# Predictive Model on Interest to Own Smart Meter

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***Abstract*—Smart meter is an enhanced energy meter that computes the energy consumption of a consumer, and delivers added information to the utility company compared to a conventional energy meter. The objective of this paper is to determine the interest level of owning smart meter amongst the Tenaga Nasional Berhad (TNB) customers in the area of Melaka, Malaysia. Questionnaire Survey method was adopted in this study and 440 numbers of questionnaires were successfully collected. The questionnaire survey was conducted using face-to-face method. The survey was conducted during pre-installation of smart meter phases in order to determine the customers' level of interest to own smart meters. The findings shows that the majority of the customers were convinced that their personal data will be well protected, hence increasing their acceptance level to own smart meter. However, a minority of customers have expressed their concerns on privacy issues in the smart meter system. This study shows that TNB customers in Melaka, regardless of demographic profiles and background, overall have good awareness on smart living concept which was reflected in their positive feedbacks towards smart meters. The findings of this study can be inferred to similar residential and commercial areas. In general, it provides some insights on the attitude, perceptions and acceptance levels of Malaysian users towards smart metering.**

***Index Terms*—Acceptance level, customers, predictive model, smart meter**

## I. Introduction

In the past decade, as the electricity consumption has grown at a remarkable rate, so does the development of technology in electricity monitoring and billing. Many countries have already started the smart meter implementation, for example France, Germany, Netherlands, Norway, United Kingdom and United States of America [1]. It is estimated that more than 100 million end users are benefiting from smart meter technologies worldwide [2]. China has also projected its capital Beijing to have 100% smart meter coverage for residential users by the end of 2015 [3]. Following many studies conducted on the development process of smart meter, there are numerous literatures which provide in-depth study on the use of smart meters [1], the related challenges and issues [4], and methods of efficient monitoring [5]. A recent advance smart meter networking has enabled fine-grained appliance state monitoring. Reference [5] pointed out that in order to achieve efficient energy control, one important strategy is to monitor the real-time on/off states of electrical appliances using the smart devices which collect these. Efficient energy control will lead to low cost, accurate and scalable energy auditing system. Smart meters can be foreseen to play an important role in future electricity distribution, as well as usage, performance and grid load monitoring. Regular data input from the customers will allow the utility companies to manage electricity demand more efficiently and also to advise the customers about the most cost efficient way to use their appliances.

There are many researches that has been conducted recently on smart meters and its enabled services that focused on the use of smart meter to provide feedback to consumers, public perception on smart meter and consumer acceptance of various demand-side response options [6]

The integration of smart meters will also help utility companies to detect unauthorized consumption and electricity theft [4]. Electricity theft otherwise known as 'illegal abstraction', 'tampering' or 'interference', is a physical methods used to evade payment for some or all of the electricity consumed. This is typically done by slowing or stopping the meter installed from recording consumption, or bypassing it completely [7]. Thus, this paper focuses on TNB customer's acceptance or interest towards owning smart meters during pre-installation of smart meter phase.

## II. Methodology

### A. Questionnaire Survey

A Quantitative approach using questionnaires survey was adopted in this study and was conducted during pre-installation phase. The survey was conducted using mixed survey methods which include self-administered and face-to-face (door-to-door) survey. The target respondents in this study were the customers of TNB. The study area involves few districts in Melaka, Malaysia which were chosen due to its receptiveness of the Melaka state government to technological changes especially on smart living initiative. Melaka Tengah and Alor Gajah area were selected by TNB to be involved in the Smart Meter pilot project with the total population of 1500 TNB customers. The questionnaire for customer profiling and survey was designed through extensive literatures and also 'syndication and focus group' sessions with the

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subject matter experts from various departments in TNB which includes TNB Research Sdn. Bhd.; TNB Customer Services Department; TNB Transformation Department; Corporate Planning and Sustainability Department (Regulatory Economics and Planning Division); TNB ICT Division; and TNB smart meter demonstration project team. The questionnaire was designed consisting of four (4) sections, Section A: customer profile; Section B: customers' awareness and knowledge on smart living; Section C: customers' perception, expectation and interest on smart meter; and Section D: customers' preferences on smart meter features. However, this paper focuses on results and findings based on Section A on the customer profile and Section C on customers' perception, expectation and interest on smart meter. Data were successfully collected from a total of 440 TNB customers within the Malacca area using two questionnaire distribution methods: self-administered (conducted at Melaka International Trade Centre (MITC) during the launching of smart meter event and face-to-face/door-to-door around Melaka Tengah and Alor Gajah area. Two (2) types of analyses were used to analyse the data from the questionnaire survey as described in the following sub-sections.

### B. Descriptive Analysis

A descriptive analysis was used to study the profile of the respondents. Cross-tabulation was used to show the joint frequency distribution of cases which are based on two or more categorical variables.

### C. Logistic Regression Analysis

The logistic regression analysis is to predict the interest of the respondents to own smart meters in their home. Logistic regression is a statistical model for predicting the probability of a categorical or binary dependent variable. Binary logistic regression is a type of regression analysis where the dependent variable is a dummy variable (coded 0, 1). Binary logistic allows estimating the probability of an event happening. The probabilities describing the possible outcomes of a single trial are modelled, as a function of the explanatory (predictor) variables, using a logistic function.

## II. Results and Analysis

This section presents the descriptive analysis on the customers' profile together with the binary logistic regression analysis.

### A. Customers' Profile

A detailed description of the customer profiles is summarized in Table I. It is observed that the majority (62.4%) of TNB customers surveyed were males. Almost half (49.7%) aged between 25 to 44 years with a mere (3.1%) who were beyond 64 years of age. Close to three quarters (74.3%) of the customers surveyed were Malays. Just under one-third (28.7%) of the customers came from households with monthly income of more than RM6000, and approximately a two-third (64.8%) of the customers has tertiary education. On average, every household has 4.67 members with a standard deviation of 1.95 members. The total number of members in a household ranged from 1 to 15. In addition, almost all (99%) customers came from Melaka Tengah area.

TABLE I: PERCENTAGE DISTRIBUTION OF THE CUSTOMERS' CHARACTERISTICS

| Characteristics | | Number of Customers | % |
|---|---|---|---|
| Gender | Male | 260 | 62.4 |
| | Female | 157 | 37.6 |
| Age | Less than 25 years | 8 | 2.1 |
| | 25 – 44 | 190 | 49.7 |
| | 45 – 64 | 172 | 45.0 |
| | More than 64 years | 12 | 3.1 |
| Race | Malay | 324 | 74.3 |
| | Chinese | 86 | 19.7 |
| | Indian | 23 | 5.3 |
| | Others (Bangladesh, Nepal & Eurasian) | 3 | 0.7 |
| Highest educational qualification | Primary school | 4 | 1.0 |
| | Secondary school | 105 | 27.6 |
| | Vocational/Technical | 21 | 5.5 |
| | Tertiary | 247 | 64.8 |
| | Others (Not specified) | 4 | 1.0 |
| Monthly household income | Less than RM901 | 13 | 3.7 |
| | RM901 - RM2000 | 27 | 7.6 |
| | RM2001 - RM3000 | 45 | 12.7 |
| | RM3001 - RM4000 | 62 | 17.5 |
| | RM4001 - RM5000 | 65 | 18.3 |
| | RM5001 - RM6000 | 41 | 11.5 |
| | More than RM6000 | 102 | 28.7 |

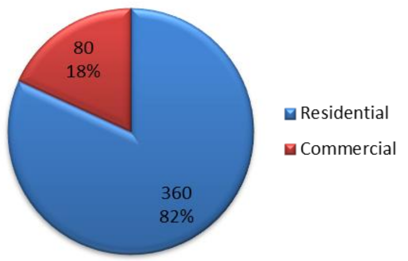


Fig. 1. Percentage distribution of type of customer

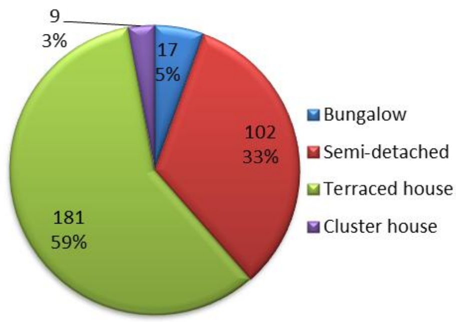


Fig. 2. Percentage distribution of type of residence

Fig. 1 shows the percentage distribution based on types of customer. Eighty-two percent (82%) of the premises interviewed are households from residential areas. The rest are from commercial premises while Fig. 2 depicts the percentage distribution of customers based on types of residence. Most of those who were from the residential area live in terrace houses (59%) or semi-detached houses (33%)

## B. Binary Logistic Regression Analysis

The binary logistic regression modeling for the smart meter interest involves three steps: 1) determining the predictive ability of the model using a "classification table", 2) model evaluation by carrying out the Omnibus test of model coefficient, Cox & Snell R2 and Nagelkerke R2 tests and Hosmer-Lemeshow Goodness of Fit (GoF) test and 3) assessing the contribution of individual predictors based on a "coefficients of predictor variables in the equation" table as described in the following sub-sections.

## C. Predictive Ability of the Smart Meter Interest Modelling

In the binary logistic regression model, eight independent factors were regressed against interest to own a smart meter. Table II shows the classification table which has the ability to describe the predictive ability of the interest model. In other words, it is able to assess how well the model distinguishes TNB customers who are interested to own a smart meter from those who are not interested. According to Table II, 356 customers who are interested to own a smart meter are predicted as interested. Hence, the model correctly predicts those who are interested to own Smart meter 97% of the time. Thirty nine (39) customers who specified that they are not interested to own a smart meter was predicted as interested.

TABLE II: CLASSIFICATION TABLE FOR SMART METER INTEREST

| Observed | | Predicted: Are you interested to own a smart meter? No | Predicted: Are you interested to own a smart meter? Yes | Percentage correct |
|---|---|---|---|---|
| Are you interested to own a smart meter? | No | 20 | 39 | 33.9 |
| | Yes | 11 | 356 | 97.0 |

Therefore, the model was able to correctly predict those who were not interested to own Smart meter only 33.9% of the time. From these findings it can be concluded that the percentage of customers who has interest to own smart meter is significantly low. This is expected because smart meter is a new technology in Malaysia. The awareness on smart meters and its benefits among Malaysians are still at the initial stage.

## D. Model Evaluation

The classification table in Table II for the smart meter interest does not give any measure of significance, and it is therefore, not easily to compare and fit in linear regression. Initially, there were eight factors that were regressed on interest to own a smart meter namely; usage & technology, smart meter features, PDPA, customer type, gender, age, monthly household income and highest educational qualification. Thus, the following measures of model fit were developed for logistic regression under model evaluation. The interest model was evaluated based on several methods such as Omnibus test, -2 log-likelihood value, Cox & Snell, Nagelkerke and Hosmer & Lemeshow test with results summarized in Table III. The results reveals that the Omnibus test of model coefficients is significant; [$\chi^2$ (5) = 83.225, $p < 0.05$] which indicates that the model has a good set of independent (predictor) variables. Thus, the small p-value from the Omnibus test indicated that the binary logistic regression model performs well. The R square statistics from Cox & Snell and Nagelkerke indicate how useful interest on smart meter features and PDPA as the explanatory variables in predicting interest to own smart meter (response variable).

The variation in interest to own smart meter which is explained by both factors ranged between 17.7 to 32.1 %. The p-value of 0.687 which is much greater than 0.10 from the Hosmer & Lemeshow test indicated that the binary logistic model is considered worthwhile.

TABLE III: RESULTS FROM MODEL EVALUATION

| Omnibus Test | | | Model Summary | | | Hosmer & Lemeshow Test | | |
|---|---|---|---|---|---|---|---|---|
| Chi-square | df | Sig. | -2LL | Cox & Snell $R^2$ | Nagelkerke $R^2$ | Chi-square | df | Sig. |
| 83.225 | 5 | .000 | 259.472 | 0.177 | 0.321 | 5.644 | 8 | 0.687 |

TABLE IV: COEFFICIENTS OF PREDICTOR VARIABLES IN THE EQUATION

| Factors | Variables in Equation | | | | | | 95% C.I. for Exp(B) | |
|---|---|---|---|---|---|---|---|---|
| | Coefficient | S.E. | Wald | df | Sig. | Exp (B) | Lower | Upper |
| SM Features | 1.209 | 0.243 | 24.862 | 1 | .000* | 3.351 | 2.083 | 5.391 |
| PDPA (S. Disagree) | | | 47.485 | 4 | .000 | | | |
| PDPA (S. Agree) | 1.524 | 0.787 | 3.747 | 1 | .053* | 4.589 | 0.981 | 21.460 |
| PDPA (Agree) | 1.934 | 0.795 | 5.916 | 1 | .015* | 6.919 | 1.456 | 32.879 |
| PDPA (Neutral) | -0.903 | 0.817 | 1.221 | 1 | .269 | 0.405 | 0.082 | 2.012 |
| PDPA (Disagree) | -0.867 | 1.771 | 0.240 | 1 | .624 | 0.420 | 0.013 | 13.526 |
| Constant | -3.970 | 1.182 | 11.287 | 1 | .001 | 0.019 | | |

* Significant at 10%

## E. Assessing the Contribution of Individual Predictors

The contribution or the impact of each predictor on the likelihood of the customers' interest to own smart meter is also assessed in this section. Table IV known as "coefficient of predictor variables in the equation" provides information on the contribution or importance of each of the predictors in the smart meter interest model. Based on Table IV, the coefficients (B) and "Wald" statistic values were used to identify the independent variables that are good predictors. It assesses the successive accuracy of a model by evaluating its ability to predict correctly the category in cases for which the outcome is known, in this case for customers that are interested to own smart meters. By looking at the values under the fifth column labeled "Sig.", the factors corresponding to the values that are less than 0.10, are the factors that contribute significantly to the predictive ability of the smart meter interest model. The findings show two predictors or factors (smart meter features, PDPA - Strongly Agree and PDPA - Agree) are statistically significant having Sig. values of 0.000, 0.053, and 0.15. In general, these are the factors that were considered by the customers before determining their interest to own smart meters. On the other hand, the PDPA - Neutral factor with a "Sig." value of 0.269 (>0.10), did not signify-cantly influence the customers' interest to own smart meters. The Wald tests also show that both explanatory variables contribute significantly to the model. This can be seen in the confidence intervals for the odds ratios, none of which include 1. Based on Table IV, the fitted model can be illustrated in (1) as follows:

$$\text{Logit}(p) = -3.97 + (1.209 \text{ Smart meter features}) + 1.524 \text{ PDPA(Strongly Agree)} + 1.934 \text{ PDPA(Agree)} \quad (1)$$

where $p$ is the probability of interest to own a smart meter with smart meter features and PDPA as the explanatory variables.

Another important element from Table IV is the interpretation of the odds ratio (OR), the values provided by the Exp (B) value (seventh column). For this, the B values (second column) are used in the equation to calculate the probability of a case falling in to a specific category of the smart meter interest decision either "interest" or "not interested". Thus, these values are the odds ratios (OR) for each of the predictor variables for the smart meter interest. The OR represents 'the change in odds' of being in one of the categories of outcome when the value of a predictor increases by one unit. Since each predictor is a continuous variable, "increase" is reported for values more than 1 of the odds for each unit increase in the predictor variable. On the other hand, "decrease" is reported for values less than 1 of the odds for each unit increase in the predictor variable. The odds ratios for significant variables (smart meter features and PDPA) are explained in the following sub-sections based on smart meter features and PDPA issue.

Smart meter features - Smart meter features: Exp ($B$) = 3.351. The smarter meter features that the TNB customer prefer, the more likely he is interested to own a smart meter. For each additional increase in smart meter feature score, the odds of a customer to be interested to own a smart meter increases by a factor of 3.351. Therefore, a TNB customer who prefers smarter meter's features has a 77% chance of being interested to own a smart meter.

PDPA - PDPA (Strongly Agree): exp($B$) = 4.589. A TNB customer who strongly agrees if a smart meter application does not violate his privacy as subjected to Personal Data Protection Act (PDPA) is 4.589 times more likely to be interested to own a smart meter as compared to a customer who strongly disagrees. In other words, a TNB customer who strongly agrees if a smart meter application does not violate his privacy as subjected to Personal Data Protection Act (PDPA) smart meter features has 82.1% chance of being interested to own a smart meter.

PDPA (Agree): exp ($B$) = 6.919. A TNB customer who agrees to the idea that a smart meter application does not violate his privacy as subjected to Personal Data Protection Act (PDPA) is 6.919 times more likely to be interested to own a Smart meter as compared to a customer who strongly disagrees. In other words, a TNB customer who agrees with the idea that a smart meter application does not violate his privacy as subjected to Personal Data Protection Act (PDPA) smart meter features has 87.4% chance of being interested to own a smart meter.

## III. Discussion

Eight (8) factors were initially examined using binary logistic regression to determine their influence on user's interest to own a smart meter, namely: usage & technology, smart meter features, PDPA, customer type, gender, age, monthly household income, and highest educational qualification. Out of these eight factors, only two, i.e. smart meter features and PDPA, are found to influence the interest to own a smart meter. Hence, the more features smart meter has to offer, the tendency is customers would be more interested to own it. Customers realized many advantages for themselves in smart-home offerings including the chance to reduce their energy bills [8], [9] that increased their desire for a smart meter.

Since implementation of all features at once will be very costly to TNB, the rankings reported in this section serve as a reference for TNB to consider which of the features to be deployed first.

It is found that a minority (12%) of respondents indicated their fears regarding violation of privacy under the Personal Data Protection Act (PDPA) when using TNB smart meter. Similar finding has also been reported [9]-[11]. However, majority (88%) of the respondents were convinced that their personal data will be well protected, and they are more likely to be interested to own smart meters. In previous studies [12] stated that customers are fear about their data privacy and increase in stress levels (because of additional energy consumption information) through the use of smart meter. However, these fears would be addressed if the customers have proper knowledge regarding smart meter, its functions and benefits. As such, a good communication channels such as word of mouth or recently also social media plays an important role in the smart meter enrollment success [13]. It is also important to have a clear and transparent communication with the general public to clarify what consumer expectation on a consequence of smart metering [6].

In addition, by increasing the knowledge of consumption pattern using smart meter, it can lead to a better energy consumption which will lead to a better way to save energy for both consumers and the utility company [14], [15]. Education plans are required to increase the awareness about energy consumption to the consumers [16]. Furthermore, the enhancement in security mechanisms such as using encryption, digital signature, firewall, access control and trusted platform need to be implemented in the software and the communication infrastructure to prevent to data theft [17].

## IV. Conclusion

The study was successfully conducted in several districts in Melaka. A total of 440 number respondents participated during the launching of smart meter in MITC, and through door-to-door survey in Melaka. This involved both domestic and commercial users. From the findings, regardless of demographic profiles and background, the customers have a good level of awareness on smart living concept which was reflected in their positive feedbacks towards smart meter. The majority of the customers were convinced that their personal data are well protected, hence increasing their acceptance level to own smart meters. However, a small number of customers expressed their concerns on the privacy issue regarding their personal data. Thus, awareness on PDPA and security issues ought to be addressed to better convince this group of customers. The findings of this study can be inferred to similar residential and commercial areas. In general, it provides some insights on the attitude, perceptions and acceptance levels of Malaysian users towards smart metering.

## Conflict of Interest

The authors declare no conflict of interest.

## Author Contributions

Siti Rashidah is the team leader for the smart meter research project and assisted by the team consist of Datin Siti Laila, Asnawi and Azmi; Datin Siti Laila engaged with the stakeholder and managed issues related to customers during the execution of the project; Asnawi assisted in data collection; Siti Rashidah, Asnawi and Azmi analyzed the data; all authors wrote the paper; all authors had approved the final version.

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