Combined structural equation modelling – artificial neural networks model for predicting customer loyalty

M A Hadiyat
Department of Industrial Engineering, University of Surabaya, Raya Kalirungkut, Surabaya, 60293, Indonesia
E-mail: arbi@staff.ubaya.ac.id

Abstract. Customer loyalty becomes considerations by service providers to maintain for reducing the churn rate. Many studies propose factors that are significantly influencing customer loyalty, and apply them for predicting it. Based on mathematical models, loyalty prediction methods are developed, and it involves new approaches including machine learning. This research aim is predicting customer loyalty using the combination of structural equation model (SEM) and artificial neural networks (ANN). The methodology starts by applying SEM for selecting statistically significant factors affect the loyalty. The linear SEM model ensures this relationship by fulfilling statistical hypothesis and fulfilled assumptions. Once selected factors are found, they are treated as inputs for ANN modelling. ANN is selected because of its ability in nonlinear modelling to enhance its prediction. ANN then learns the relationship between those inputs and the loyalty in real time as any additional observation recorded in. Based on trained ANN, prediction of customer loyalty based on input factors could be done. A case study was conducted at a Hotel by asking 130 customers. SEM inputs includes tangibles, facility, and staff attitudes, while loyalty scores become output. Combination of SEM-ANN has successfully predicted the customer loyalty and brought up chances for improvement strategies.

1. Introduction
Customer loyalty becomes one of important targets in marketing strategies. Many studies discuss about how to improve customer loyalty by practicing customer relationship management. The main reason why this loyalty should be noticed by product or service provider is about its effect on frequent customer purchase exclusively [1], and of course it leads to domination of the market. Once the providers identify factors influencing customer loyalty, then customer service and relationship can be designed [2]. Some quantitative methods have been developed in measuring customer loyalty (see [3]), and some of them focus on predicting customer loyalty. Service or product provider uses this prediction to gain information about what customer relationship strategies should be deployed based on significant influencing factors (see [4]). Moreover, the prediction model can retrieve customer perception data taken from periodic survey to improve individual loyalty prediction, as done by [5]. Some researchers apply mathematical model to predict the loyalty, such as logistic regression [6], discriminant analysis [7], and artificial neural networks [8]. Some of them even combine the prediction model with data mining techniques (see [5]).
However, applying only mathematical model to determine factors influencing the customer loyalty has limitation in updating the fitted model with periodically survey data. Thus, the researcher needs to re-fit the model with new data and re-analyse it based on statistically significant factors. On the other hand, implementing only artificial neural networks (ANN) model for predicting customer loyalty leads to ineffectiveness, where this model involves all the factors without considering their statistical significance. The absence of these such statistical hypothesis also leads the ANN to black-box modelling which is hard to be interpreted by researchers.

The objective of this research is to propose alternative framework in combining the mathematical structural equation model (SEM) for determining factors influencing the customer loyalty with prediction techniques of it based on artificial neural networks (ANN). This framework applies iterative ANN fitting based on updated customer survey data to improve the prediction accuracy. Along with the amount of data collected by survey periodically, this iterative procedure forms simple data mining technique in loyalty prediction.

2. Literature review
2.1. Customer loyalty
In [9], it is mentioned that customer loyalty is a customer emotion that comes to the product or service provider, in spite of the presence of another competitor, more financially lucrative offers on the market. Providers should create strategies to improve this loyalty by determining specific factor, action, and activities to increase the indicator values of loyalty. Predicting customer loyalty could be useful for designing customer relationship management and improving customer perception about benefits they received from service or product providers [10].

2.2. Structural equation modelling (SEM)
Since firstly proposed by Sewall Wright at 1921, structural equation modeling (SEM) has become important tools for understanding relationship between latent and indicator variables in terms of reflective and formative causality.[11]. An example of simple SEM is shown in Figure 1.

![Simple SEM model](image)

**Figure 1. Simple SEM model**

In this research, SEM model takes part in determining significant factors or variables that affect the customer loyalty. Indicator variables are measured by valid and reliable questionnaire taken from survey activity. Theses significant factor are then treated as input in ANN model for loyalty prediction.
2.3. Artificial neural networks model (ANN)

Many studies apply ANN for several purposes, and some of them use it as part of data mining system (see [12]). It is a complex mathematical model that has flexibility for modelling nonlinear causality among variables, and some literatures categorize it as an artificial intelligence model [13]. However, ANN didn’t provide any statistical hypothesis testing for their input variables, and modelling process lead to black-box analysis [13]. General ANN architecture with single hidden layer that is used in this research shown in Figure 2. Each node in a layer is connected (as weights) with another node at the closest layer. A general mathematical model of ANN is shown in equation (1)

\[ y = \sum \beta_j f(\sum \gamma_j x_i) + \epsilon \]

Where \( i \) represents the number of inputs, \( j \) expresses the number of hidden nodes, and function \( f \) represents pre-determined activation function which commonly uses logistic function. The ANN learning or training process estimates the weights \( \gamma_j \) and \( \beta_j \) based on observed input (\( x \)) and output (\( y \) (target)) variables. Once the weights are estimated, then this model uses new observed input data to predict its output. Some papers have successfully combined the SEM and ANN to predict such targeted variable based on questionnaire responses (see [14] and [15])

3. Proposed framework

The proposed customer loyalty prediction framework consists of four steps including iterative ANN weight updating process. Charted steps are shown in Figure 3.

- **First step**: research on customer loyalty should be conducted based on ordinary survey using pre-determined variables potentially influence the loyalty. Next, all observed survey data leads the fitted SEM model to find significant \( X \) variables that affect customer loyalty (\( Y \) variable).
- **Second step**: all significant \( X \) variables obtained from SEM are then treated as input for ANN model. ANN learning process also involves \( Y \) variable as response or targeted output. The ANN produces weights which is used to predict of customer loyalty.
- **Third step**: as new customer comes and fills the questionnaire, the provider could predict the loyalty based on his/her answer using ANN prediction. Every new recorded data from new customer gives information for the ANN to update its weights and improve prediction accuracy.
- **Fourth step**: ANN would update the weights by using re-learning process as new customer data recorded. Once the weights updated, ANN uses these new weights to predict loyalty of another new customer, and then again update the weights iteratively.
The framework involves iteratively updating ANN weights, the more data from new customer will then result to more accurate loyalty prediction. These steps form simple data mining process for customer loyalty prediction based on combination between SEM and ANN model.

4. Implementation result

4.1. SEM modelling

The framework in figure 2 takes case study on a digital printing service provider. Twenty variables are shown in Table 1, measured in Likert scale questionnaire filled by 100 customers that have been using this service. All predictor variables are involved in SEM model to find the significance ones. The SEM path model is shown in figure 4. Based on common analysis in SEM on some statistical goodness of fit test including Akaike’s Information Criterion (see [16]), significance predictors are then chosen. ANN modelling needs these predictors as input to predict customer loyalty.

4.2. ANN modelling

As significance predictor variables was determined by SEM modelling, ANN started the learning process by first created its architecture (see figure 5). As shown in Table 1, there are 8 predictor which should be involved in ANN, including two dimensions. This information is needed by ANN to set the input layer with 8 nodes, and to set the single hidden layer with two nodes. The learning process was then started with back-propagation algorithm [13], and the weights result is shown in Table 3. The Akaike’s Information Criterion (AIC) was also used to compare model performance between ANN and SEM.

Figure 3. Proposed SEM-ANN framework
Table 1. Predictor and response variable in SEM

| ID | Variable                                      | Code | Predictor Significance | Variable dimension | Dimension Significance | Goodness of fit |
|----|-----------------------------------------------|------|------------------------|--------------------|------------------------|-----------------|
| 1  | Various service                               | M1   | No                     |                    |                        |                 |
| 2  | Latest technology equipment                   | M2   | Yes                    |                    |                        |                 |
| 3  | Price according to quality                    | M3   | No                     |                    |                        |                 |
| 4  | Competitive price                             | M4   | No                     |                    |                        |                 |
| 5  | Friendly staffs                               | M5   | No                     |                    |                        |                 |
| 6  | Experienced staffs                            | M6   | Yes                    |                    |                        |                 |
| 7  | Responsive staffs                             | M7   | No                     | Marketing mix      | Significant            | Akaike’s Information Criterion (AIC) for SEM model -19.378 |
| 8  | Effective promotion                           | M8   | No                     | dimension (predictors) | Significant |                 |
| 9  | Easy access information                       | M9   | No                     |                    |                        |                 |
| 10 | Modern interior design                        | M10  | Yes                    |                    |                        |                 |
| 11 | Clean and comfort environment                 | M11  | No                     |                    |                        |                 |
| 12 | Strategic location                            | M12  | No                     |                    |                        |                 |
| 13 | Easy to find location                         | M13  | No                     |                    |                        |                 |
| 14 | Simple order procedure                        | M14  | No                     |                    |                        |                 |
| 15 | Monitored order progress                      | M15  | Yes                    |                    |                        |                 |
| 16 | Satisfaction for service provided             | S1   | Yes                    | Satisfaction       | Significant            |                 |
| 17 | Fulfilling customer expectation                | S2   | Yes                    |                   |                        |                 |
| 18 | Customer comfort and trust                    | S3   | Yes                    |                   |                        |                 |
| 19 | Empathy and care                              | S4   | No                     |                   |                        |                 |
| 20 | Excellence service                            | S5   | No                     |                   |                        |                 |
| 21 | Response (target) variable                    | T1   | Customer loyalty       |                   |                        |                 |

4.3. Customer loyalty prediction

New three customer with new answer then asked with only statistically significant variables, because SEM model has selected them for ANN inputs, and remove insignificant ones. Answers shown in Table 2. These new data then becomes input in learned ANN to predict the loyalty (see Table 3).
Table 2. New customer loyalty prediction by ANN (8 input nodes, 2 hidden nodes)

| New Customer 1 questions | Answer (Likert scale) | New Customer 2 questions | Answer (Likert scale) | New Customer 3 questions | Answer (Likert scale) |
|-------------------------|-----------------------|--------------------------|-----------------------|--------------------------|-----------------------|
| M2                      | 3                     | M2                       | 3                     | M2                       | 5                     |
| M3                      | 3                     | M3                       | 3                     | M3                       | 4                     |
| M6                      | 4                     | M6                       | 4                     | M6                       | 4                     |
| M10                     | 4                     | M10                      | 4                     | M10                      | 4                     |
| M15                     | 5                     | M15                      | 4                     | M15                      | 5                     |
| S1                      | 4                     | S1                       | 5                     | S1                       | 5                     |
| S2                      | 4                     | S2                       | 5                     | S2                       | 5                     |
| S3                      | 4                     | S3                       | 5                     | S3                       | 5                     |
| Predicted loyalty       | 3.08 (loyal)          | Predicted loyalty        | 3.83 (loyal)          | Predicted loyalty        | 4.42 (loyal)          |

Table 3. Updated ANN weights

| ANN path                  | Previous weights | Weights after updating | ANN path                  | Previous weights | Weights after updating | Goodness of fit |
|----------------------------|------------------|------------------------|----------------------------|------------------|------------------------|-----------------|
| M2 \( \rightarrow \) hidden unit 1 | 1.419            | 0.045                  | M2 \( \rightarrow \) hidden unit 2 | 0.834            | 0.745                  | AIC for ANN model   |
| M3 \( \rightarrow \) hidden unit 1 | 0.267            | 0.551                  | M3 \( \rightarrow \) hidden unit 2 | -1.258           | 0.465                  |                 |
| M6 \( \rightarrow \) hidden unit 1 | 2.217            | -0.23                  | M6 \( \rightarrow \) hidden unit 2 | -0.338           | -0.33                  |                 |
| M10 \( \rightarrow \) hidden unit 1 | 1.409            | 0.223                  | M10 \( \rightarrow \) hidden unit 2 | -0.571           | 0.674                  |                 |
| M15 \( \rightarrow \) hidden unit 1 | 3.153            | 0.211                  | M15 \( \rightarrow \) hidden unit 2 | 2.079            | 0.326                  |                 |
| S1 \( \rightarrow \) hidden unit 1 | 1.843            | -0.341                 | S1 \( \rightarrow \) hidden unit 2 | 0.325            | 0.152                  | -48.9398        |
| S2 \( \rightarrow \) hidden unit 1 | 0.799            | -0.315                 | S2 \( \rightarrow \) hidden unit 2 | -0.028           | 0.571                  |                 |
| S3 \( \rightarrow \) hidden unit 1 | 1.228            | -0.027                 | S3 \( \rightarrow \) hidden unit 2 | -1.863           | 0.298                  |                 |
| Hidden unit 1 \( \rightarrow \) T1 | 0.787            | 0.218                  | Hidden unit 2 \( \rightarrow \) T1 | -0.472           | 0.912                  |                 |

4.4. Updating ANN weights
These data from new customer then become new raw input for ANN in updating the weights. Using similar learning process, ANN then updates the weights and produces new ones, as shown in Table 3. Every new raw data involved in ANN would then update the weights. This iterative procedure is repeated as new customer continuously comes to the provider, and ANN prediction becomes better with more data inputted in. The AIC criterion also shows better (smaller) result than SEM model.

5. Concluding remark
The framework proposed in Figure 3 has been successfully implemented, including iterative procedures to improve prediction accuracy. With additional programming techniques, this framework becomes a simple data mining system to predict customer loyalty, as there are steps for saving customer answer and updating the ANN weights continuously and automatically.

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