Trust in Smart Energy Meters: The Role of Perceived values

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Abstract
A smart energy meter is one of the smart city applications that record, monitor, control, analyze, and predict in-house energy consumption. Although smart energy meters have great capabilities, this technology is still in very early stages in many developing countries, and little is known about users' trust in this technology and what perceived values are associated with trust from users' perspectives. Therefore, this research aimed to fill this gap by examining the influence of four different types of perceived values on residents' trust in smart meters in UAE. By following a quantitative approach, 266 survey responses were tested by using Structural Equation Modeling-Partial Least Squares. The statistical results genuinely indicated that perceived epistemic values significantly impact emotional values, monetary values and convenience values, and that emotional values, monetary value and convenience values significantly influence users' trust in smart energy meters. In addition, the three perceived values of monetary, emotional and convenience also play a significant mediating role between perceived epistemic values and trust in smart energy meters. Theoretical and practical implications are indicated, and directions of future research are specified afterwards.

Keywords
Convenience values, Emotional values, Epistemic values, Monetary values, Trust in smart meters.

1. Introduction
IoT (Internet of Things) technologies are ubiquitous nowadays, and they have different applications and services (Shuhaiber, Mashal, & Alsaryrah, 2019a). As one example, smart metering system is an integrated solution for recording, monitoring and controlling energy consumption rates at homes. They do not only measure the energy consumption, but also send the status wirelessly to the energy supplier company, which means there is will be longer a need to read the meter readings manually. In its simplest form, the smart metering system consists of two devices: a smart energy meter of electricity and a separate In-Home Display device – IHD (Shuhaiber, 2020a). The smart meter sends real time data about the current usage of energy from different devices to the IHD which displays the consumption rates in 24/7, and the display instantly shows how much energy in use and how much it costs.

The smart meter, therefore, can provide many benefits to users from several aspects: (a) providing helpful automated visual readings of daily energy consumption that can help users in making decisions associated with their energy usage behavior, (b) helping users in utilizing power resources efficiently by balancing electric loads while reducing power outages (Gianniou, Reinhart, Hsu, Heller, & Rode, 2018) (c) mining the frequent patterns and data association generated from the smart meters (Reddy, Chakravarthy, ReddiNeelima, & Zion, 2018), (d) enabling users for better controlling and forecasting energy loads in regular basis (Fallah, Deo, Shojafar, Conti, & Shamshirband, 2018). This is also associated with enabling dynamic pricing and contributing in optimizing income with existing resources, and (e) avoiding technical, legal, ethical and social issues associated with device malfunctioning, energy leaking and unjustified high bills, government bribery, energy thieving, and others (Shuhaiber, 2018).

2. Previous Studies
Perceived benefits are considered the root construct of performance expectancy and other relevant constructs, such as perceived usefulness, motivation, Job-fit, and perceived outcomes that include the advantages and benefits of a specific kind of technology (Shuhaiber, 2020b). However, some other factors are directly associated with perceived values, such as perceived monetary values, perceived convenience, perceived social values, perceived environmental values, and

emotional values, perceived Epistemic values and trust which have little, if any, focus by scholars and researchers (Bertoldo, Poumadère, & Rodrigues Jr, 2015). As a response, the aim of this research is to examine the influence of perceived values of smart meters on users' trust and behavior on intending to use smart meters, in one developing country which will benefit a lot from such technology: United Arab Emirates. This was achieved by crafting a conceptual model that illustrates the associations between the variables, testing and validating the model, and then providing a discussion about the associated results. Descriptions and details about these types of perceived values are detailed in the subsequent sections.

1.1 Trust

Trust is defined as a justified true belief in smart metering system that determines the associated reliability levels in this technology (Shuhaiber & Mashal, 2019). It is one of the intrinsic values that is important to help people overcome concerns about risk associated with smart energy metering systems (Shuhaiber, Lehmann, & Hooper, 2014). Trust is usually linked to positive attitudes towards a technology and, thus, could be considered as a positive indicator towards the acceptance and adoption. In general, trust construct is usually measured through the dimensions: benevolence, competence, honesty and integrity (Shuhaiber, 2016). In smart meters context, trust in this technology requires establishing reliability about the hardware, software, and information displayed by the display. Trust is also established against perceived security, privacy and technical concerns that could be associated with smart meters from the customer perspective (Mashal & Shuhaiber, 2018). In addition, some perceived values relate to trust, especially when users perceive smart meters as convenient, useful, cutting expenses, emotional and attitude values. Overall, trust is a complex and multidisciplinary concept that is hard to establish in smart technology but easy to break.

1.2 Emotional values

Perceived emotional value referred to as extrinsic values that motivate individual towards smart meter technology and services (Bertoldo et al., 2015). Perceived emotional values assess the three-layer criterion of pleasure, comfort and security. Perceived pleasure, sometimes called perceived enjoyment is considered the hedonic motivation that shows how much fun the user feels about using smart meter IHD and associated technologies of hardware and software (Mashal & Shuhaiber, 2018). Comfort feelings reflect on how much ease and distressful the user feels about smart meters (Shuhaiber, 2018). Security, however, means to what extent the users feels he/she will be secured when using smart meters. These emotional dimensions are believed to have a significant influence on users' trust in smart meters as both attributes are considered intrinsic values, and thus the researcher hypothesize that:
H1: perceived emotional value can significantly and positively influence residents' trust in using a smart meter

1.3 Monetary values

In some specific contexts, the usage of smart metering allows hourly pricing to customers and the freedom to switch between energy suppliers, as in the model available in Sweden (Chou, Kim, Ung, Yutami, Lin, & Son, 2015). In this case, smart meters can alert consumers to shift at peak hours to other times where electricity use is much cheaper prices (Bertoldo et al., 2015). Furthermore, some energy metering services could offer prepaid plans for easier credit tracking by topping up from a computer or a smartphone application, such as in the model available in Turkey. Ideally, smart meters could perform better and save more energy and money by linking them to other smart home devices towards a fully integrated smart home energy solution (Zhou & Brown, 2017). Thus, we hypothesize that:
H2: Perceived monetary value can significantly and positively influence residents' trust in using a smart meter

1.4 Convenience values

Perceived convenience values indicate the suitability and helpful is smart metering system to users (Kranz, Gallenkamp, & Picot, 2010). Time savings is seen as a key convenience value of smart energy meters. The accessibility of smart meter data and monitor are also another key value of convenience. In addition, the availability and readability of real energy data are associated with convenience through which users can access and understand their energy consumption patter whenever they wish and wherever they are located (given that many smart meters provide In Smartphone Application Display (ISAD) in addition to the IHD monitor. Given this, the researcher proposes the following hypothesis:
H3: Perceived convenience values can significantly and positively influence residents' trust in using a smart meter

1.5 Epistemic value

Epistemic value is associated with the amount of knowledge, familiarity and awareness that are users have about smart metering systems IoT and smart applications in general. Usually, the level of awareness of new and innovative technology is considered not high due to the nature of the emerging technology and its innovativeness (Al-Jundi, Shuhaiber, & Augustine, 2019; Shuhaiber, Mashal, & Alsaryrah, 2019b)

In the context of smart meters, epistemic value is particularly important for the understanding the benefits of such a new technology (Kranz et al., 2010), and the researcher suspects that greater perceived epistemic value will be associated with greater intention to use smart meters, thus we hypothesize that:
H4: Perceived epistemic value can significantly and positively influence residents' perceived emotional values in smart meters.
H5: Perceived epistemic value can significantly and positively influence residents' perceived monetary value in smart meters.
H6: Perceived epistemic value can significantly and positively influence residents' perceived convenience values in smart meters.

3. Methodology

In order to address the research aims, a quantitative approach was used in this research. A survey questionnaire was developed to obtain responses in UAE, by revising the literature and pooling relevant items. Afterwards, the most relevant items were chosen and rephrased. The researcher then organized the sequence and blocks of the items. As a result, a total of 25 items were developed to measure the research constructs and to test the research hypothesis.
Online-based surveys were distributed randomly and through the snow-ball technique among people of UAE. Hosting the survey on the web easy to administer, reach respondents easily and cheaply in a huge mass. The targeted respondents were Abu Dhabi residents who are aware of smart meter technology, older than 18 years and willing to participate and share knowledge and perceptions about smart meters. Convenience sampling is one of the most popular sampling approaches for reaching a sample being drawn from a population that is approachable (Bell, Bryman, & Harley, 2018). Social media links and email invitations were shared hyperlinks across personal networks, online blogs and groups. In order to increase the response rate, the researcher sent follow up reminders.

Overall, 266 responses were gathered over online channels and web portals. Each response was checked against bias and incomplete record. As a result, all records showed completeness and no major bias cases were detected, and thus considered valid for data analysis. This sample size is considered for this study; following the rule of thumb which indicates that the sample size should be equal to the larger of 10 times the largest number of structural paths directed at a particular construct in the structural model (Hair Jr, Hult, Ringle, Sarstedt, 2016).

4. Data Analysis and findings discussion

The data was analyzed by using SmartPLS3.0 to perform the Structural Equation Modelling-Partial Least Squares (SEM-PLS) multiple regression analysis. Structural Equation Modelling (SEM) is a casual modelling technique that analyzes the structural relationships among latent variables by combining factor analysis with multiple regression PLS is an iterative process that provides successive approximations for the estimates, subset by subset, of loadings and structural parameters (Hair et al., 2016). The PLS regression algorithm usually examines the items and constructs associated with individual constructs (outer loadings), and then examine the structural model by testing the regression paths, p-values and T-statistics through running PLS algorithm and bootstrapping option of generating random samples of the existing one (Fornell & Larcker, 1981). According to Hair et al. (2016), the threshold point of item loadings is 0.4, but preferably not less than 0.6. Other items with less than 0.4 item loadings should be eliminated as mentioned in the same reference. As a result, all loadings demonstrated reliable items, with all item loadings greater than 0.65 as shown in Table 1.

Table 1. Item Loadings

	Convenience Values	Emotional Values	Epistemic Values	Monetary Values	Trust in Smart meters
Conv1	0.838				
Conv2	0.886				
Conv3	0.829				
Emo1		0.865			

Emo2		0.873			
Emo3		0.843			
Epi1			0.848		
Epi2			0.854		
Epi3			0.686		
Mon1				0.783	
Mon2				0.889	
Mon3				0.852	
Trust1					0.817
Trust2					0.828
Trust3					0.808
Trust4					0.79

Construct validity was also assessed, including both convergent and discriminant validity. Convergent validity refers to the extent all associated items are corelated to the same construct (Hair et al., 2016), and was examined through the Average Variance Explained (AVE) score which should exceeds the cut-off point of 0.5 (Fornell & Larcker, 1981). As shown in Table 2, the AVE scores for all constructs exceeded 0.5, which meets demonstrate convergent validity.

Table 2. Construct Reliability and Validity

	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
Convenience Values	0.81	0.812	0.888	0.725
Emotional Values	0.825	0.826	0.895	0.74
Epistemic Values	0.721	0.758	0.841	0.64
Monetary Values	0.795	0.808	0.88	0.71
Trust in Smart meters	0.826	0.826	0.885	0.658

The internal consistency of all constructs was all assessed by measuring Cronbach's alpha scores, which is achieved by having the score greater than or equal to .70 as the most common threshold (Hair et al., 2016). As presented in Table II, all reliability estimates were found greater than the cut-off point of 0.7 and thus demonstrating internal consistency. The discriminant validity also examined to reflect on how distinct one construct from other latent constructs in predicting the dependent variable (Fornell & Larcker, 1981). The results in Table 3 indicate that none of the off-diagonal elements exceeded the respective diagonal element, as conditioned in the criterion (Fornell & Larcker, 1981), and thus, discriminant validity was achieved.

Table 3. Discriminant Validity

	Convenience Values	Emotional Values	Epistemic Values	Monetary Values	Trust in Smart meters
Convenience Values	0.852				
Emotional Values	0.555	0.86			
Epistemic Values	0.528	0.643	0.8		
Monetary Values	0.682	0.621	0.56	0.842	
Trust in Smart meters	0.613	0.695	0.697	0.612	0.811

The PLS inner structural model was examined to investigate the significance of the paths and the predictive power of the model by considering a bootstrapping process (Hair et al., 2016). Table IV highlights the Beta values of each the latent variables, T-Statistics, P-Values and hypotheses results (Hair et al., 2016). As a result, all hypotheses were supported in 0.05 significant level, as shown in Table 4.

Table 4. Regression Results

Regression path (Based on hypotheses)	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
Convenience Values → Trust in Smart meters	0.252	0.255	0.064	3.951	0
Emotional Values → Trust in Smart meters	0.459	0.453	0.065	7.024	0
Epistemic Values → Convenience Values	0.528	0.526	0.066	7.96	0
Epistemic Values → Emotional Values	0.643	0.641	0.053	12.063	0
Epistemic Values → monetary Values	0.56	0.561	0.06	9.383	0
Monetary Values → Trust in Smart meters	0.156	0.158	0.075	2.075	0.038

Figure 1 shows item loadings associated with all constructs, Beta scores and the R squared scores of exogenous constructs.

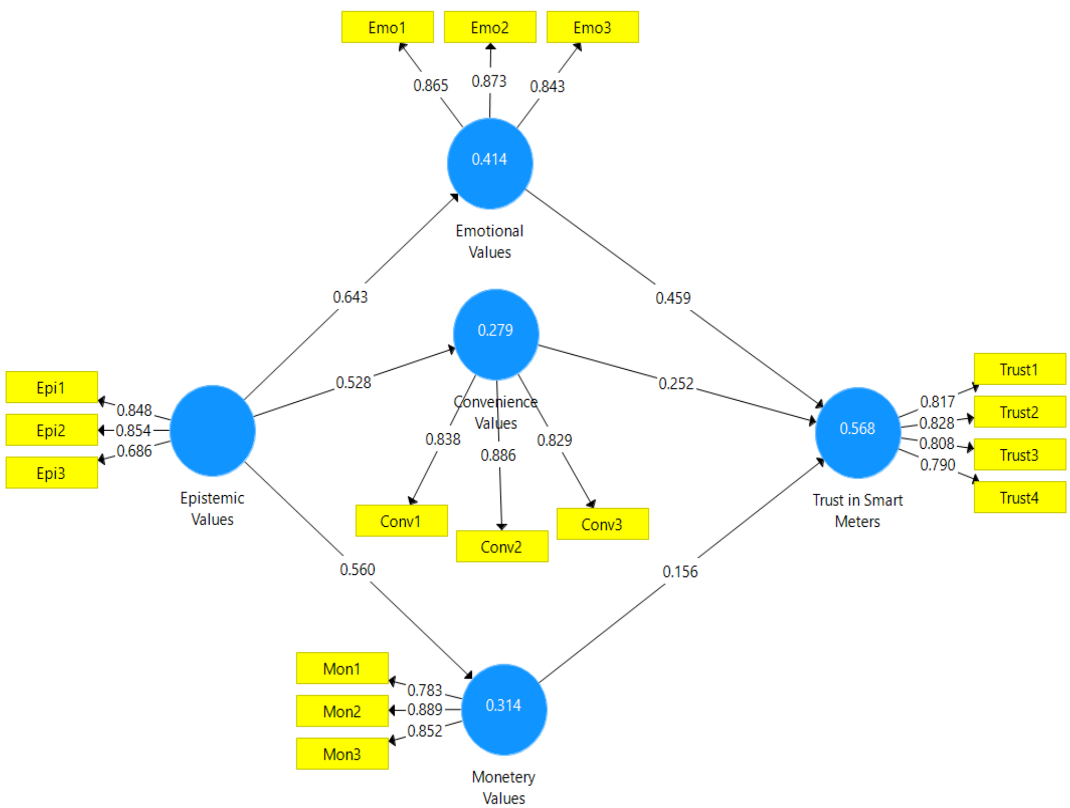

Figure 1: Tested and Validated Research Model

5. Conclusion

It is noteworthy that the strongest path in the research model is the influence of perceived epistemic value on monetary value (β = 0.643), whereas perceived monetary value scored the lowest value in affecting trust in this technology (β = 0.156), but it was still found a significant path on 5% confidence interval. The amount of variance explained by R^2 provides an indication of the model fit as well as the predictive ability of the endogenous variables. The R^2 scores should be greater or equal to 0.10 (Hair et al., 2016). As a result, the R^2 value of 'Trust' was found moderate and equal to 56.8%. Other R^2 scores are presented and shown in Figure 1. Overall, the four dimensions of perceived values are found to have a significant influence on either trust in smart meter in a direct or indirect way. Perceived epistemic value formulates the awareness about smart meters which is a vital element to trust in the technology and accept it, supporting previous research (Shuhaiber, 2018). Perceived emotional value could also impact users' trust in smart meters, which indicates that users' feelings of pleasure, comfort, and security are effective for accepting and using smart meter. Perceived monetary value in turn could contribute positively and significantly to users' trust, which means that the financial aspect of smart meters in terms of costs and savings can affect the resident's trust in this technology.

The result of this research is in line with other results found by Kaufmann, Künzel & Loock (2013) which indicate that perceived customer value significantly influences social acceptance and the implementation of smart metering system. However, the result of this research could be slightly different from the results found by Gerpott & Paukert (2013) which indicate that smart Meter-triggered electricity volume saving, and environmental awareness are found to have to customers' willingness to accept and pay for smart meters. Overall, and a discussed earlier, not sufficient studies were found to examine the influence of the dimensions of perceived values (epistemic, emotional, monetary, and convenience) on consumer trust and intention to accept smart meters, and, therefore, the current findings are considered original in that relevant literature.

6. Limitations and Future Directions

This study has some limitations, such as the one associated with the survey-based method that is prone to measurement errors (Bell, Bryman, & Harley, 2018). To minimize the effect of this limitation, the researcher developed the items based on the literature and previous studies. For future research work, the researcher suggests conducting research to understand residents' intention to use smart meter services by extending the current research model, not only on the UAE but also in other Gulf and foreign countries through cultural studies. This also suggests extending the current model with other perceived values such as social values and conditional values, for better holistic view of smart meter trust and behavioral intentions.

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Biography

Ahmed Shuhaiber is an Assistant Professor at the college of Technological Innovation at Zayed University since fall 2018, and an assistant professor at Al Ain University since 2016. He earned his PhD Degree in Information Systems from Victoria University of Wellington (VUW), New Zealand in 2016, and has computer science and management information systems background for his bachelor and master's degrees. Prior earning his PhD, Ahmed served as a lecturer at Al Zaytoonah University of Jordan for many years, and as a teaching and research assistant at Victoria University for several years. Ahmed is qualified as Certified International Professional Trainer from the American Certification Institute, Certified IBM Business Intelligence Analyst, ExclL Intercultural skills certificate (Excellence in Cultural Experiential Learning and Leadership) and others, and professionally serves as a trainer and corporate consultant. Dr Shuhaiber's research interests lie in the fields of IoT and smart city applications and services.