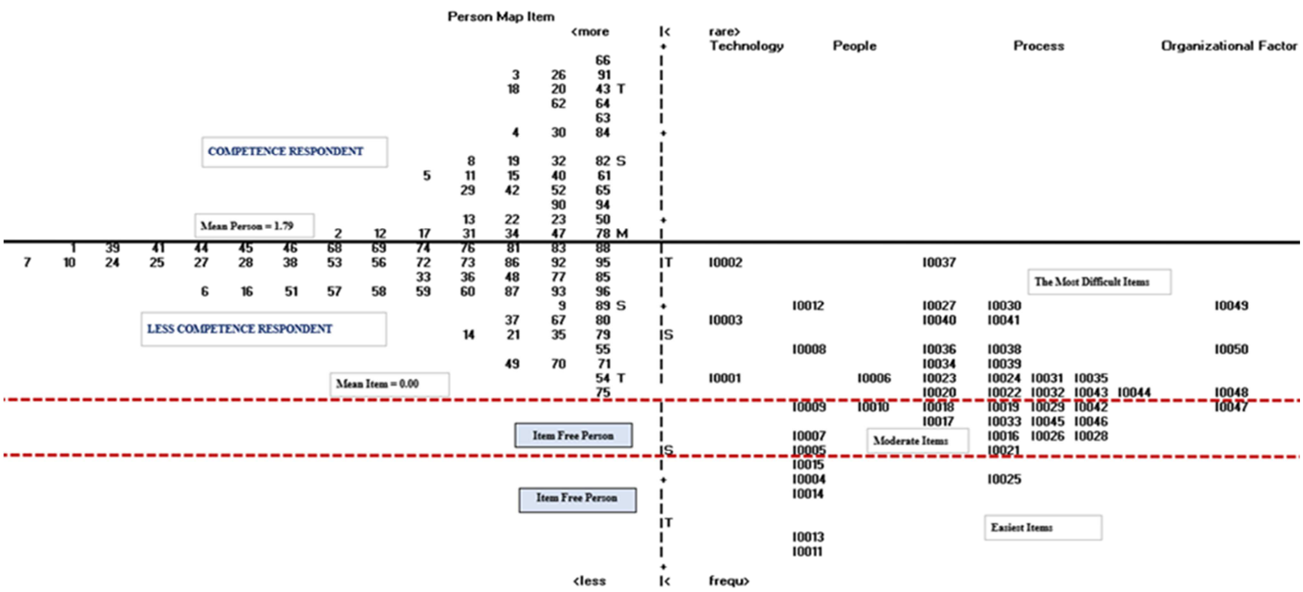

Fig. 6 Person Item Distribution Map

TABLE III
CRITICAL FACTORS AFFECTING SCE

Item Number	Item Measure	Factors	Dimension	Sub-Dimension
I0011	-1.86	Programmer capability significance towards the success of a project.	People	Personnel/Team Capabilities
I0013	-1.65	Top management support is essential for the project to be successful.	People	Top Management
I0014	-1.11	Top management understands the objectives of the project.	People	Top Management
I0025	-1.04	Risks that occur during software development are managed well.	Process	Risk Management
I0004	-1.04	The project manager is knowledgeable and competent in ICT.	People	Project Manager
I0015	-0.84	Top management is involved and committed to the project.	People	Top Management

Likewise, the fifth factor affecting SCE is that "the project manager is knowledgeable and competent in ICT", which is under the people dimension. Although the programmer develops the software, the project manager role substantially affects the success of a project. The project manager is responsible for controlling the project so that it is on track with the estimation. This includes the time, cost, and quality of the software, which has been stated in the scope and requirements of the project. Furthermore, the fourth factor is under the process dimension, which is "Risks that occurs during the software development project are managed well." Software cost estimation has many uncertainties. Thus, many risks might occur during the software development project. Consequently, the most critical factors that significantly impact software cost estimation in the Public Sector are the people and process dimensions.

IV. Conclusion

Many factors contribute to the inaccurate results of software cost estimation, which include technology, process, project team capability, and organizational factor dimensions. These factors should be considered, especially as each factor has a meaningful impact on the software cost estimation result. Furthermore, six critical factors influence software cost estimation, which fall under the people and process dimensions such as top management, project manager, and risk management sub-dimensions. Hence, many aspects need to be considered because the software cost estimation process is complex and many uncertainties might occur during software development.

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