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Multilevel Structural Equation Model with Gifi System in Understanding the Satisfaction of Health Condition at Java

Alfatihah R. M. N. S. P. Munaf, Hari Wijayanto and Asep Saefuddin

Department of Statistics, Bogor Agricultural University, Indonesia

I Wayan Mangku

Department of Mathematics, Bogor Agricultural University, Indonesia

Abstract

This study will model the satisfaction of health conditions in Java on 2014 using Multilevel Structural Equation Model (SEM) with Gifi transformed variables. Multilevel SEM chosen in order to see the effects of healthcare facilities to the satisfaction of health conditions. Two data sources are used: Health Indicators of Happiness Level Measurement Survey held by Statistics Indonesia in 2014, to explain individual level; and health facilities in 2014 based on records of the Ministry of Health of the Republic of Indonesia, to explain the provincial level. Gifi system chosen in order to handle data transformation. The results obtained Gifi transformed variables showed improved performance on SEM, especially on the efficiency of the time needed for computation. It helps to reduce the complexity in Multilevel SEM. Through the result of Multilevel SEM, it can be seen that the satisfaction of health conditions is also influenced by the health facilities that received, in addition to what is perceived by the respondents. Satisfaction of health conditions at the individual level is determined by healthcare behavior (1,000), and at the provincial level is determined by the health facilities (1,024).

Keywords: Multilevel SEM, Gifi system, Gifi transformed variables

1 Introduction

Every problem requires the right tools to resolve it. The curiosity to know the effectiveness, success and sustainability of a situation is often resolved by measurements. However, not all of the problems in the world that can be measured directly. To answer this, we use real variables and form the indicators that are used to describe the latent variables. Multilevel Structural Equation Model (SEM) is used when involving observation that has levels within the structure of the data, and variables that are measured using several indicators [1, 2]. Study on Multilevel Model begins with the development of the multilevel model by Hox [3]. Curran, [4], examines the combination of SEM and Multilevel Modeling, then conclude the potential of Multilevel SEM to be developed in the next research. The application in Multilevel SEM introduced by Rabe-Hesketh et al. [5]. Mehta [6] develop Multilevel SEM to N-level.

The data handling is required when we want to use SEM to analyze categorical data. There are several methods that can be used in data transformation, one of which is transformation using the Gifi system. The method of Gifi transformation [7] was one to one transformation method which can be restored to their original form, and is known to have good information complexity criteria, when applied on a wide range of models [8, 9].

We will apply Multilevel SEM to evaluate the influence of someone's perception of his health condition (level 1) and health facilities provided by the Government (level 2) to the satisfaction of health conditions. In level 1, we are using the health indicators from The Measurement of Happiness Level Survey by 2014 [10], with 13,684 observations. In level 2, we use the number of health facilities for each province at Java Island, with a population of 6 provinces.

2 SEM with Gifi System

Data transformation with Gifi algorithms can maximize the homogeneity of data, and handles information complexity [8, 11]. Data transformation procedures using the Gifi algorithm is described in the following order:

1. We consider the data $\boldsymbol{X}$ as m x n matrix.
2. Create $\boldsymbol{G}$ as indicator matrix of $\boldsymbol{X}$, and $\boldsymbol{D}$ as diagonal matrix of $\boldsymbol{G}$.
3. Let $\boldsymbol{X}^*$ ~ rand(n,1).
4. Update $\boldsymbol{A} = (\boldsymbol{G}' * \boldsymbol{X})/\boldsymbol{D}$
5. Update $\boldsymbol{X}^* = (\boldsymbol{G} * \boldsymbol{A})/m$
6. Perform the convergence test by $lossfunction(i) = \frac{\boldsymbol{X}^*=(\boldsymbol{G}*\boldsymbol{A})'*\boldsymbol{X}^*=(\boldsymbol{G}*\boldsymbol{A})}{m}$
7. We accept $\boldsymbol{X}^*$ as the new variables if the stopping criteria is met, where $lossfunction(i) - lossfunction(i-1) < 0.001$.

We adapt the satisfaction model from New Economic Foundation and the Office for National Statistics (Figure 1), as outlined in Table 1. First, we apply SEM to model the original variables. As a comparison, we made 100 sets of Gifi variables. Then, we apply the same model to these variables. The result is presented in Table 2.

Table 1. Indicators of latent variables

The Latent exchangeable and The Indicators	The relationship to the customer satisfaction toward the health
(1)	(2)
ξ_1 : Health conditions	History of disease in the last month (X1), history of the disease five months before (X2), and history of chronic disease (X3).
ξ_2 : Ownership of insurance	Health insurance ownership (X4).
ξ_3 : Physical limitations	To See (X5), to hear (X6), to walk (X7), to remember (X8), to communicate (X9), and taking care of his self (X10).
ξ_4 : Symptom of stress	Headache (X16), Eating disorders (X17), Sleeping disorders (X18), Loneliness (X19), Anxiety (X20), Fear (X21), Laziness (X22), Indigestion (X23), Exhaustion (X24), Tired of life (X25)
η_1 : Healthcare behavior	Sport (X11), dietary (X12), sleep well (X13), vitamin (X14), and medical check-up (X15).
η_2 : Health satisfaction	The satisfaction of health condition (Y1).

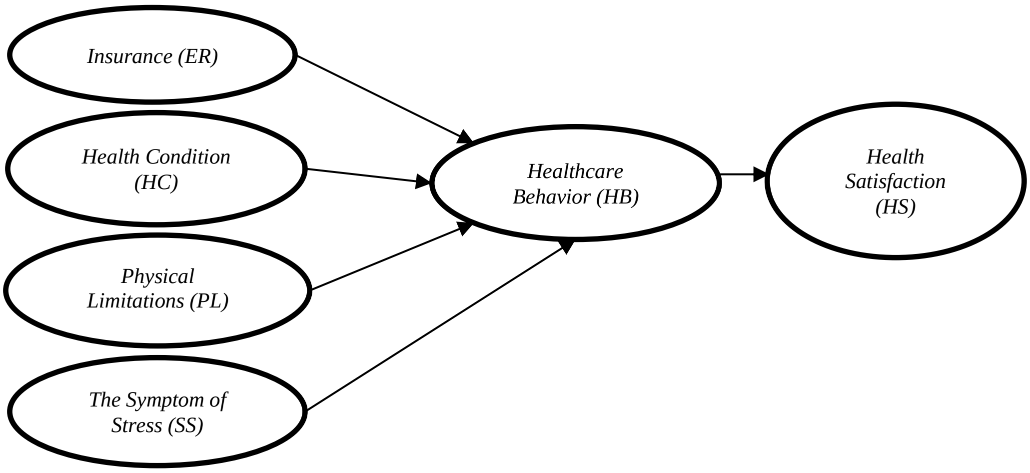

Figure 1. SEM for measuring Satisfaction of Health

Based on the results obtained in table 2, it indicates that the model with Gifi system can significantly reduce time consumption in computing. This is an advantage when dealing with a complex model. But for the goodness of fit, the *Incremental Fit Index* (CFI and TLI), the performance of the SEM with Gifi transformed variables is not as good as the first model. However, its value are still at an acceptable range, and we can say that the model is good enough.

Table 2. Model summary on the base model and the model with Gifi transformed variables

	Base Model	Model with Gifi transformed variables
The number of iterations	142	67,510
Chi-square	13788,52	12018,209
CFI	0,822	0,748
TLI	0,801	0,717
RMSEA	0,058	0,054
SRMR	0,068	0,062

A summary of the model with Gifi transformed variables after modifications are described as follows.

```
  Number of observations                         13684

  Degrees of freedom                               249
  P-value (Chi-square)                           0.000
  Comparative Fit Index (CFI)                    0.900
  Tucker-Lewis Index (TLI)                       0.869
  RMSEA                                          0.038
  SRMR                                           0.041

Parameter Estimates:

Regressions:
                   Estimate  Std.Err  z-value  P(>|z|)
  HB ~
    ER                1.000
    HC               -1.303    0.165   -7.885    0.000
    SS               -0.731    0.199   -3.664    0.000
    PL               -0.034    0.058   -0.583    0.560
  HS ~
    HB                1.000
```

Based on the summary of the model, we can say that the physical limitations are not significant in determining healthcare behavior (P = 0.560). We will exclude physical limitations in modeling with Multilevel SEM.

3 Multilevel Modeling

Multilevel SEM is a combination of SEM and Multilevel Model, where this method is good to be used as a tool in decision making when involving the unit of observation that have levels within the structure of the data [2]. Multilevel SEM become more interesting when in each level there are also models of SEM. This model is also known as the N-level SEM [6]. The constraints in N-level SEM is the complex calculations, which is very time-consuming computation. The Gifi transformed variables becomes the solution in abbreviating the computation.

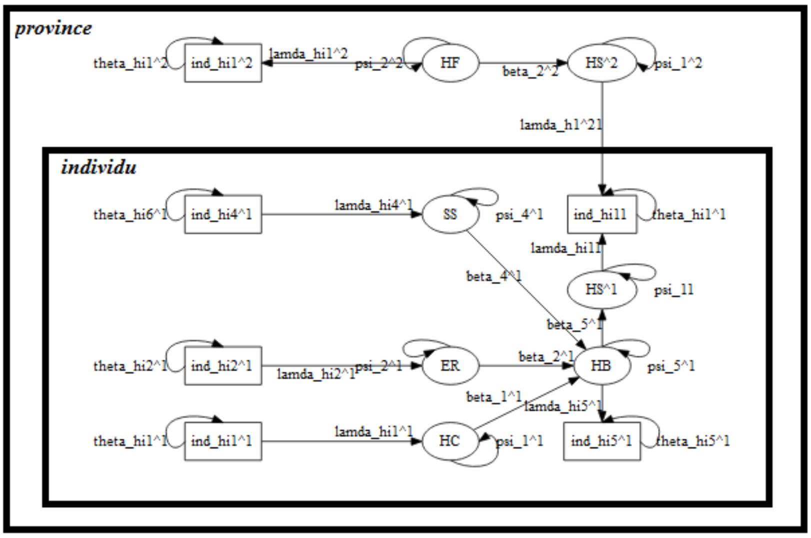

Figure 2. Multilevel SEM for satisfaction on health condition

Based on Figure 2, Multilevel SEM is expected to provide an explanation of satisfaction of health conditions at the individual level and the provincial level. The parameters is predicted based on the following procedures.

1. The formation of a sub-model in individual level (the first level)

$$\boldsymbol{y}_{hij}^{1} = \boldsymbol{\nu}_{hij}^{1} + \boldsymbol{\lambda}_{hij}^{1} \times \boldsymbol{\eta}_{hj}^{1} + \boldsymbol{e}_{hij}^{1}. \tag{1}$$

Where y_{hij}^{1} is the indicator i of the latent h on observation j. Superscript 1 is to indicate that this equation is located on the first level. The assumption that used:

$$\boldsymbol{\eta}_{hj}^{1} \sim N\left(0, \boldsymbol{\psi}_{hj}^{1}\right) \tag{2}$$

$$\boldsymbol{e}_{\mathrm{hij}}^{1} \sim N\left(0, \theta_{\mathrm{hij}}^{1}\right). \tag{3}$$

For each of the latent h, there are a number of i-1 *factor loadings* λ_{hij}^{1} with the first loading factor is 1. A residual variance for each of the indicators i stated with $\theta_{\mathrm{hij}}^{1}$, while a residual variance for latent h stated with ψ_{hj}^{1}. Intercept for each of the indicators i stated with ν_{hij}^{1}. The latent variable Healthcare Behavior (HB) is a regression of the three other latent, and stated with this equation:

$$\boldsymbol{\eta}_{1\mathrm{j}}^{1} = \beta_{1\mathrm{j}}^{1} * \boldsymbol{\eta}_{1\mathrm{j}}^{1} + + \boldsymbol{\beta}_{2\mathrm{j}}^{1} * \boldsymbol{\eta}_{2\mathrm{j}}^{1} + \boldsymbol{\beta}_{4\mathrm{j}}^{1} * \boldsymbol{\eta}_{4\mathrm{j}}^{1} + \boldsymbol{\xi}_{1\mathrm{j}}^{1} \tag{4}$$

assuming

$$\boldsymbol{\xi}_{1\mathrm{j}}^{1} \sim N\left(0, \boldsymbol{\psi}_{hj}^{1}\right). \tag{5}$$

2. The formation of a sub-model in province level (the second level)

$$\boldsymbol{y}_{\mathrm{hik}}^{2} = \boldsymbol{\nu}_{\mathrm{hik}}^{2} + \boldsymbol{\lambda}_{\mathrm{hik}}^{2} \times \boldsymbol{\eta}_{\mathbf{hk}}^{\mathbf{2}} + \boldsymbol{e}_{\mathrm{hik}}^{2} \tag{6}$$

assuming

$$\boldsymbol{\eta}^2_{\mathrm{hk}} \sim N\,(0, \boldsymbol{\psi}^2_{hk}) \tag{7}$$

$$e^2_{\mathrm{hik}} \sim N\left(0, \theta^2_{\mathrm{hik}}\right). \tag{8}$$

Health facilities (HF) is a regression of the other latent, and stated with this equation:

$$\boldsymbol{\eta}^2_{1\mathrm{k}} = \boldsymbol{\beta}^2_{2\mathrm{k}} * \boldsymbol{\eta}^2_{\mathbf{2k}} + \boldsymbol{\xi}^2_{\mathrm{k}} \tag{9}$$

assuming:

$$\boldsymbol{\xi}^2_{\mathrm{k}} \sim N\,(0, \boldsymbol{\psi}^2_{1k}). \tag{10}$$

3. The formation of a model that connects the first level sub-model with the second level sub-model.

$$\boldsymbol{y}^1_{11j} = \boldsymbol{\lambda}^1_{11j} \times \boldsymbol{\eta}^1_{1j} + \boldsymbol{\lambda}^{12}_{12k} \times \boldsymbol{\eta}^2_{2k} \tag{11}$$

Then we use all the matrices to complete the specification of the model, as described in Table 3.

Table 3. A summary of the matrix used for model specification SEM

	Matrices	Pattern
Level 1: Θ	$\Theta^{1,1} = \begin{bmatrix} \theta^{1,1}_{1,1} & & & \\ \theta^{1,1}_{2,1} & \theta^{1,1}_{2,2} & & \\ \vdots & \vdots & \ddots & \\ \theta^{1,1}_{26,1} & \theta^{1,1}_{26,2} & \cdots & \theta^{1,1}_{26,5} \end{bmatrix}$	$\Theta^{1,1} = \begin{bmatrix} 1 & & & \\ 0 & 1 & & \\ \vdots & \vdots & \ddots & \\ 0 & 0 & \cdots & 1 \end{bmatrix}$
Level 1: ν	$\nu^1 = \begin{bmatrix} \nu^1_1 \\ \nu^1_{1,2} \\ \vdots \\ \nu^1_{10,6} \end{bmatrix}$	$\nu^1 = \begin{bmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix}$
Level 1: Λ	$\Lambda^{1,1} = \begin{bmatrix} \lambda^{1,1}_{1,1} & 0 & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & 0 & \lambda^{1,1}_{1,6} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & 0 & \lambda^{1,1}_{10,6} \end{bmatrix}$	$\Lambda^{1,1} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & 0 & 1 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$
Level 1: Ψ	$\Psi^{1,1} = \begin{bmatrix} \psi^{1,1}_{1,1} & & & \\ \psi^{1,1}_{2,1} & \psi^{1,1}_{2,2} & & \\ \vdots & \vdots & \ddots & \\ \psi^{1,1}_{6,1} & \psi^{1,1}_{6,2} & \dots & \psi^{1,1}_{6,6} \end{bmatrix}$	$\Psi^{1,1} = \begin{bmatrix} 1 & & & \\ 0 & 1 & & \\ \vdots & \vdots & \ddots & \\ 0 & 0 & \dots & 1 \end{bmatrix}$

Table 4. (Continued): A summary of the matrix used for model specification SEM

Level 1: **B**	$\beta^{1,1} = \begin{bmatrix} \beta^{1,1}_{1,1} & & & \\ \beta^{1,1}_{2,1} & \beta^{1,1}_{2,2} & & \\ \vdots & \vdots & \ddots & \\ \beta^{1,1}_{6,1} & \beta^{1,1}_{6,2} & \dots & \beta^{1,1}_{6,5} \end{bmatrix}$	$\beta^{1,1} = \begin{bmatrix} 0 & & & \\ 0 & 0 & & \\ \vdots & \vdots & \ddots & \\ 0 & 0 & \dots & 0 \end{bmatrix}$
Level 2 -> Level 1: Λ	$\Lambda^{1,2} = \begin{bmatrix} \lambda^{1,2}_{1,1} & 0 \\ 0 & 0 \\ \vdots & \vdots \\ 0 & 0 \end{bmatrix}$	$\Lambda^{1,2} = \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ \vdots & \vdots \\ 0 & 0 \end{bmatrix}$
Level 2: Θ	$\Theta^{2,2} = \begin{bmatrix} \theta^{2,2}_{1,1} & & & \\ \theta^{2,2}_{2,1} & \theta^{2,2}_{2,2} & & \\ \vdots & \vdots & \ddots & \\ \theta^{2,2}_{7,1} & \theta^{2,2}_{7,2} & \cdots & \theta^{2,2}_{7,7} \end{bmatrix}$	$\Theta^{2,2} = \begin{bmatrix} 1 & & & \\ 0 & 1 & & \\ \vdots & \vdots & \ddots & \\ 0 & 0 & \cdots & 1 \end{bmatrix}$
Level 2: ν	$\nu^2 = \begin{bmatrix} \nu^2_1 \\ \nu^2_2 \\ \vdots \\ \nu^2_7 \end{bmatrix}$	$\nu^2 = \begin{bmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix}$
Level 2: Λ	$\Lambda^2 = \begin{bmatrix} \lambda^2_1 \\ \lambda^2_2 \\ \vdots \\ \lambda^2_7 \end{bmatrix}$	$\nu^2 = \begin{bmatrix} 0 \\ 1 \\ \vdots \\ 1 \end{bmatrix}$
Level 2: Ψ	$\Psi^{2,2} = \begin{bmatrix} \psi^{2,2}_{1,1} & \\ \psi^{2,2}_{2,1} & \psi^{2,2}_{2,2} \end{bmatrix}$	$\Psi^{2,2} = \begin{bmatrix} 1 & \\ 0 & 1 \end{bmatrix}$
Level 2: **B**	$\beta^{2,2} = \begin{bmatrix} \beta^{2,2}_{1,1} & \\ \beta^{2,2}_{2,1} & \beta^{2,2}_{2,2} \end{bmatrix}$	$\beta^{2,2} = \begin{bmatrix} 0 & \\ 1 & 0 \end{bmatrix}$

Based on Figure 3, the satisfaction of health conditions at individual level determined by healthcare behavior (1,000), and at the provincial level is determined by the health facilities (1,024).

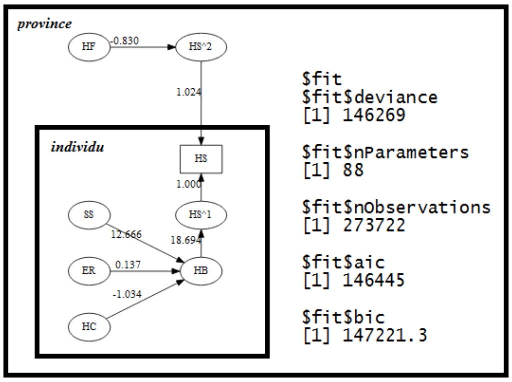

Figure 3. Result of Multilevel SEM for satisfaction on health condition

4 Conclusion

The Gifi transformed variables increase the computational efficiency in SEM. Physical limitations are not significant in determining healthcare behavior. The result of Multilevel SEM indicates that the satisfaction of health conditions is more influenced by the health facilities that received than what is perceived by the respondents.

References

[1] S. Rabe-Hesketh, A. Skrondal, X. Zheng, in: S.-Y. Lee (Ed.), *Handbook of Latent Variable and Related Models*, Elsevier, Boston, 2007.

[2] P.D. Congdon, *Applied Bayesian Modeling*, John Wiley & Sons Ltd, United Kingdom, 2014. https://doi.org/10.1002/9781118895047

[3] J. Hox, *Multilevel Analysis : Techniques and Applications*, Lawrence Erlbaum Associates., Mahwah, NJ, 2002.

[4] P.J. Curran, Have Multilevel Models Been Structural Equation Models All Along?, *Multivariate Behavioral Research*, **38** (2003), no. 4, 529-569. https://doi.org/10.1207/s15327906mbr3804_5

[5] S. Rabe-Hesketh, A. Skrondal, A. Pickles, *Generalized multilevel structural equation modeling*, *Psychometrika*, **69** (2004), 167-190 https://doi.org/10.1007/bf02295939

[6] P. Mehta, *N-Level Structural Equation Modeling*, Routledge, 2013, 329-362.

[7] A. Gifi, *Nonlinear Multivariate Analysis*, Jhon Wiley & Sons, Great Britain, 1990.

[8] S. Katragadda, *Multivariate Mixed Data Mining with Gifi System using Genetic Algorithm and Information Complexity*, Diss., Department of Statistics, Operations and Management Science, The University of Tennessee, Knoxville, 2008.

[9] E.D. Howe, H. Bozdogan, S. Katragadda, Structural equation modeling (SEM) of categorical and mixed-data using the novel Gifi transformations and information complexity (ICOMP) criterion, *Istanbul University Journal of the School of Business Administration*, **40** (2011), 86-123.

[10] BPS, Panduan Pelaksanaan Studi Pengukuran Tingkat Kebahagiaan (SPTK) 2014, in: B.S. Sosial (Ed.), Badan Pusat Statistik, Jakarta (ID), 2014.

[11] J. De Leeuw, P. Mair, Multidimensional Scaling Using Majorization: SMACOF in R, *Journal of Statistical Software*, **31** (2009), 1-30. https://doi.org/10.18637/jss.v031.i03

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