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# Mathematical Model for Computation of Reliability of "Online Off-Campus Paperless Admissions" System

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**ABSTRACT**
A number of e-Governance projects are being initiated worldwide, however, success rate of such projects is not encouraging, study reveals that it is somewhere between 30-40%. Besides this, any e-governed system used by public should also be reliable. As we know that, in the age of Internet, Mobile and Cloud-computing, dependencies on the e-Governed systems have been increasing day by day. Hence, it becomes inevitable that e-Governed systems must be tested thoroughly for reliability also. Therefore, need felt for a mathematical model to compute and predict reliability of systems for the awareness of common man. In this regard, the system of "Online Off-campus Paperless Admissions", an initiative by the Government of Haryana, Department of Technical Education implemented since 2006, studied to formulate a mathematical model using SEM (Structural Equation Modeling) for computation and prediction of Reliability. This system streamlines the admission processes of all AICTE approved courses run by the State Universities, Colleges of Engineering, Management, Pharmacy and Polytechnics to achieve transparency, to minimize human interference and to provide students and parent's friendly system which could also minimize travel burden on them. Eligible students can apply and submit choices of courses and institutions along with depositing fees in bank by sitting at home or from any nearby internet point. Finally, seat allotment letter can be downloaded by the successful students to report in the allotted institute for documents verification and taking admission. Major achievements of this system are Transparency, 'NO fear of leakages and NO human interference in admission process. Many other states influenced by the success of this system adopted and implemented it. However, it is difficult to ensure the success and reliability of the developed system in different conditions of Technological platforms, Planning, Implementation, Management, Support and Functionality requirements. Therefore, a Mathematical Model was formulated by using SEM and tested by taking a data set of 114 institutions which was further processed by using the LISREL 9.2 to know the weights and loading factors of relationships between Observable and Latent variables helping in computing the reliability. The data inputs to the model consists of adoption of technology and other 19 parameters on Planning (Resources, Cost and Duration), Design & Development (Scalable, Technology Independent, Requirements, Branding and Secure), Implementation & Measurement (Ownership, Institutionalization, Testing, Operation), Support (Training, Capacity building, Change Management and Maintenance), Participation (Students, Parents, Banks and Institutions), Reliability (Quality, Quantity, Continuity and Performance), Sustainability (Impacts, Benefits, Availability, Functionality and Income). Result of the investigation produces mathematical equation of Reliability model, Index of Reliability which ranges between 0.742 to 3.267 and Standard Deviation and RMSEA 0.118 along with Goodness of Fit for the mode. Also, recommended methodology for decision making about the project, like validation of model using separate sample of dataset, selection of robust technology, capacity building, and establishment of help desks for improved reliability.

**KEYWORDS:** Computation, Mathematical Model, Online admissions, Prediction, Reliability, SEM, Sustainability

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## I. INTRODUCTION

Reliability is the probability that an item will 'perform' a required function under stated 'operating conditions' for a stated 'period of time'. Also reliability refers to the repeatability of findings as tested by Ringlee et al. (1994) in bulk power system reliability criteria, if the study were to be done a second time, would it yield the same results? If so, the data and the product are reliable. Testing and ensuring reliability of the systems is sole responsibility of the System developers. In this regard, the system of "Online Off-campus Paperless Admissions" studied and found reliable during its 10 years of implementation by more than 500 technical institutions/universities across the Haryana State. Navarro et al. (2002) also designed reliable academic counseling system on the similar pattern. Stuart et al. (2002), Bhuria and Dixit (2011) also studied online off-campus counselling system for students' persistence and academic performance. But one cannot consider that a system if found reliable under one set of conditions may also be reliable under different conditions of technology platforms, implementations norms, planning features, social and economical conditions, skills of operational manpower, capacity building, demography etc. The brief introduction of the web based online off campus admissions system, follows as under:

The web based paperless admissions workflow systems were less successful in the country during 1995-2003 mainly due to less penetration of Internet-web-based technology among public as well as less techno savvy officials in the institutions. The State Government in 2006 stopped the process of manual admissions and implemented the web based system of admissions through NIC across the state for admission to Engineering, Architecture, Management, Pharmacy, Hotel Management and Diploma level courses through AICTE approved Govt. / Govt. Aided / Private Institutions and University departments. Table-1 shows the number of institutions participated in the year 2006 & 2016 along with number of seats, i.e. the exponential growth from 2006 to 2016 is the result/impact of the online admissions system. The objective of online admission system was to provide a transparent, hassle free system of admissions with minimum human interference and minimized travel burdens on students and parents.

**Table 1. Technical institutions and Annual intake**

| # | Type of institution | No of institutions | | Annual intake | |
|---|---|---|---|---|---|
| | **Year of Admissions** | **2006** | **2016** | **2006** | **2016** |
| 1 | Engineering Institutes | 41 | 137 | 36070 | 90930 |
| 2 | MBA Institutes | 34 | 115 | 3142 | 8971 |
| 3 | MCA Colleges/UTDs | 32 | 44 | 1805 | 3056 |
| 4 | Pharmacy Colleges | 27 | 30 | 2986 | 1886 |
| 5 | Polytechnics | 42 | 178 | 25350 | 92726 |
| | Total | 179 | 504 | 69343 | 197569 |

The admission process runs from April-October every year which includes online registration by the students, submission of choices, allotments of seats, reporting to the allotted institutions, depositing of fees, verification of documents by affiliated Universities/colleges etc. in which more than 500 institutions /Universities participates in the process. Figure 1 below display the seats versus admission position across the years.

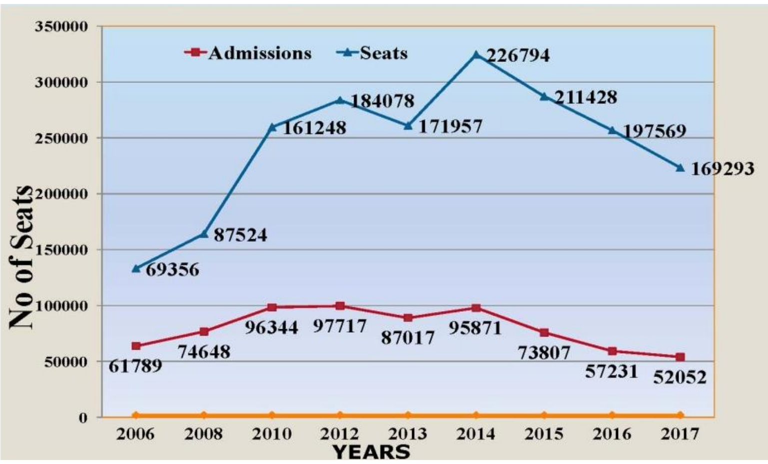


**Figure 1. A Line graph showing Admissions and Seats**

The information work flow of the online system of admissions resemble with the information flow in the field of Technology Utilization for Counselling as tested by Creamer and Michael (2002). Figure 2, below shows implemented framework view of technology utilization, Sellappm and Tan (2006) also designed web-based counselling system on the similar pattern.

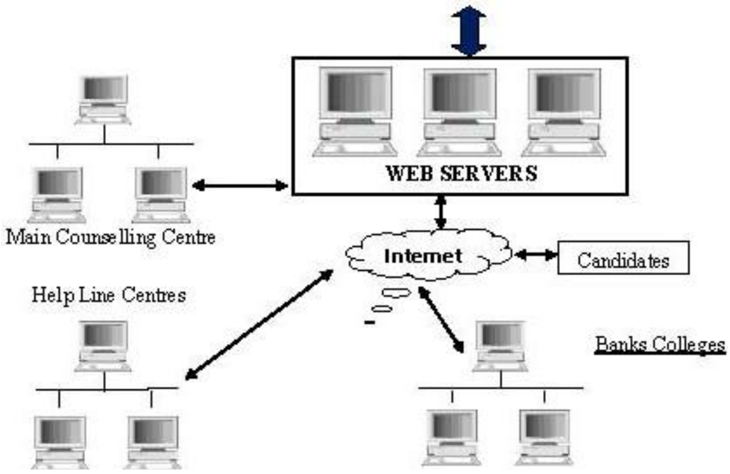


**Figure 2. Technical Diagram of information flow for online paperless admissions system**

Mathematical model of reliability has been planned to be formulated by using SEM techniques and online admission data of last 10-11 years of different participating institutions of the State. Arhonditsis et al. (2006) also explored ecological pattern with SEM, which has been used in environmental research for investigating the interaction of submerged plants with environmental factors by Hung et al. (2007). SEM technique is well tested for formulation of predictive models for computation of reliability. Therefore, it is being used for the proposed system of 'Online off-campus admissions' as and when implemented in any other State under different conditions of technology and operating environments is needed by using an appropriate modeling process.

To know the situation before, IT initiatives is quite helpful in formulation of the problem in optimal way, following are some of the main problems of the legacy system:

a) Students did not have choices to appear in the exams on a date and time of their choice. Fear of leakage of the question papers, human interference in evaluations and preparation of merits
b) Calling all students for physical counseling at a single location for entire State, resulted in heavy rush at one point, all participants have to travel to the counseling place
c) There was No transparency in displaying of availability of seats, Candidates do not get enough time for selection of streams and institutions No iterative method of seat allotment.

## II. DEVELOPMENT OF MATHEMATICAL MODEL AND EQUATIONS

The model built in this research is also based on both qualitative and quantitative data and can be applied to compute & predict a phenomenon based on qualitative data and not solely on quantitative data of admissions as tested by Masduqi et al. (2007) for prediction of rural water supply system's sustainability for Indonesia under different conditions of technology, cost, manpower, support etc. Figure 3 shows Data Model formulated under this research by using a set of variables, the same Model has shown in the Figure 4 with mathematical notations and relational operators. Development of the model begins from the theoretical model that was tested by using indication test. The model has been developed using the admission data of 114 different participating institutions across the State. The data inputs to the model consists of adoption of technology and 19 other parameters on Planning (Resources, Cost and Duration), Design & Development (Scalability, Technology independence, Requirements, Branding, Secure), Implementation & Measurement (Ownership, Institutionalization, Testing, Operation), Support (Training, Capacity building, Change Management, Maintenance), Participation (Students & Parents, Banks, Institutions), Reliability (Quality-required-output, Quantity, Continuity, Performance), Sustainability (Satisfactory-output, Benefits, Availability, Functionality, Income-revenue generation). SEM has been used in formulating of the model and defining of relationships between manifest and unobservable variables i.e Latent variables of Reliability and Sustainability. SEM with the complete structure consists of two main parts, the measurement model (relationship between observed and latent variables) and the structural model (which describes the relationship among dependent and independent latent variables). The model is expressed as mathematical equations. The two types of equation are described as follow:

**Measurement Model Equation:**

- Equation of measurement model of independent variables:

$$X = \Lambda_x \xi + \delta \qquad (1)$$

- Equation of measurement model of Dependent variables:

$$Y = \Lambda_y \eta + \varepsilon \qquad (2)$$

**Structural Model Equation:**

$$\eta = B^*\eta + \Gamma\xi + \rho \qquad (3)$$

Where:

$X$ = q×1 vector of observed variables of $\xi$
$\Lambda x$ = q×n matrix of coefficients relating X to $\xi$
$\xi$ = n×1 vector of independent latent variables
$\delta$ = q×1vector of measurement errors for X
$Y$ = p×1vector of observed variables of $\eta$
$\Lambda y$ = p×m matrix of coefficients relating Y to $\eta$
$\eta$ = m×1 vector of dependent latent variables
$\varepsilon$ = p×1vector of measurement errors for Y
$B$ = m×m matrix of coefficients for the Dependent latent variables
$\Gamma$ = m×n matrix of coefficients for the independent Latent variables
$\rho$ = m×1vector of latent (structural) errors

Based on results of SEM, the Mathematical equations are derived on the basis of model parameters depicted in the Figures 3. & Figure 4. The equations consist of vectors and matrices that are constructed from the model.

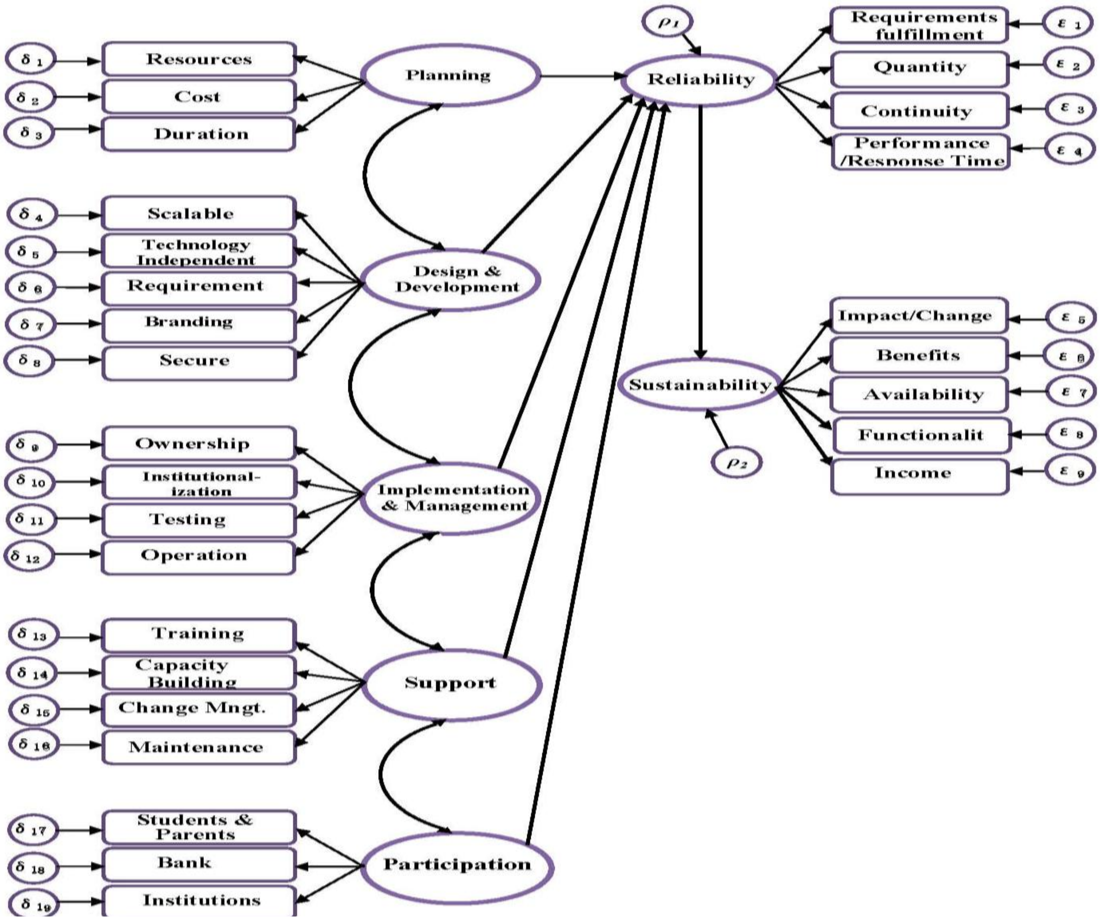


**Figure 3. Path diagram of model that depicts influence of variables to the reliability**

Details of derivations of equations of Measurement models and Structural model have given below using the mathematical model shown in the Figure-4.

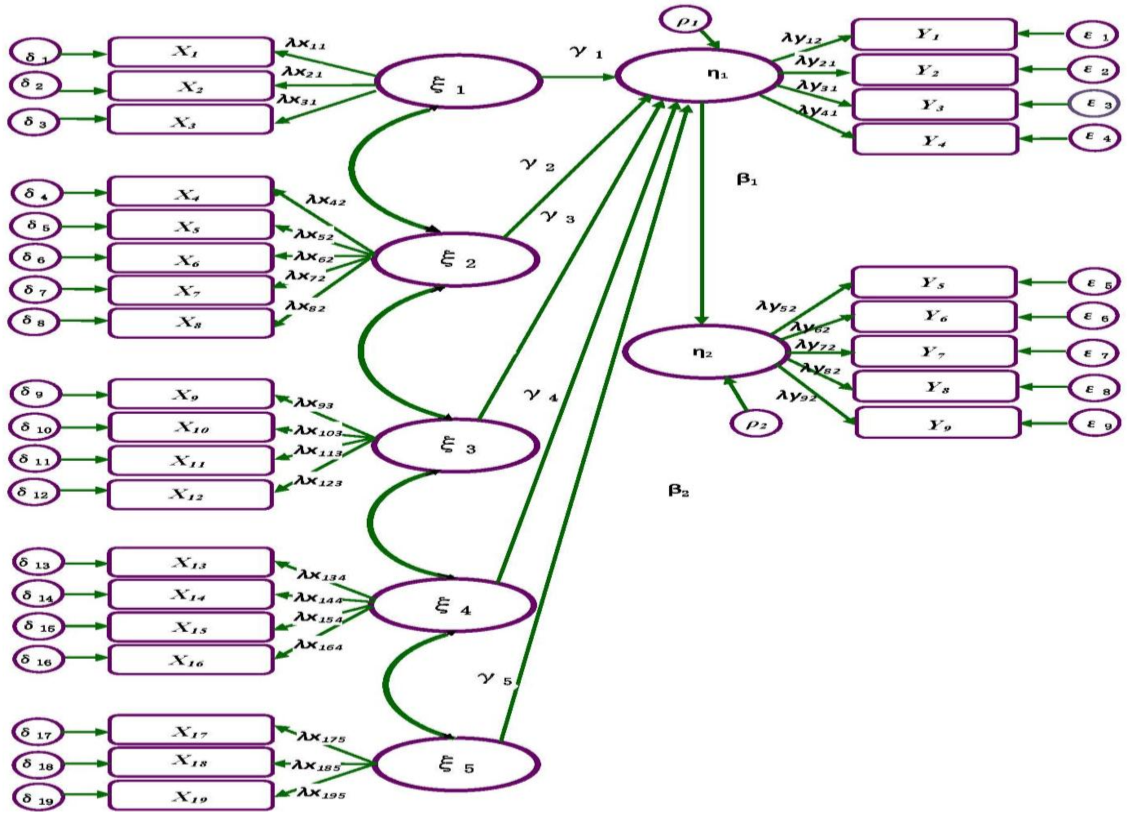


**Figure 4. Model of Reliable Online admission systems in Mathematical Notation**

We have 19 observable manifest variables (X) of independent variables of ξ in the model i.e. vector/set of observed variable of X. Path diagram in the Figure 7 of measurement Model of X variables through CFA also called confirmatory factor analysis Model. The Matrix of such variables is formed as under using the model shown in Figure 4: where,

$$X = \begin{bmatrix} X_1 \\ X_2 \\ : \\ : \\ X_{19} \end{bmatrix}_{19x1} \qquad \xi = \begin{bmatrix} \xi_1 \\ \xi_2 \\ : \\ : \\ \xi_5 \end{bmatrix}_{5x1} \qquad \delta = \begin{bmatrix} \delta_1 \\ \delta_2 \\ : \\ : \\ \delta_{19} \end{bmatrix}_{19x1}$$

Matrix $\mathbf{\Lambda}_{x[19x5]}$ are 19 linear equations have been formulated as under:

$$X_1 = \lambda_{x11}\xi_1 + \delta_1$$
$$X_2 = \lambda_{x21}\xi_1 + \delta_2$$
$$X_3 = \lambda_{x31}\xi_1 + \delta_3$$
$$X_4 = \lambda_{x42}\xi_2 + \delta_4$$

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$$X_{18} = \lambda_{x185}\xi_5 + \delta_{185}$$
$$X_{19} = \lambda_{x195}\xi_5 + \delta_{195}$$

Hence equations for Measurement Model of observed variables 'X' i.e. manifest variables of factor ξ (independent LVs) form following matrix & Equation (1)

$$\begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ : \\ : \\ X_{19} \end{bmatrix} = \begin{array}{c} \begin{array}{ccccc} \xi1 & \xi2 & \xi3 & \xi4 & \xi5 \end{array} \\ \begin{bmatrix} \lambda_{11} & 0 & 0 & 0 & 0 \\ \lambda_{21} & 0 & 0 & 0 & 0 \\ \lambda_{31} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & \lambda_{42} & 0 & 0 & 0 \\ & \lambda_{52} & 0 & 0 & 0 \\ - & - & - & - & - \\ - & - & - & - & - \\ - & 0 & 0 & 0 & \lambda_{195} \end{bmatrix} \end{array} x \begin{bmatrix} \xi_1 \\ \xi_2 \\ \xi_3 \\ \xi_4 \\ \xi_5 \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \end{bmatrix}$$

$X = \Lambda x\xi + \delta$ **(1)**

We have 9 numbers of Y observable variable i.e. manifest variables of the dependent latent variable of $\eta_1$ and $\eta_2$ as per the Path diagrams of measurement model of Y (Figure-8) dependent variable through CFA also called Confirmatory Factor Analysis Model. The equation relationship of such variables can be formed as under:

$$Y = \begin{bmatrix} \gamma_1 \\ \gamma_2 \\ \vdots \\ \vdots \\ \gamma_9 \end{bmatrix}_{9x1} \qquad \eta = \begin{bmatrix} \eta_1 \\ \eta_2 \end{bmatrix}_{2x1} \text{ and } \quad \epsilon = \begin{bmatrix} \epsilon_1 \\ \vdots \\ \vdots \\ \epsilon_9 \end{bmatrix}$$

$\boldsymbol{\Lambda}_Y = [_{9X2}]$ 9 linear equations have been derived as under:

$$Y_1 = \lambda_{y11}\eta_1 + \epsilon_1$$
$$Y_2 = \lambda_{y21}\eta_1 + \epsilon_2$$
$$Y_3 = \lambda_{y31}\eta_1 + \epsilon_3$$
$$Y_4 = \lambda_{y41}\eta_1 + \epsilon_4$$
$$Y_5 = \lambda_{y52}\eta_2 + \epsilon_5$$

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$$Y_9 = \lambda_{y92}\eta_2 + \epsilon_9$$

$$Y = \begin{bmatrix} \gamma_1 \\ \gamma_2 \\ \vdots \\ \vdots \\ \gamma_9 \end{bmatrix}_{9X1} = \begin{bmatrix} \lambda_{11} & 0 \\ \lambda_{21} & 0 \\ \lambda_{31} & 0 \\ \lambda_{41} & 0 \\ 0 & \lambda_{52} \\ 0 & \lambda_{62} \\ 0 & \lambda_{72} \\ - & \lambda_{82} \\ - & \lambda_{92} \end{bmatrix} \eta = \begin{bmatrix} \eta_1 \\ \eta_2 \end{bmatrix} + \begin{bmatrix} \epsilon_1 \\ \epsilon_2 \\ \epsilon_3 \\ \vdots \\ \epsilon_9 \end{bmatrix}$$

$\mathbf{Y} = \boldsymbol{\Lambda_Y \eta} + \boldsymbol{\epsilon}$ **(2)**

Mathematical Equation of Structural Model of dependent and independent Latent variables **η & ξ** respectively can be derived as under from the Mathematical Model shown in the Figure 4 and its automated path diagram obtained using LISREL 9.2 is a computer programme developed and tested by Joreskog and Sorbom (2015) on Microsoft Windows platform for easy access and solving of Structural Equation Modelling problems as shown in Figure 9.

| η | | ξ | | | | |
|---|---|---|---|---|---|---|
| $\eta_1$ | $\eta_2$ | $\xi_1$ | $\xi_2$ | $\xi_3$ | $\xi_4$ | $\xi_5$ |

$$\eta_1 = 0 \quad 0 \quad \gamma_{11}\,\xi_1 + \gamma_{12}\,\xi_2 + \gamma_{13}\,\xi_3 + \gamma_{14}\,\xi_4 + 0 + \rho_1$$
$$\eta_2 = \beta_{21} \quad 0 \quad 0 + 0 + 0 + 0 + \gamma_{25}\xi_3 + \rho_2$$

$$\begin{bmatrix} \eta_1 \\ \eta_2 \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0.975 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \end{bmatrix} + \begin{bmatrix} 0.450 & -0.71 & 0.005 & 0.646 & 0.221 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} + \begin{bmatrix} 0.001 \\ 0.001 \end{bmatrix}$$

$$\begin{bmatrix} \eta_1 \\ \eta_2 \end{bmatrix} = \begin{bmatrix} 0.926 \\ 0.904 \end{bmatrix}$$

$\boldsymbol{\eta} = \boldsymbol{\beta}\,\boldsymbol{\eta} + \boldsymbol{\Gamma}\xi + \boldsymbol{\rho}$ **(3)**

Where;

$$\eta \;\rightarrow\; \begin{bmatrix} \eta_1 \\ \eta_2 \end{bmatrix}_{mx\,1} \rightarrow \text{ Endogenous variables ( Dependent Latent)}$$

where m=2

$$\xi \;\rightarrow\; \begin{bmatrix} \xi_1 \\ \xi_2 \\ \vdots \\ \xi_5 \end{bmatrix}_{nx\,1} \rightarrow \text{ Exogenous variables (Independent latent)}$$

$$\gamma \quad \rightarrow \quad \begin{bmatrix} \gamma_1 \\ \gamma_2 \\ : \\ \gamma_9 \end{bmatrix}_{px\,1} \quad \rightarrow \text{ Observed manifest variables of } \eta$$

$$X \quad \rightarrow \quad \begin{bmatrix} X_1 \\ X_2 \\ : \\ X_{19} \end{bmatrix}_{qx\,1} \quad \rightarrow \text{ Observed manifest variables of } \xi$$

$$\rho \quad \rightarrow \quad \begin{bmatrix} \rho_1 \\ \rho_2 \end{bmatrix}_{mx\,1} \quad \rightarrow \text{ Structural error of latent variable of } \eta$$

$$\varepsilon \quad \rightarrow \quad \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ : \\ \varepsilon_5 \end{bmatrix}_{px\,1} \quad \rightarrow \text{ Measurement error of variable Y}$$

$$\delta \quad \rightarrow \quad \begin{bmatrix} \delta_1 \\ \delta_2 \\ : \\ \delta_{19} \end{bmatrix}_{qx\,1} \quad \rightarrow \text{ Measurement error of variable X}$$

$$\Lambda x[19x5] = \begin{bmatrix} \lambda_{11} & 0 & 0 & 0 & 0 \\ \lambda_{21} & 0 & 0 & 0 & 0 \\ \lambda_{31} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & \lambda_{42} & 0 & 0 & 0 \\ 0 & \lambda_{52} & 0 & 0 & 0 \\ - & - & - & - & - \\ 0 & 0 & 0 & 0 & \lambda_{195} \end{bmatrix}_{qxn} \quad \text{where } q = 19,\ n = 5$$

$$\Lambda y[9x2] = \begin{bmatrix} \lambda_{11} & 0 \\ \lambda_{21} & 0 \\ \lambda_{31} & 0 \\ \lambda_{41} & 0 \\ 0 & \lambda_{52} \\ 0 & \lambda_{62} \\ 0 & \lambda_{72} \\ - & \lambda_{82} \\ - & \lambda_{92} \end{bmatrix}_{pxm} \quad \text{where } p=9,\ m=2$$

$$\beta = \begin{bmatrix} 0 & 0 \\ \beta_{21} & 0 \end{bmatrix}_{mxm} \quad \text{where } m=2$$

$$\Gamma = \begin{bmatrix} \gamma_{11} & \gamma_{12} & \gamma_{13} & \gamma_{14} & 0 \\ 0 & 0 & 0 & 0 & \gamma_{25} \end{bmatrix}_{mxn}$$

Where $\Lambda x[19x5]$, $\Lambda y[9x2]$, $\beta[2x2]$ and $\Gamma[2x5]$ are coefficients matrices of X to $\xi$, Y to $\eta$, dependent latent variable of $\eta$ & independent latent variables of $\xi$.

## III. MATHEMATICAL COMPUTATION AND ANALYSIS

This section discusses about obtaining of covariance's matrices of relationship weights between manifest and latent variables using LISREL software which was tested by Paul and Maiti (2008) for further solving of such matrices using MATLAB to obtain reliability indexes and other goodness of fit parameters of the mathematical model. Also, various path diagrams of relationship between observable variables of 'X' and 'Y' and Latent variables obtained through LISREL has been shown. Besides that LISREL output containing standard measurement errors of manifest variables has also been listed. It also consists of description of model parameters along with factors affecting reliability and methodology of processing and decision making etc.

### 3.1. FACTORS AFFECTING RELIABILITY

The mathematical model has derived using SEM. The SEM shows the factors that influence reliability as illustrated in Figure 3 & 4. Magnitude of the influences is shown by the regression weights and loading factor values as listed in Table 3, also on the standard path diagram shown in the Figure 5, obtained by data processing using LISREL 9.2. Error of model that is expressed as root mean square error of approximation (RMSEA) is 0.118. The influence of some variables to the reliability, resulted by this study have been described in Table 2.

**Table 2. Factors affecting Reliability of the system**

| Common Factors | Reliability actions /Impacts |
|---|---|
| Planning (Resources, Cost & Time duration) | Sustainability and Reliability of a project highly depends on the Planning part of the project. |
| Feasibility, scalability , Technology, Secure , Design & Development | Reliability highly depends on technology adoption, its availability, maintenance and scalability. |
| Management & Ownership | Government /institutions owns , monitor, review and manage the project for better results, and gives a reliable feeling |
| Fulfillment of requirements | Referring the feedback mechanism of Govt through call centres and surveys |
| Performance | The systems should perform as per the requirements. Performance played important role for a system to be reliable. |
| Operational Support | Round the clock operational support shall be ensured by the Govt /Institutions |
| Availability | The system should be highly available e.g 24x7 basis to be reliable |
| Change management | The Changes should be reviewed and after approval of competent authority should be incorporated. |
| Community Participation | Community should adopt the change and should give feed back to make the systems more reliable and sustainable. |

### 3.2. MATHEMATICAL MODEL OF RELIABILITY

Model of online admission system as depicted in Figure 4 has been illustrated again in Figure 5 (obtained after data processing using LISREL) which shows relationship between Observable and Latent variables and corresponding mathematical equations are constructed, where **λ** is loading factor of relationship between observed and latent variables, **γ** is regression coefficients between exogenous (independent) variables and endogenous (dependent) variables, and β is regression coefficient between endogenous variables and other independent variables.
Basic equation of SEM are (1), (2) & (3). By substituting equation (1) and equation (2) into equation (3), the model of reliability equations are obtained as follows:

$$\eta = B\eta + \Gamma\frac{(X-\delta)}{\Lambda x} + \rho \qquad (4a)$$

$$\eta = B^*\eta + \Gamma^*(\Lambda x \backslash (X-\delta)) + \rho \qquad (4b)$$

From Equation (1) to (4b), the matrices of vectors that can be obtained by taking values from Figure 5 and Table 3, the equation (4b) becomes

$$\begin{bmatrix}\eta_1\\ \eta_2\end{bmatrix} = \begin{bmatrix}0 & 0\\ 0.975 & 0\end{bmatrix} x \begin{bmatrix}1\\ 1\end{bmatrix}_{\text{assumption}} +$$

$$\begin{bmatrix}0.450 & -0.71 & 0.008 & 0.646 & 0.221\\ 0 & 0 & 0 & 0 & 0\end{bmatrix} x$$

$$\left[\begin{bmatrix} 0.461 & 0 & 0 & 0 & 0 \\ 0.383 & 0 & 0 & 0 & 0 \\ 0.633 & 0 & 0 & 0 & 0 \\ 0 & 0.310 & 0 & 0 & 0 \\ 0 & 0.320 & 0 & 0 & 0 \\ 0 & 0.385 & 0 & 0 & 0 \\ 0 & 0.231 & 0 & 0 & 0 \\ 0 & 0.323 & 0 & 0 & 0 \\ 0 & 0 & 0.01 & 0 & 0 \\ 0 & 0 & -0.037 & 0 & 0 \\ 0 & 0 & -0.021 & 0 & 0 \\ 0 & 0 & -0.009 & 0 & 0 \\ 0 & 0 & 0 & 0.383 & 0 \\ 0 & 0 & 0 & 0.473 & 0 \\ 0 & 0 & 0 & 0.795 & 0 \\ 0 & 0 & 0 & 0.285 & 0 \\ 0 & 0 & 0 & 0 & 0.679 \\ 0 & 0 & 0 & 0 & 0.779 \\ 0 & 0 & 0 & 0 & 0.759 \end{bmatrix} \backslash \begin{bmatrix} 0.600 \\ 0.478 \\ 0.861 \\ 0.557 \\ 0.463 \\ 0.558 \\ 0.283 \\ 0.483 \\ 0.001 \\ -0.039 \\ -0.022 \\ -0.011 \\ 0.562 \\ 0.691 \\ 1.068 \\ 0.396 \\ 0.903 \\ 1.157 \\ 1.002 \end{bmatrix} - \begin{bmatrix} 0.195 \\ 0.186 \\ 0.196 \\ 0.388 \\ 0.249 \\ 0.240 \\ 0.188 \\ 0.266 \\ 0.124 \\ 0.147 \\ 0.150 \\ 0.215 \\ 0.251 \\ 0.221 \\ 0.139 \\ 0.236 \\ 0.148 \\ 0.157 \\ 0.126 \end{bmatrix} + \begin{bmatrix} 0.001 \\ 0.001 \end{bmatrix}\right] \qquad \textbf{.........(5)}$$

On solving the above equation using Matlab following results are obtained. However, the values of Factor loadings of X on ξ ($\Lambda_x$ matrix) have been obtained using LISREL 9.2 (Linear Structural Relations). Also the values of X observed variables (indicators of ξ) have obtained from OUTPUT of LISREL 9.2 in the above matrix, hence following estimates of latent variables obtained

$$\begin{bmatrix} \eta_1 \\ \eta_2 \end{bmatrix} = \begin{bmatrix} 0.926 \\ 0.904 \end{bmatrix} = \begin{bmatrix} \text{Reliability} \\ \text{Sustainability} \end{bmatrix}$$

The equation can predict the reliability $\boldsymbol{\eta_1}$ and sustainability $\boldsymbol{\eta 2}$. Further to obtain observed variables (Indicators) equation (2) need to be rearranged to become equation (6).

$$\text{Y}= \begin{bmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \\ \gamma_6 \\ \gamma_7 \\ \gamma_8 \\ \gamma_9 \end{bmatrix} = \begin{bmatrix} 0.586 & 0 \\ 0.726 & 0 \\ 0.823 & 0 \\ 0.862 & 0 \\ 0 & 0.763 \\ 0 & 0.579 \\ 0 & 0.673 \\ 0 & 0.684 \\ 0 & 0.545 \end{bmatrix} \text{x} \begin{bmatrix} 0.926 \\ 0.904 \end{bmatrix} + \begin{bmatrix} 0.119 \\ 0.110 \\ 0.0996 \\ 0.0829 \\ 0.126 \\ 0.140 \\ 0.160 \\ 0.152 \\ 0.183 \end{bmatrix} \qquad \text{-----------------} \ \textbf{(6)}$$

$$\text{Y} = \begin{bmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \\ \gamma_6 \\ \gamma_7 \\ \gamma_8 \\ \gamma_9 \end{bmatrix} = \begin{bmatrix} 0.7417 \\ 0.7823 \\ 0.8618 \\ 0.8812 \\ 0.8707 \\ 0.7051 \\ 0.8168 \\ 0.8196 \\ 0.7149 \end{bmatrix} \qquad \text{-------------------} \ \textbf{(7)}$$

### 3.3. RELIABILITY INDEX

Reliability index states total value of four indicators namely user requirements fulfillment (quality), quantity (results) , system availability (continuity), Performance (response time) generation from the system (Y1, Y2, Y3, Y4) as listed in equation 7. Value of each indicator is based on the assessment criteria that have highest possible value of 1 and the lowest value of 0. Thus, value of reliability index will range from 0 to 4. Reliability index is classified into three intervals i.e. high, medium and low. This classification is made by considering the following:
Results of simulation using the model shows that maximum and minimum value of reliability index that may occur are 3.267 and 0.742, respectively, the average value of Reliability index in the study area is 0.817, the standard deviation of Reliability index in the study area is 0.057014. And RMSEA is 0.118.
Based on these considerations, classification of reliability is determined to be of three levels as follows:

- Low Reliability, if Reliability index
  = 0.742 to 1.524
- Medium Reliability, if index

= 1.525 to 2.386

- High Reliability, if index
= 2.387 to 3.267

### 3.4 BASIC MODEL OF RELIABILITY

Following Path diagram (Basic Model) obtained after processing of data set of 114 different engineering institutions using LISREL 9.2

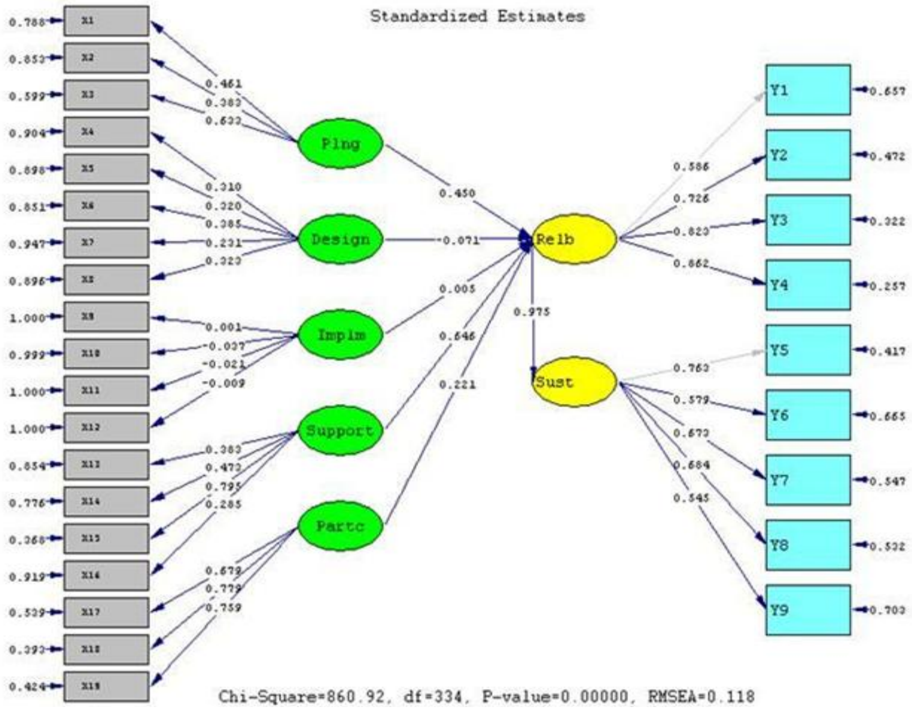


**Figure 5. Path Diagram of Basic Model obtained using LISREL 9.2 (Automated diagram of Figure 4) showing factor loadings and regression weights**

Following Table 3 contains values of Loading factors, Estimates and Standard errors of measurement model obtained by the OUTPUT table of LISREL after processing of data of 114 engineering institutions.

**Table 3. Loading Factors and Regression weight Estimates**

| Relationship | | | Estimate | Standardized Estimates | Standard Error (S.E.) | Error (ρ) |
|---|---|---|---|---|---|---|
| Reliability | ← | Planning | 0.450 | 0.450 | 0.162 | 0.004 |
| Reliability | ← | Design &Dev | -0.071 | -0.071 | 0.160 | *** |
| Reliability | ← | Imp & Management | 0.005 | 0.005 | 0.0129 | *** |
| Reliability | ← | Support | 0.645 | 0.646 | 0.209 | *** |
| Sustainability | ← | Reliability | 0.986 | 0.975 | 0.144 | 0.0011 |
| Resources (Tech & Manpower) | ← | Planning | 0.600 | 0.461 | 0.195 | *** |
| Cost | ← | Planning | 0.478 | 0.383 | 0.186 | *** |
| Time-line | ← | Planning | 0.861 | 0.633 | 0.196 | *** |
| Quality | ← | Reliability | 0.870 | 0.657 | 0.199 | *** |
| Quantity | | Reliability | 0.952 | 0.472 | 0.110 | *** |
| Continuity/ | ← | Reliability | 1.155 | 0.322 | 0.0996 | *** |
| Performance | ← | Reliability | 1.194 | 0.257 | 0.0829 | *** |
| Satisfaction | ← | Sustainability | 1.048 | 0.417 | 0.126 | *** |
| Benefits | ← | Sustainability | 0.749 | 0.665 | 0.140 | *** |
| Functionality | ← | Sustainability | 0.949 | 0.532 | 0.152 | 0.0011 |
| Availability | ← | Sustainability | 0.946 | 0.547 | 0.160 | *** |
| Income | ← | Sustainability | 0.748 | 0.703 | 0.183 | *** |
| Ownership | ← | Imp &Management | 0.001 | 0.001 | 0.124 | *** |
| Institutionalization | ← | Imp &Management | 0.039 | -0.037 | 0.147 | *** |
| Testing | ← | Imp &Management | -0.022 | -0.021 | 0.150 | *** |
| Operation | ← | Imp &Management | -0.011 | -0.009 | 0.215 | *** |
| Scalable | ← | Design &Dev | 0.557 | 0.310 | 0.388 | 0.033 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Technology Independent | ← | Design &Dev | 0.463 | 0.320 | 0.249 | *** |
| Requirements | ← | Design &Dev | 0.558 | 0.385 | 0.240 | *** |
| Branding | ← | Design &Dev | 0.283 | 0.231 | 0.188 | *** |
| Secure | ← | Design &Dev | 0.483 | 0.323 | 0.266 | *** |
| Training | ← | Support | 0.562 | 0.383 | 0.251 | *** |
| Capacity Building | ← | Support | 0.691 | 0.473 | 0.221 | *** |
| Change | ← | Support | 1.068 | 0.795 | 0.139 | *** |
| Maintenance | ← | Support | 0.396 | 0.285 | 0.236 | *** |
| Students | ← | Participation | 0.903 | 0.679 | 0.148 | *** |
| Banks | ← | Participation | 1.157 | 0.779 | 0.157 | *** |
| Institutions | ← | Participation | 1.002 | 0.759 | 0.126 | *** |

Note: ***: $\rho<0.001$ (values taken from OUT table of LISREL 9.2 standardized errors

## IV. PARAMETERS DESCRIPTION & METHODOLOGY

The decision making methodology for implementation of the system, comprises of few steps as shown in Figure 6, the methodology should need to be taken before a project plan is developed or implemented or rolled-out. The contents and requirements of the project plan should be reviewed for feasibility, sustainable development & implementation. The first step is data inventory, includes19 independent data items which required for testing of the Reliability model as shown in Figure.4, description follows as under:

1) Availability of Resources(X1); It is assumed that data pertaining to resources like Technological platform, connectivity, Technical Manpower and Institutions etc as required in development and implementation of the system are available.
2) Project cost (X2); data about estimated project costs and sources of funding, easy availability and payment schedule & term as required for execution of different component of the project.
3) Time duration (X3); during the planning phase itself, it is always better to chalk out the time line that is activities time schedule to achieve different mile stones for project implementation.
4) Scalability (X4); the system design should be flexible to add/delete any institution and should seamless function for 'n' number of institutions, courses and students at any point of time.
5) Technology Independent(X5); Design should be technology independent that is the system should run on any technology platform proprietary or open source.
6) Functional requirements (X6); the System design should meet all requirements.
7) Branding (X7); The system should have some trusted brand name so that participants could join confidently.
8) Security (X8); the design system should secure and should not vulnerable to any external un authorize access.
9) Ownership (X9); the system should be owned by some agency or Govt., for better growth and maintenance.
10) Institutionalization(X10); the system once developed should be adopted legally for effective implementation.
11) Testing (X11); the system should be well tested and required trail runs should be performed before formally launch
12) Operationalization (X12); during implementation, system must be operated properly, for that trained manpower, computer and electricity resources needed
13) Training & Capacity Building (X13) & (X14) of all the identified staff of institutions responsible for implementation & execution of the system is an essential part.
14) Change management (X15); i.e. the system should meet the local requirements, if any &maintenance (X16) i.e. corrective action in the machinery due to breakdown /damage control.
15) Participation of Students (X17) & Banking institutions (X18) & Technical Institutions (X19) is must, because the system has been developed for them, number of participating students, institutions reflects about the system reliability and also help the owner and developers in scaling of technology, machinery etc.

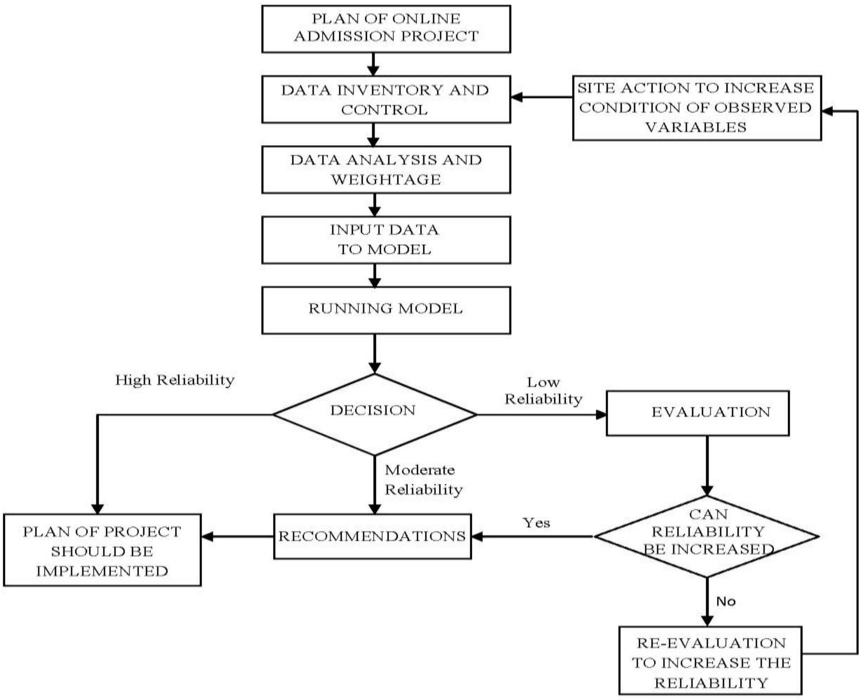


**Figure 6. Broad Flowchart of Online admission system**

## V. GRAPHICAL VIEWS OF DIFFERENT MODELS

Measurement Model of X manifest variables is given below in the Figure 7:

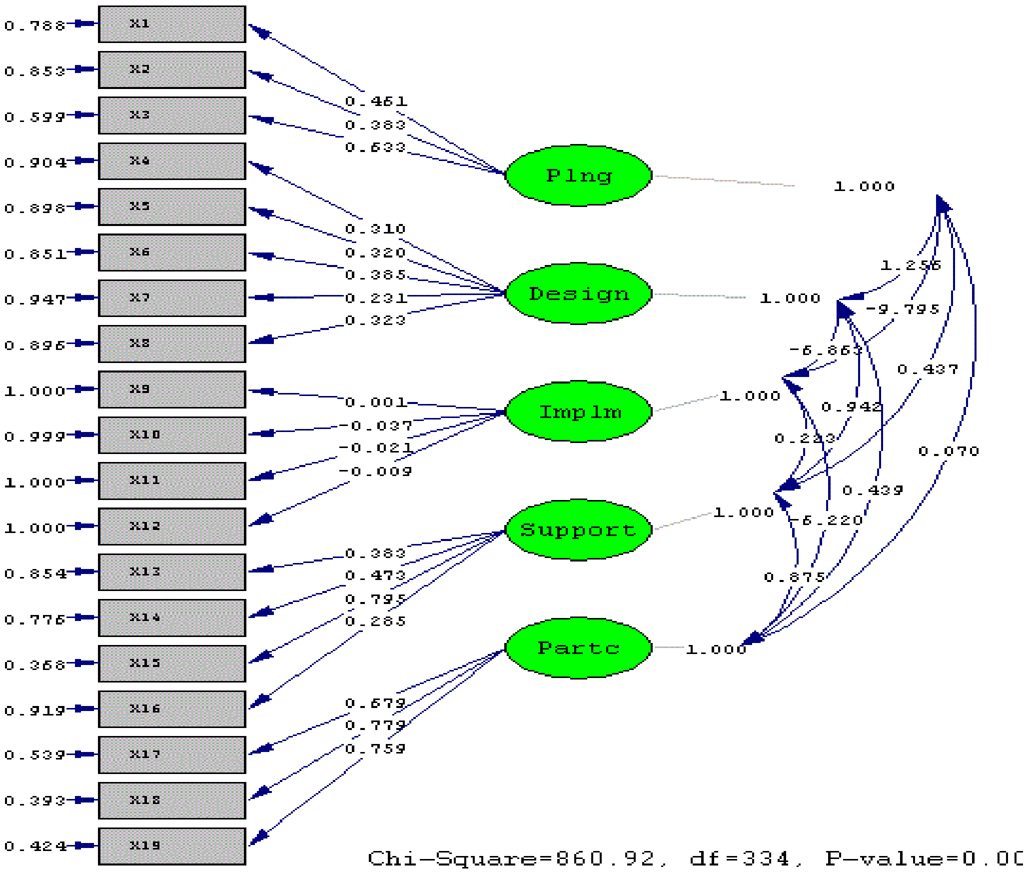


**Figure 7. Path Diagram of Standardized estimates of Measurement Model of Independent Latent variables and their Indicators (Observable) variables of X**

Measurement Model of Y manifest variables is given below in the Figure 8.

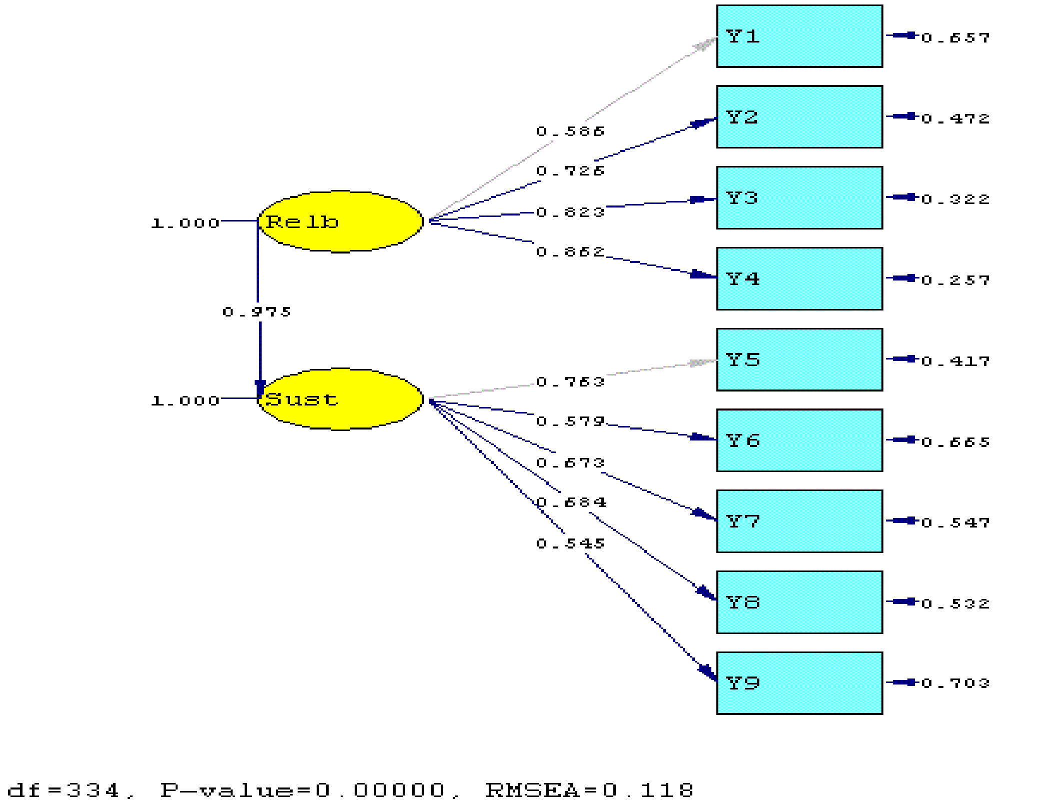


**Figure 8. Path Diagram of Standardized estimates of Measurement Model of dependent Latent variables and their Indicators (Observable) variables of Y**

The Path diagram of Standardized estimates of Structural Model of Independent & dependent Latent variables have been shown in the Figure 9.

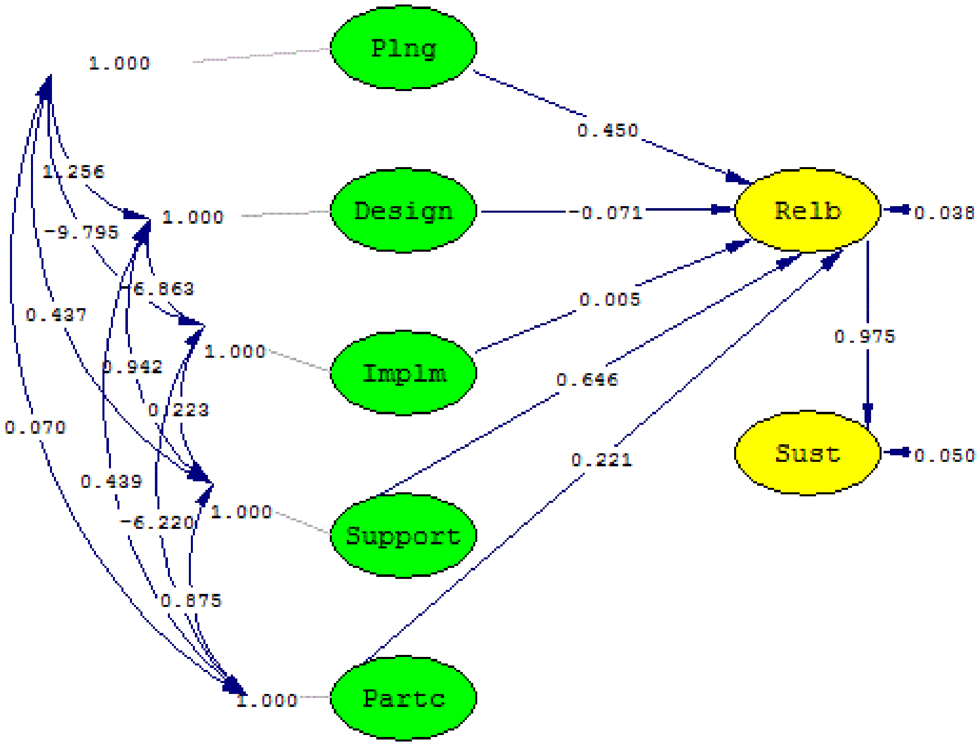


**Figure 9. Path diagram of Standardized estimates of Structural Model of Ind. & dependent Latent variables.**

## VI. GOODNESS OF FIT

| | |
|---|---|
| Degrees of Freedom for (C1)-(C2) | 334 |
| ML Ratio Chi-Square (C1) | 860.917(P=0.0000) |
| Degrees of Freedom for Difference | 0 |
| Chi-square Difference (C1) | 1.172 (P =1.0000) |
| Estimated Non-centrality Parameter (NCP) | 526.917 |
| 90 Percent Confidence Interval for NCP | (444.057;617.443) |
| Minimum Fit Function Value | 7.552 |
| Population Discrepancy Function Value (F0) | 4.622 |
| 90 Percent Confidence Interval for F0 | (3.895 ; 5.416) |
| Root Mean Square Error of Approximation (RMSEA) | 0.118 |
| 90 % Confidence Interval for RMSEA | (0.108 ; 0.127) |
| P-Value for Test of Close Fit (RMSEA < 0.05) | 0.000 |
| Chi-Square for Independence Model (378 df) | 1803.600 |
| Normed Fit Index (NFI) | 0.523 |
| Non-Normed Fit Index (NNFI) | 0.582 |
| Parsimony Normed Fit Index (PNFI) | 0.462 |
| Comparative Fit Index (CFI) | 0.630 |
| Incremental Fit Index (IFI) | 0.641 |
| Relative Fit Index (RFI) | 0.460 |
| Root Mean Square Residual (RMR) | 0.208 |
| Standardized RMR | 0.117 |
| Goodness of Fit Index (GFI) | 0.648 |
| Adjusted Goodness of Fit Index (AGFI) | 0.572 |
| Parsimony Goodness of Fit Index (PGFI) | 0.533 |

## VII. DISCUSSIONS AND CONCLUSION

Results of the study are formation of Mathematical data model and deriving the mathematical equations to compute and predict Reliability and its range intervals. Accordingly, recommendations & methodology for decision-making, whether the system of online off-campus admission is reliable and replicable, may be decided. This methodology includes the steps that must be taken before a project plan implementation starts.

The discussion is focused on computation of Reliability of the paperless online off campus admission system which is constantly executed since 2006 pan Haryana by more than 500 institutions and found sustainable. From the perspective of students and government the system is quite cost effective, transparent, efficient and helpful in increasing of e-readiness among students and institutions for replication of the system at other locations and states. It is inevitable to ensure Reliability under different conditions of technology usage, implementation plan, capacity building for adequate operations, power availability, change management etc. Structural Equation Modelling (SEM) technique has been tested by formulating a data model and deriving mathematical equations. Subsequently, formation of co-variances and regressions metrics and solving them uses LISREL & MATLAB for computing Reliability of the system. The index of Reliability varies between 3.267 and 0.742 (4-0 interval), respectively, and the RMSEA of reliability index in the study area is 0.118, which further tested goodness of fit for the derived model. Also for decision making, recommendations like validation of Mathematical model using separate sample of dataset, selection of robust technology, capacity building, and establishment of help desks etc may be followed for improved sustainability.

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