Validity Of The Measures Of Constructs Used To Revise The Innovation Decision Framework

Raja Peter, Massey University, New Zealand
Laurence Dickie, Curtin University of Technology, Western Australia
Vasanthi Peter, Whitireia Community Polytechnic, New Zealand

Abstract

This paper examines the validity and reliability of multi-item measures of three constructs used to extend the diffusion of innovations model proposed by Rogers (1995) and Kaplan’s (1999) new innovation-decision framework. The item pool for the three constructs — Government Initiatives, Demonstration Sites and Finance was drawn largely from renewable energy literature. The confirmatory factor analysis approach adopted in the study and the results of the congeneric models show that each construct was well defined by multiple indicator variables. An examination of issues pertaining to reliability, construct validity, convergent validity and discriminant validity revealed that requisite conditions for these were met, paving the way for the development of scales to measure these constructs.

Keywords: Reliability, Validity, Government Initiatives, Demonstration Sites, Finance

Introduction

This research emerges from the integration of the diffusion of innovations and renewable energy literature. The objective of this paper is to examine the validity and reliability of multi-item measures of constructs that have been used to extend the diffusion of innovations model proposed by Rogers (1995) and Kaplan’s (1999) new innovation-decision framework. Kaplan examined the factors that influenced the interest of utility managers in adopting solar-based technology. He proposed that Interest is the product of heightened Knowledge of the technology. Knowledge is the product of Motivation and Experience. In an attempt to fill the gap between Knowledge and Interest, Kaplan included Experience and Familiarity as intervening variables.

Further investigation of literature led to the identification of other variables. The effect of independent variables such as Government Initiatives, and Demonstration Sites on Experience, Knowledge and Interest has not been studied in the context of adoption of photovoltaic (PV) power supply systems in developing countries. The availability of Finance is another crucial factor in the adoption of PV Systems. Finance was identified as another intervening variable in addition to, Experience, Knowledge and Familiarity. Peter and Dickie’s (2005) revised framework establishes the relationships between these variables and the Decision to adopt.

The discussion in this paper revolves around issues pertaining to the validity and reliability of measures of Government Initiatives, Demonstration Sites and Finance. These constructs were developed largely from renewable energy literature and there are no scales to measure them. This paper is a first step in the development of scales to measure these constructs. The importance of this research stems from the valid operationalisation of key constructs that influence the adoption decision of high-tech innovations such as PV systems. This paper
extends our knowledge of constructs such as Government Initiatives, Demonstration Sites and Finance by developing and testing parsimonious multi-item scales. Marketers and policy makers need to recognize the importance of the different dimensions of these constructs and develop strategies that will foster the adoption of PV systems in the context of global environmental concerns. Researchers can use these constructs and scales in other product/country contexts to carry out further empirical research.

**Government initiatives**

The government can play a leading role through the formulation of favourable policies, by showing a practical commitment and by enhancing public awareness of the potential of PV in all walks of life. (Muntasser et al. 2000). It should disseminate information pertaining to the environmental and other benefits of PV with a view to educating the industry and public (Cesta & Decker 1978). Government intervention for fostering diffusion of PV systems include provision of: tax incentives soft loans, subsidies, credit services, direct support of the distribution system and liberalized foreign investment procedures (Rubab & Kandpal 1996; Martinot 1998; Muntasser et al. 2000). Government should also publish the results of comparative analysis of solar systems and conventional systems (Cesta & Decker 1978). There is a need to develop system standards for all the main system components. Establishing performance standards for PVs, establishing independent testing centres and government endorsing of solar systems are measures that will serve to boost the confidence level of PV users (Cesta & Decker 1978). Government intervention, therefore, is necessary in a number of ways to promote solar energy

**Demonstration sites**

Demonstration plants are being set up in developing countries as they serve a number of purposes. However, their numbers are limited and therefore more are needed in different parts of these nations in order to significantly raise the level of awareness of PV systems (Adurodija, Asia & Chendo 1998). Demonstration projects facilitate trials of PVs and provide data for comparison with conventional systems (Nayar 1997, Koner & Dutta, 1998). The publication of these results leads to these projects serving as centres for dissemination of information on PV systems. Further they enhance the delivery and installation infrastructure that is available in the country as they provide technical assistance, technician training and other valuable inputs (Marawanyika 1997). Qualified and trained workers install PV systems. End-users are trained on preventive maintenance. These measures increase the quality of the installation infrastructure (Gope, Aghdasi & Dlamini 1997).

**Finance**

The capital needs are high when investing in renewable energy technologies (RETs) such as PV systems. Therefore, well-adapted financial schemes and financial support are essential for the adoption of these technologies (Langniss 1996). Financial institutions are not always interested in giving or opening lines of credit for private PV investors (Muntasser et al. 2000). Hence, there is a need for some sort of financing mechanism along the lines of traditional banking channels. The Indian Renewable Energy Development Agency (IREDA) provides credit for renewable energy users, manufacturers and producers at concessional
terms initially, which progressively approach commercial market rates as the technology gains wider acceptance (Nayar 1997). The initial costs of PV systems are high and, hence, the acceptance of PV systems will depend on the financial viability of investments in PV systems (Bugaje 1999; Rubab & Kandpal 1996). The high outlay required of these systems is a major barrier for a broader market penetration of this technology (Hass et al. 1999). A comparative cost analysis of PV power generation and DG power generation, undertaken by Koner and Dutta (1998) based on six years of field data revealed that the unit cost of PV electricity is cheaper or comparable with that from DG power at present market price.

Methodology

Operationalization of variables

A combination of extensive literature review and results of the pre-tests led to the development of the final questionnaire, which was used as the survey instrument in this study. Multi-item interval/Likert scales were used and the item pool was drawn from literature. Government initiatives was assessed by eleven items (GI1 to GI11). Demonstration sites was measured using 5 items DS1 to DS5. Finance was operationalised through five variables, FIN1 to FIN5 in the final questionnaire (see Appendix).

Sampling & data collection

The Directory of Hotels and Resorts in India was used as the sampling frame as it provided a comprehensive listing of the target population comprising of 769 hotels of different star ratings. The questionnaires were initially administered to the entire population through mail surveys. The response rate to the initial mail out and the follow up mail out was very low despite the respondents being requested to mail the questionnaires back to the address of a local academic in India. Low response rates (3%) necessitated a change to the adoption of administering the questionnaires through trained interviewers from a prestigious market research firm in India.

Proportional stratified random sample was used to ensure that the number of hotels drawn from each category of star rating across the four different regions in the country was in proportion to the relative population size of that stratum in each region. Thus the sample size of 205 hotels was spread across the different star ratings of these hotels and the four regions of the country. The process of stratification and randomization was followed in order to minimise sampling errors.

Managers can be used as proxies for the decision-making unit, which in this case is the respective hotel (Kaplan 1999). The utility managers of the hotels are considered to be individuals with specialized knowledge for the purposes of this research since they have access to the relevant information. Hence utility managers occupying identical positions in each individual unit of analysis were chosen as the respondents for this study (Hass et al. 1999; Mitchell 1994).

The authors employed structural equation model and path analysis to test Peter-Dickie’s (2005) model. However only the results of the one factor congeneric models for three
constructs that were used to extend the diffusion of innovations model proposed by Rogers (1995) and Kaplan’s (1999) new innovation-decision framework are discussed in this paper.

Results

One-factor congeneric models were used to confirm the relationships specified between the observed variables and their underlying factors. In this research we used the type of measurement model proposed by Joreskog (1971). The new composite latent variable was computed as suggested Holmes-Smith & Rowe (1994) using the factor score weights and the observed variables which were retained in the congeneric model. The reliability was calculated as a maximised reliability of the composites ($\tau_c$) since factor score weights maximise the composite score reliability (Holmes-Smith & Rowe 1994; Joreskog 1971; Werts et al 1978). The measurement errors $\theta$s, associated with each composite variable and the regression coefficient $\lambda$, of each composite variable on its latent construct were calculated using Munck’s (1979) formula. Validity is concerned with the ability of a scale to measure what it intends to measure and issues pertaining to construct validity, convergent validity and discriminant validity were examined.

Government initiatives

The issue of Government Initiatives was assessed by eleven items (GI1 to GI11). The variables GI4, GI9 and GI11 were dropped because of low squared multiple correlations. GI5 and GI7 were dropped because of the negative sign of their respective factor score weights. Thus six variables GI1, GI2, GI3, GI6, GI8 and GI10 were retained as the indicator variables in this one-factor congeneric model. The t-values (CRs) for these six variables were significant and greater than 10. The squared multiple correlation was greater than 0.5 for all the indicator variables except GI10, which was marginally, lower than 0.5. However, the factor loadings for GI10 and the other five variables were greater than 0.7 and hence these six items were used as measures of Government Initiatives. Details of the parameter estimates are shown in Table 1. The fit of the congeneric model was good with Chi-square ($\chi^2$) = 10.439, $p = 0.107$.

Table 1: Parameter estimates for measures of Government Initiatives

<table>
<thead>
<tr>
<th>Observed Variable</th>
<th>Factor Loading ($\lambda$)</th>
<th>Squared Multiple Correlations ($r^2$)</th>
<th>Error Variance ($\theta$)</th>
<th>t-values</th>
<th>Factor Score weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>GI1</td>
<td>0.737</td>
<td>0.543</td>
<td>0.457</td>
<td></td>
<td>0.123</td>
</tr>
<tr>
<td>GI2</td>
<td>0.799</td>
<td>0.639</td>
<td>0.361</td>
<td>13.083</td>
<td>0.058</td>
</tr>
<tr>
<td>GI3</td>
<td>0.820</td>
<td>0.672</td>
<td>0.328</td>
<td>11.715</td>
<td>0.191</td>
</tr>
<tr>
<td>GI6</td>
<td>0.820</td>
<td>0.672</td>
<td>0.328</td>
<td>10.133</td>
<td>0.128</td>
</tr>
<tr>
<td>GI8</td>
<td>0.868</td>
<td>0.754</td>
<td>0.246</td>
<td>11.537</td>
<td>0.202</td>
</tr>
<tr>
<td>GI10</td>
<td>0.702</td>
<td>0.493</td>
<td>0.507</td>
<td>11.715</td>
<td>0.088</td>
</tr>
</tbody>
</table>

Demonstration sites

Four variables DS2, DS3, DS4 and DS5, which loaded onto the factor Demonstration Sites, were the indicator variables in this one-factor congeneric model. The variable DS1 was dropped from the analysis because of low squared multiple correlation. The factor loadings of DS2, DS3, DS4 and DS5 were significant with t-values (CRs) greater than 13.0. The standard
errors were low and the squared multiple correlations were all greater than 0.5. Hence these items were retained as measures of Demonstration Sites. Details of the parameter estimates are shown in Table 2. The fit of the congeneric model was acceptable with Chi-square ($\chi^2$) = 10.656, $p = 0.059$.

<table>
<thead>
<tr>
<th>Observed Variable</th>
<th>Factor Loading ($\lambda$)</th>
<th>Squared Multiple Correlations ($r^2$)</th>
<th>Error Variance ($\theta$)</th>
<th>t-values</th>
<th>Factor Score weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>DS 2</td>
<td>0.807</td>
<td>0.651</td>
<td>0.349</td>
<td>13.904</td>
<td>0.248</td>
</tr>
<tr>
<td>DS3</td>
<td>0.861</td>
<td>0.741</td>
<td>0.259</td>
<td>15.279</td>
<td>0.238</td>
</tr>
<tr>
<td>DS4</td>
<td>0.825</td>
<td>0.725</td>
<td>0.275</td>
<td>15.279</td>
<td>0.238</td>
</tr>
<tr>
<td>DS5</td>
<td>0.825</td>
<td>0.725</td>
<td>0.275</td>
<td>15.279</td>
<td>0.238</td>
</tr>
</tbody>
</table>

**Finance**

Finance was measured by five observed variables FIN1 to FIN5. The factor loadings of all the items were significant with t-values (CRs) greater than 6.0 and the standard errors were low. However, the squared multiple correlations for FIN4 and FIN5 were lower than the recommended level of 0.5. Hence these items were deleted from the model and FIN1, FIN2, and FIN3 were retained as measures of Finance. Details of the parameter estimates are shown in Table 3.

<table>
<thead>
<tr>
<th>Observed Variable</th>
<th>Factor Loading ($\lambda$)</th>
<th>Squared Multiple Correlations ($r^2$)</th>
<th>Error Variance ($\theta$)</th>
<th>t-values</th>
<th>Factor Score weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIN1</td>
<td>0.795</td>
<td>0.523</td>
<td>0.368</td>
<td>12.982</td>
<td>0.704</td>
</tr>
<tr>
<td>FIN2</td>
<td>0.964</td>
<td>0.930</td>
<td>0.070</td>
<td>11.307</td>
<td>0.080</td>
</tr>
<tr>
<td>FIN3</td>
<td>0.723</td>
<td>0.632</td>
<td>0.477</td>
<td>11.307</td>
<td>0.080</td>
</tr>
</tbody>
</table>

The factor loadings and the squared multiple correlations suggested that the indicator variables FIN1, FIN2, and FIN3 were reliable measures of Finance. The fit of the congeneric model was acceptable with Chi-square ($\chi^2$) = 1.054, $p = 0.305$.

The values pertaining to maximised composite reliability, error variance, regression coefficient ($\lambda$) and variance extracted for each of the composite variables are given in Table 4. An examination of the maximised composite reliabilities ($r_{cs}$) reveal that all of them were greater than 0.7. The scale reliability was very good and the variance extracted were greater than 0.50 which implied that all the indicator variables were good measures of their respective latent variables. The t-values of the individual parameter estimates were all significant, thereby establishing convergent validity. The regression coefficient $\lambda$s which represent the regression of the composite variable on its latent construct had all been estimated. The measurement error variance $\theta$s which represent the measurement error associated with each composite variable had also been calculated.
Table 4: The Latent Constructs

<table>
<thead>
<tr>
<th>Measures</th>
<th>Government Initiatives</th>
<th>Demonstration Sites</th>
<th>Finance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximised Composite Reliability (( r_c ))</td>
<td>0.913</td>
<td>0.909</td>
<td>0.942</td>
</tr>
<tr>
<td>Error Variance (( \theta ))</td>
<td>0.062</td>
<td>0.108</td>
<td>0.144</td>
</tr>
<tr>
<td>Regression Coefficient (( \lambda ))</td>
<td>0.803</td>
<td>1.042</td>
<td>1.525</td>
</tr>
<tr>
<td>Variance Extracted</td>
<td>0.629</td>
<td>0.711</td>
<td>0.695</td>
</tr>
</tbody>
</table>

In order to demonstrate discriminant validity the Variance Extracted (VE) was calculated for each construct. The average variance extracted for two constructs was compared with the square of the correlation between the constructs. As can be seen from Table 5, in all cases the average variance extracted was greater than the square of the correlations, thereby satisfying the requirement of discriminant validity.

Table 5: Establishing Discriminant Validity

<table>
<thead>
<tr>
<th>Latent Variable</th>
<th>Variance Extracted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government Initiatives</td>
<td>0.629</td>
</tr>
<tr>
<td>Demonstration Sites (VE 2)</td>
<td>0.711</td>
</tr>
<tr>
<td>VE 1 and VE 2</td>
<td>0.670</td>
</tr>
<tr>
<td>Finance (VE 3)</td>
<td>0.695</td>
</tr>
<tr>
<td>VE 1 and VE 3</td>
<td>0.662</td>
</tr>
</tbody>
</table>

*VE = Variance Extracted

Conclusion

The results of the congeneric (measurement) models show that each construct was well defined by multiple indicator variables. This is further attested by the measures of reliability and validity. All the measurement models were validated using confirmatory factor analysis. An examination of issues pertaining to construct validity, convergent validity and discriminant validity revealed that requisite conditions for these were met, paving the way for the development of scales to measure Government Initiatives, Demonstration Sites and Finance. The contribution of the study to theory development emerges from the valid operationalisation of constructs that have hitherto not been considered. A set of parsimonious and multi-item scales have been developed to measure Government Initiatives, Demonstration Sites and Finance. Marketers and policy makers need to recognize the importance of the different dimensions of these constructs and develop strategies that will foster the adoption of PV systems in the context of global environmental concerns. Researchers can use these constructs and scales in other product/country contexts to carry out further empirical research. The present study draws its inferences from empirical testing of data from India, which is a developing country.
References:


Government Initiatives

Government initiatives refer to the actions that are required to be taken by the government to promote and foster the adoption of solar-based power supply systems. This construct is assessed by eleven items (GI1 to GI11) drawn from Cesta & Decker (1978), DeLaquil (1996) Adurodija et al (1998) and Muntasser (2000). Respondents were asked to rate the importance of the role of government in fostering the commercialization of solar PV systems on a seven point Likert type scale from 1 = Not Important to 7 = Very Important as the anchor points (Cesta & Decker 1978). The items measuring government initiatives are:

GI1: Creating awareness by providing helpful information (Adurodija et al. 1998).
GI2: Disseminating relevant information (Adurodija et al. 1998).
GI3: Promoting use of solar systems (Cesta & Decker 1978).
GI5: Providing tax incentives for users (DeLaquil 1996).
GI6: Providing tax incentives for producers (DeLaquil 1996).
GI7: Providing subsidies for installing PV systems (Cesta & Decker 1978).
GI8: Providing concessional financing for installing PVs (Adurodija et al. 1998).
GI10: Establishing independent testing centers for PVs (Cesta & Decker 1978).
GI11: Removing subsidies to fossil fuels such as diesel (DeLaquil 1996; Edinger & Kaul 2000).

Scales of Measurement for Demonstration Sites

Demonstration sites/projects of PV systems have an important role to play in creating awareness, disseminating information, facilitating trials, providing comparative data and promote the use of PV Systems. The proximity of these demonstration projects to the potential user is an important factor (Marawanyika 1997) and this was assessed through DS1 where the respondent was asked to rate its importance on a 7-point scale of 1 = Not Important to 7 = Very Important.

Respondents’ assessments for the other four items were obtained via a 7 point Likert scale from 1 = Strongly Disagree to 7 = Strongly Agree and they include:

DS2: Demonstration projects promote awareness of PVs (Sastry 1997; Adurodija et al. 1998).
DS3: Demonstration projects provide comparative data of PV systems against conventional systems. (Koner & Dutta 1998; Nayar 1997)
DS4: Demonstration projects serve as centres for dissemination of information on PV systems (Nayar 1997; Adurodija et al. 1998).
**DS5**: A number of demonstration projects/sites set-up in different parts of India would serve to promote the use of PV systems to a greater degree (Choffray and Lilien 1978; Adurodija et al. 1998).

**Scales of Measurement for Finance**

Finance relates to financial support that may be available through the government/funding agencies in the form of concessional loans at attractive credit terms. The other elements of finance are the initial cost of PV based power supply systems and their comparative costs. These are operationalised through five variables, FIN1 to FIN5 in the final questionnaire. A seven point Likert type scale from 1 = Not Important to 7 = Very Important (Labay & Kinnear 1981) was used to assess the responses of respondents. The five items are:

**Fin1**: Availability of Concessional Loans (Sastry 1997; Nayar 1997).
**Fin2**: Availability of finance exclusively for renewable energy projects from lending institutions such as IREDA (Gope et al. 1997; Nayar 1997; Sinha et al. 1998).
**Fin3**: Credit terms of these Financial Institutions (Marawanyika 1997; Nayar 1997; Sinha et al. 1998).
**Fin4**: Initial capital cost of PV systems (Labay and Kinnear 1981; Roy and Gupta 1996; Gope et al. 1997).
**Fin5**: Comparative cost of PV systems vis-à-vis conventional systems (Bugaje 1999; Koner & Dutta 1998; Roy & Gupta 1996).