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# Operating Room Version of Safety Attitudes Questionnaire – An Analysis Using Structural Equation Models

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Liyong Zheng

Supervisor: Fan Yang-Wallentin

Department of Statistics, Uppsala University

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## **Abstract**

Assessing the safety attitude of caregivers in hospital is important for improving patients' safety. Safety Attitudes Questionnaire (SAQ) is widely used to investigate this. SAQ has six dimensions: Job Satisfaction (JS), Teamwork Climate (TC), Working Condition (WC), Safety Climate (SC), Perception of Management (PM) and Stress Recognition (SR). A SAQ survey in three Swedish hospitals' Operating Room has been analyzed in this paper. The aim of the study is one to verify the validity of SAQ; two to explore the relationships between these different factors; three to identify there are relations between Job Satisfaction and the rest five factors. The results suggests all the measurements are valid and reliable for the SAQ. By using Structural Equation Modeling, we found that Job Satisfaction was strongly associated with TC, WC, SC and PM. In addition, the relationship between JS and SR is relatively weak compared to the others.

Keyword: safety attitude questionnaire, measurement model, structural equation models

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# 1. Introduction

How to improve the patients' safety from harm is a common interest for the hospitals. One of the most common used definitions is "patient safety is a new healthcare discipline that emphasizes the reporting, analysis, and prevention of medical error that often leads to adverse healthcare events." There are many factors that influence the patient safety, for instance: human factors, medical complexity and so on. From previous researches, the climate of workplace, attitudes and knowledge among health professionals also affects the patients' safety in practice. In this paper, we focus on Safety Attitudes Questionnaire (SAQ) which is a widely used tool to measure safety climate in Operating Room. The following questions are of interest: What is the structure of Safety Attitudes Questionnaire (SAQ) and how it can be used in practice? Are all the measurements for SAQ reliable? Since there are six dimensions (Job Satisfaction, Teamwork Climate, Safety Climate, Working Conditions, Perception of Management and Stress Recognition) existing in SAQ, are there any relationships between them? How they relate to each other.

## 1.1 Safety Attitudes Questionnaire

Safety Attitudes Questionnaire (SAQ) is one of the most popular tools to measure safety culture which is an important concept in health care environment. SAQ has been developed over 18 years. SAQ is a refined instrument of the Intensive Care Unit Management Attitudes Questionnaire (ICUMAQ) (Sexton, Thomas & Helmreich, 2000) which was derived from the Flight Management Attitudes Questionnaire (FMAQ) (Helmreich, Meritt, Sherman, Gregorich & Wiener, 1993). The brief description of SAQ is shown in table 1. The items of SAQ were evaluated through pilot testing and exploratory factor analysis which led to identification of the following six factors: Teamwork Climate (TC), Safety Climate (SC), Perception of Management (PM), Job Satisfaction (JS), Working Conditions (WC), and Stress Recognition (SR) (Ellen T Deilkås, 2008).

Normally, a short version SAQ has 30 items and all the items belong to six dimensions. A full SAQ is with 60 items and other questions are related to demographics information (i.e. age, sex, experience, and nationality). The answer alternatives of all 60 items are in five-point Likert scale, i.e., Disagree Strongly, Disagree Slightly, Neutral, Agree Slightly and Agree Strongly.

Factor definitions	Example of items
<b>Teamwork climate:</b> perceived quality of collaboration between personnel	<ul style="list-style-type: none"> <li>-Disagreements in the OR are resolved appropriately (i.e., what is best for the patient)</li> <li>-The physicians and nurses here work together as a well- coordinated team</li> </ul>
<b>Job satisfaction:</b> positivity about the work experience	<ul style="list-style-type: none"> <li>-I like my job</li> <li>-This hospital is a good place to work</li> </ul>
<b>Perceptions of management:</b> approval of managerial action	<ul style="list-style-type: none"> <li>-Hospital administration supports my daily efforts</li> <li>-Hospital management is doing a good job</li> </ul>
<b>Safety climate:</b> perceptions of a strong and proactive organizational commitment to safety	<ul style="list-style-type: none"> <li>-I would feel perfectly safe being treated here as a patient</li> <li>-Personnel frequently disregard rules or guidelines that are established for the OR</li> </ul>
<b>Working conditions:</b> perceived quality of the OR's work environment and logistical support (staffing, equipment etc.)	<ul style="list-style-type: none"> <li>-Our levels of staffing are sufficient to handle the number of patients</li> <li>-Medical equipment in the OR is adequate</li> </ul>
<b>Stress recognition:</b> acknowledgement of how performance is influenced by stressors	<ul style="list-style-type: none"> <li>-I am less effective at work when fatigued</li> <li>-When my workload becomes excessive, my performance is impaired</li> </ul>

**Table 1** SAQ Factor Definitions and Example Items (Sexton 2006)

## 1.2 Early Work Review

Safety Culture describes the way how safety is managed in the workplace, and often reflects "the attitudes, beliefs, perceptions and values that employees share in relation to safety" (Cox and Cox, 1991). Vincent *et al.* (1998) suggested that an organization's safety culture is a fundamental factor that influences system safety.

In a project "Improving Safety Culture and Outcomes in Healthcare" which is sponsored by Agency for Healthcare Research and Quality (AHRQ) in USA from 2003 to 2007, investigators compared climate data to statewide Patient Safety Indicator (PSI) rates, to examine the predicted relationship between patient safety outcomes and hospital culture/climate.

A few psychometric instruments have been developed to measure organizational patient safety culture, and their superiorities and limitations have been reviewed. All the existing instruments use Likert scales. The strengths of these tools varies, but only the Safety Attitudes Questionnaire (SAQ) showed links to patient outcomes (Colla JB, 2005): favorable scores of the SAQ were associated with fewer medication errors; lower ventilator associated pneumonia, fewer bloodstream infection, and shorter intensive care unit lengths of stay (Sexton, 2006). Furthermore, the validity and reliability of the SAQ has been documented in United States (English version) (Sexton, 2006), United Kingdom (English version, 2006), Turkey (Turkish version, 2010), China (Chinese version, 2010) and Norway (Norwegian version, 2008). The original version of SAQ is English, the other language version is translating English version into the native language of the caregivers. The SAQ has been used in different health care organizations such as intensive care units (ICUs), operating rooms (ORs), ambulatory clinics, pharmacies and so on.

In June 2010 the Swedish Parliament adopted a new act named the Patient Safety act (SFS 2010:659), which is focus on improving patient safety and supervision of the caregivers performance. The act defines healthcare injury as suffering, bodily mental harm illness and deaths which could have been avoided if adequate actions were taken with the patient's contact with health care. In October 2010, Annika Norden-H ägg from the department of pharmacy in Uppsala University did a research to assessing safety culture in pharmacies of Sweden. They concluded that "The Swedish translation of the SAQ demonstrates acceptable construct validity, for capturing the frontline perspective of safety culture of community pharmacy staff."

## **2. Motivation**

In early study, Cronbach's Alpha was used to determine the reliability of the instruments for SAQ and confirmatory factor analysis (CFA) was used for its validation. In sexton's paper (2006, BMC Health Service Research), he stated: "multilevel factor analyses yielded results at the clinical area level and the respondent nested within clinical area level." For our research, we not only focus on the reliability and validity of the SAQ - Operating Room version, but also try to find the relationships between those six factors we mentioned in section 1. Since SAQ can be used as a base to improve the satisfaction of the working staff in hospitals, it is important to clarify the connection between different factors.

Structural Equation Modeling (SEM) is a statistical technique for testing and estimating causal relations using a combination of statistical data and qualitative causal assumptions (From Wikipedia's definition). Factor analysis and path analysis are two sources for SEM. In the last of few decades, SEM is becoming more and more popular as an objective method and many application of SEM can be found in social science fields. In SEM, the focus is on latent

(theoretical construct) variables rather than on the observed variables which used to measure these constructs. It allows multiple measures to be associated with a single latent variable. A structural equation model is different from other statistical models. It chooses a structure of the covariance matrix of the measures to substitute raw data for analyzing. There are some advantages of SEM compared to other statistical models, for example: 1) SEM allows different depend variables in one model. 2) SEM allows independent and dependent variables contain measurement error. 3) It emphasis on the measurement of latent variables which is very important for measuring the abstract concepts in social science. 4) Estimate all the parameters of the whole model and calculate the fit index.

In the study of SAQ, none of the six dimensions (factor) can be directly measured. In SEM, they are all latent variables. The Operating Room version of SAQ for Swedish hospital is a unique version (57 items and personal information). In this version, there are 30 questions used to measure the six latent variables.

### **3. Research Questions**

As we mentioned above: Job Satisfaction, Teamwork Climate, Safety Climate, Working Condition, Perceptions of Management and Stress Recognition are the six factors in SAQ. The goal is to find the relationships among them. The following research questions are of interest:

1. By Wikipedia's definition: "Job satisfaction describes how content an individual is with his or her job." It is common sense that the happier people are within their job, the more satisfied they are said to be. Job Satisfaction is a general description to inflect the feeling of working stuff towards their working place. The first question is that we assume there are relationships between Job Satisfaction and the other factors.
2. Teamwork Climate, Safety Climate, Working Condition, Perception of Management measured the specific field in Operating Room. Since these factors are all from positive angle to measure the Safety Attitude. The second question: Dose Job Satisfaction take positive influences on Teamwork Climate, Safety Climate, Working Condition, and Perceptions of Management?
3. Stress can be caused by internal or external factors to the workplace. From the definition in Sexton research "Stress recognition is acknowledgement of how performance is influenced by stressors." Therefore, Stress Recognition is the only factor measured from the negative side in SAQ. Based on the above information, our third question is: Dose Job Satisfaction influence Stress Recognition negatively?

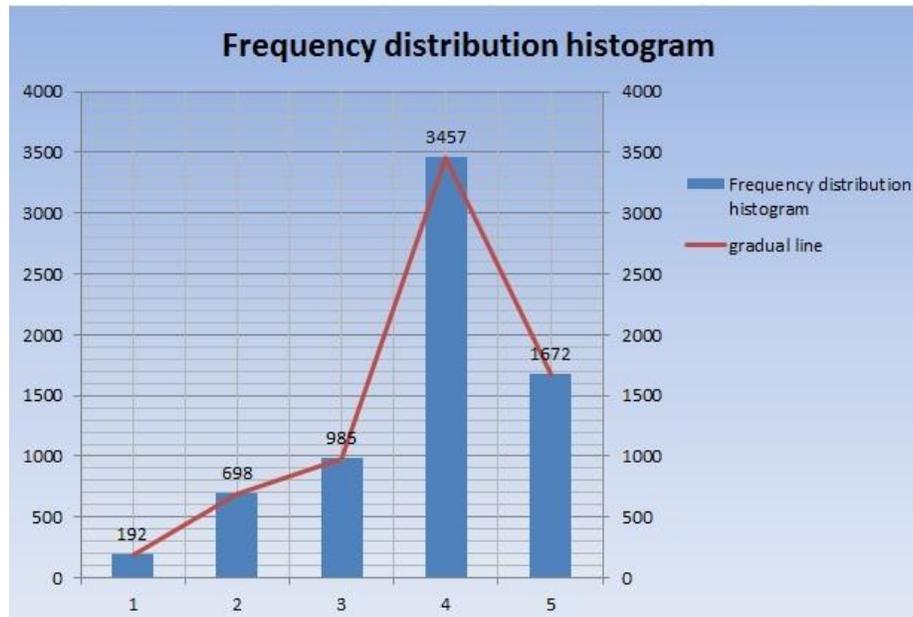
## 4. Data

### 4.1 Data Collection

Our study is based on a survey of SAQ for nurses in the operating room (OR) of three Swedish hospitals. The whole data set<sup>1</sup> contains 237 cases with 64 questions.

In our research, unlike the other SAQ versions, the OR version of SAQ has 57 items. Only 30 out of 57 items belong to six factors (table 1). Therefore, the other 27 items are not considered in this study. In this OR version, the items are not only answered on a five-point Likert scale as mentioned before, they have an extra choice: “Not applicable”. Seven questions are relative to demographics information.

All the data included in selected 30 items are ordinal from 1 to 6: 1) Disagree strongly 2) Disagree Slightly 3) Neutral 4) Agree Slightly 5) Agree strongly 6) Not Applicable. However, “Not Applicable” means the respondent avoided giving an effective answer; therefore, we treat 6 as missing value. In order to deal with the data consistently, we reverse the score of all negatively worded items to get a graph of data’s frequency distribution. (Reverse score presented = “higher is better”)



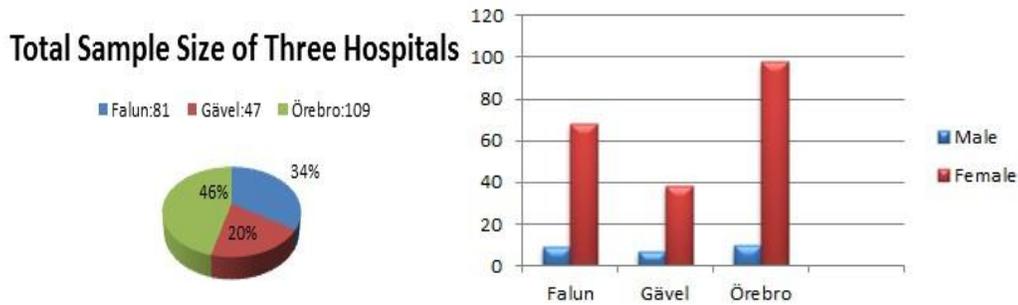
**Figure 1** Frequency Distribution Histogram of Categories

Note: 1 stand for Disagree strongly; 2 stand for Disagree Slightly; 3 stand for Neutral; 4 stand for Agree Slightly; 5 stand for Agree strongly; 6 stand for Not Applicable

<sup>1</sup> Author thank Camilla G öras for providing the data set.

From Figure 1, we can find that people working in these OR are satisfied with the safety culture in working place in general.

For this survey, 374 questionnaires were distributed with 237 respondents. The response rate is about 63% which qualified to the standard. For SAQ, to ensure the validity of the data collected, a minimum of 60% and preferably 80% response rate is necessary (From Johns Hopkins Center, 2010). The average age in three hospitals is around 46. 36 respondents don't give their age in this survey (see Table 2). According to the demographics questions, we can get a graph of personal information in three hospitals.



**Figure 2** Pie Chart of Sample Size of three Hospitals and the Gender Comparison Column

	Falun	Gävle	Örebro	Total
<b>Gender</b>	77 (4)	45 (2)	108 (1)	230 (7)
<b>Age</b>	59 (22)	42 (5)	100 (9)	201 (36)

**Table 2** Number of Responses and Non-responses for the Hospitals

Note: Number in brackets is non-response for each variable.

From Figure 1, female takes the great part in this survey. It is common phenomenon that more female work as nurse in hospital. Only seven stuffs don't want or forget to tell their gender.

## 4.2 Variable Selection and Description

As mentioned above, there are only 30 questions should be considered into our model. The names and their abbreviation of the variables involved in the model are listed as follows :

Observed Variable:

$x_1$  : I like my job. [JS1]

$x_2$  : Working at the surgical department is like being part of a community. [JS2]

$x_3$  : This hospital is a good place to work. [JS3]

$x_4$  : I am proud to be working on this operation department. [JS4]

$x_5$  : Work morale is high here at the surgery department. [JS5]

- $y_1$ : Nurse's views and proposals on patient care is well received in the operating department. [TC1]
- $y_2$ : It is different to speak up if I find problems in patient care in operating theater. [TC2]
- $y_3$ : We solve differences in a proper manner in surgery department (e.g. by building on what is best for the patient rather than who is right). [TC3]
- $y_4$ : I have the support I need from other team members to care for patients. [TC4]
- $y_5$ : It is easy for the staff to ask questions when there is something they do not understand. [TC5]
- $y_6$ : In my workplace staff work as a well-coordinated team. [TC6]
- $y_7$ : I would feel safe if I was treated here as a patient. [SC1]
- $y_8$ : Medical anomalies are dealt with properly in operating department. [SC2]
- $y_9$ : I receive constructive feedback on my work. [SC3]
- $y_{10}$ : It's different to discuss the discrepancies at the operating theater. [SC4]
- $y_{11}$ : I am encouraged by my colleagues to take up all the thoughts I have on patient safety. [SC5]
- $y_{12}$ : It is easy to learn from each other's differences in the culture that exists in the surgery department. [SC6]
- $y_{13}$ : I know how I should proceed to submit questions about patient safety at this operating room. [SC7]
- $y_{14}$ : Orientation of new employees is implemented well in operating department. [WC1]
- $y_{15}$ : All necessary information regarding the patient is available before starting operation. [WC2]
- $y_{16}$ : Employers handle problematic employees in a constructive way. [WC3]
- $y_{17}$ : Trainees in my disciplines are adequately supervised. [WC4]
- $y_{18}$ : Management supports my daily efforts. [PM1]
- $y_{19}$ : Management does not knowingly compromise the safety of patients. [PM2]
- $y_{20}$ : The levels of staffing in this clinical area are sufficient to handle the number of patients. [PM3]
- $y_{21}$ : I get adequate, timely information about events that might affect my work, from hospital management. [PM4]
- $y_{22}$ : Fatigue impairs my performance during emergency situation. [SR1]
- $y_{23}$ : When my workload becomes excessive, my performance is impaired. [SR2]

$y_{24}$ : I am less effective at work when fatigued. [SR3]

$y_{25}$ : I am more likely to make errors in tense or hostile situations. [SR4]

Latent Variable:

$\xi_1$ : Job Satisfaction [JS]

$\eta_1$ : Teamwork Climate [TC]

$\eta_2$ : Safety Climate [SC]

$\eta_3$ : Working Condition [WC]

$\eta_4$ : Perception of Management [PM]

$\eta_5$ : Stress Recognition [SR]

### 4.3 Treatment of Missing Values

Missing value is a common problem in the data of social science study. No response in a survey leads to missing data. For some reasons, people don't want to answer the question or they just forgot to answer it. Before we go further in our study, we should figure out all the missing data and try to deal with them. From Table3, we can find that there are 106 missing data of 30 items. Only three variables have no missing data in our study.

Variable	No. of M.V.	Variable	No. of M.V.	Variable	No. of M.V.
JS1	1	TC6	2	WC3	17
JS2	2	SC1	0	WC4	5
JS3	3	SC2	6	PM1	10
JS4	1	SC3	2	PM2	11
JS5	3	SC4	0	PM3	0
TC1	2	SC5	3	PM4	2
TC2	3	SC6	2	SR1	3
TC3	3	SC7	3	SR2	1
TC4	3	WC1	1	SR3	3
TC5	4	WC2	4	SR4	6

**Table 3** Distribution of Missing Values

Number of Missing Values	0	1	2	3	4	5
Number of Cases	173	38	16	5	4	1

**Table 4** Number of Cases with Missing Values

From Table 4, it appears 173 cases have no missing values, 38 cases have 1 missing values, 16 cases have 2 missing values, 5 cases have 3 missing values, 4 cases have 4 missing values and only one case has five missing values. There are several methods to deal with the missing values in practice, such as Listwise Deletion, Pairwise Deletion, Multiple Imputation. In our study, since our data set is not large, delete data might cause losing some useful information, we choose EM algorithm to do the Multiple Imputation.

Expectation–Maximization (EM) algorithm is an iterative method for finding maximum likelihood estimates of parameters (Robin, 1977). Using this method, we assume that our missing values are missing at random in data set. The EM iteration alternates between expectation (E) step and maximization (M) step. We use E step to computes the expectation of the log-likelihood evaluated using the current estimate for the parameter  $\theta$ .  $\theta$  is unknown parameters in our data set. Then we use M step to computes parameters maximizing the expected log-likelihood found on the E step. Then assuming the estimation of parameters is correct and uses them in the next E step. In our study, define  $Z$  is the date set contains the missing value.  $Z = (Z_{obs}|Z_{mis})$ , where  $Z_{obs}$  stand for observed values and  $Z_{mis}$  denotes missing values. (Song Yang, 2011)

We let  $\theta(t)$  be the current estimate of  $\theta$ . The E step of EM is calculate the expect of the complete-data log-likelihood,  $t$  stand for iteration times.

$$Q(\theta|\theta(t)) = \int l(\theta|z)f(Z_{mis}|Z_{obs}, \theta = \theta(t)) dZ_{mis} \quad (1)$$

The M step of EM looks for  $\theta(t+1)$  by maximizing this expect of complete-data log-likelihood:

$$Q(\theta(t + 1)|\theta(t)) \geq Q(\theta|\theta(t)), \quad \text{for all } \theta \quad (2)$$

In LISREL, we do the multiple imputations easily. All missing values have been imputed. The imputed data file is saved for the further research. Then we will test the multi-normal distribution of these imputed data in following section.

## 5. Model

### 5.1 Model Specification

As we mentioned before, some previous research on SAQ focus on the Confirmatory Factor Analysis (CFA). In this paper, we have also extended the analysis to SEM. The procedure is, we first adapt a CFA model to study the measurement validation and reliability. A SEM model is used to investigate the causal relations among the latent variables.

We start with confirmatory factor analysis are measured with reliable measurements. This is the foundation for our further study. A typical CFA model has the form

$$x = \Lambda_x \xi + \delta \quad (3)$$

The results show that the CFA model fits the data reasonably well. All the factor loadings are in range between 0.17 and 0.88. This indicates that the most of measurements are reliable. The goodness of fit measures is showing in table 5. It is clear that our CFA is reasonable, which means all the measurements are valid. We can see the path diagram of CFA model in appendix.

Index	Suggested Limit	Value
$\chi^2$	As small as possible	515.16
Df		390
RMSEA	< 0.08	0.037
NFI	>0.90	0.96
CFI	>0.90	0.99

**Table 5** Goodness of Fit Indices of the CFA of the SAQ model

The SEM model for the Safety Attitude Questionnaire is set to explore the relationships between latent variables. The SEM model including two parts: the structural model and the measurement model. The structures of the two models are defined as follows:

#### Structural Model

$$\eta = \Gamma \xi + \zeta \quad (4)$$

Where:

$$\eta = \begin{bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \\ \eta_4 \\ \eta_5 \end{bmatrix}, \quad \xi = \begin{bmatrix} \xi_1 \end{bmatrix}, \quad \Gamma = \begin{bmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \end{bmatrix}, \quad \zeta = \begin{bmatrix} \zeta_1 \\ \zeta_2 \\ \zeta_3 \\ \zeta_4 \\ \zeta_5 \end{bmatrix}$$

$$\Phi = \text{cov}(\xi) = [\phi_{11}], \quad \Psi = \text{cov}(\zeta) = \begin{bmatrix} \psi_{11} & 0 & 0 & 0 & 0 \\ 0 & \psi_{22} & 0 & 0 & 0 \\ 0 & 0 & \psi_{33} & 0 & 0 \\ 0 & 0 & 0 & \psi_{44} & 0 \\ 0 & 0 & 0 & 0 & \psi_{55} \end{bmatrix}.$$

$\eta_1, \eta_2, \eta_3, \eta_4, \eta_5$ , represent the independent latent variable TC, SC, WC, PM, SR, respectively,  $\xi_1$  represents the dependent latent variables JS at the same time.

For this structural model, we assume that:

1.  $E(\eta) = 0, E(\xi) = 0, E(\zeta) = 0,$
2.  $\text{Corr}(\zeta, \xi) = 0.$

Measurement Model

$$x = \Lambda_x \xi + \delta, \quad y = \Lambda_y \eta + \varepsilon \quad (5)$$

Where

$$x = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{bmatrix}, \quad \Lambda_x = \begin{bmatrix} \lambda_1^x \\ \lambda_2^x \\ \lambda_3^x \\ \lambda_4^x \\ \lambda_5^x \end{bmatrix}, \quad \delta = \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \end{bmatrix}, \quad \Theta_\delta = \text{diag}[\text{var}(\delta_1), \dots, \text{var}(\delta_5)].$$

$$y = \begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ \vdots \\ \vdots \\ y_{25} \end{bmatrix}, \quad \Lambda_y = \begin{bmatrix} \lambda_6^y & 0 & 0 & 0 & 0 \\ \lambda_7^y & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \lambda_{10}^y & 0 & 0 & 0 & 0 \\ \lambda_{11}^y & 0 & 0 & 0 & 0 \\ 0 & \lambda_{12}^y & \vdots & \vdots & \vdots \\ 0 & \lambda_{13}^y & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & \lambda_{18}^y & 0 & 0 & 0 \\ 0 & 0 & \lambda_{19}^y & 0 & 0 \\ \vdots & \vdots & \lambda_{20}^y & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \lambda_{22}^y & \vdots & \vdots \\ 0 & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \lambda_{23}^y & \vdots \\ \vdots & \vdots & \vdots & \lambda_{24}^y & \vdots \\ 0 & 0 & 0 & \vdots & 0 \\ 0 & 0 & 0 & \lambda_{26}^y & 0 \\ \vdots & \vdots & \vdots & 0 & \lambda_{27}^y \\ \vdots & \vdots & \vdots & \vdots & \lambda_{28}^y \\ 0 & 0 & 0 & 0 & \vdots \\ 0 & 0 & 0 & 0 & \lambda_{30}^y \end{bmatrix}, \quad \varepsilon = \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \vdots \\ \vdots \\ \varepsilon_{25} \end{bmatrix}$$

$$\Theta_\varepsilon = \text{diag}[\text{var}(\varepsilon_1), \text{var}(\varepsilon_2), \dots, \text{var}(\varepsilon_{25})]$$

The latent variables are unobserved. They have no origin and scale of measurement. In order to scale the latent variables, we choose the first observed variable of each latent variable as the reference variable namely:  $\lambda_1^x = 1$ ,  $\lambda_6^y = \lambda_{12}^y = \lambda_{19}^y = \lambda_{23}^y = \lambda_{27}^y = 1$ .

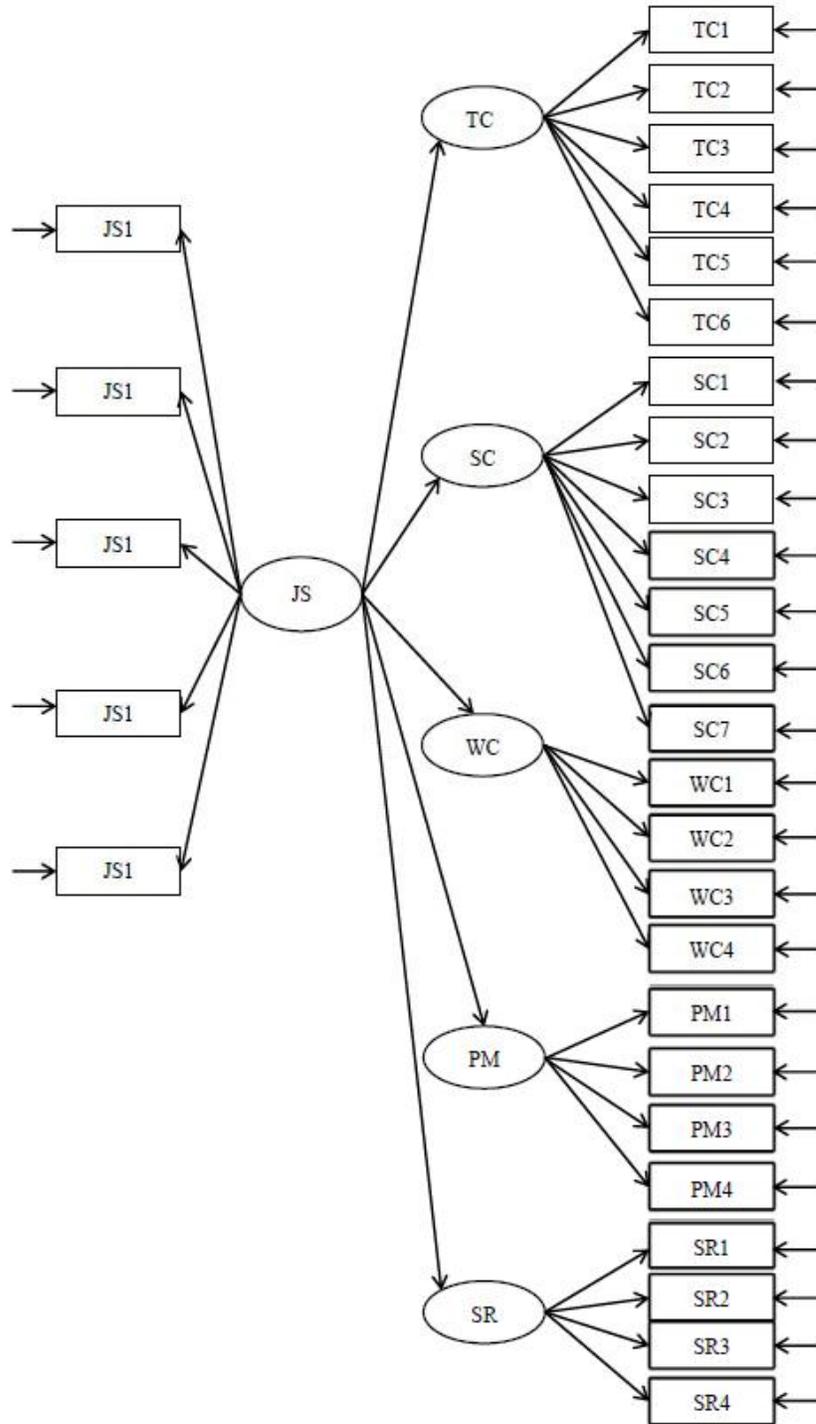
For the measurement model, we assume that:

1.  $E(\eta) = 0$ ,  $E(\xi) = 0$ ,  $E(\varepsilon) = 0$ ,  $E(\delta) = 0$ ,
2.  $\text{Corr}(\varepsilon, \eta) = 0$ ,  $\text{Corr}(\varepsilon, \xi) = 0$ ,  $\text{Corr}(\varepsilon, \delta) = 0$ ,
3.  $\text{Corr}(\delta, \xi) = 0$ ,  $\text{Corr}(\delta, \eta) = 0$ .

To sum up the free parameters in the model,

$$\theta' = [\Gamma, \Psi, \Lambda_x, \Lambda_y, \Theta_\delta, \Theta_\varepsilon].$$

The path diagram of our SAQ model is shown in figure 3:



**Figure 3** Path Diagram of SAQ model

## 5.2 Model Implied Covariance Matrix

For SAQ model, we want to estimate the parameters exist in above-mentioned matrix. Based on model definition the covariance matrices can be derived as:

$$\Sigma = \begin{bmatrix} \text{cov}(y, y) & \text{cov}(y, x) \\ \text{cov}(x, y) & \text{cov}(x, x) \end{bmatrix} \quad (6)$$

The elements in this matrix are:

$$\begin{aligned} \Sigma_{yy}(\theta) &= E(yy') \\ &= E(\Lambda_y \eta + \varepsilon)(\eta' \Lambda_y' + \varepsilon') \\ &= \Lambda_y E(\eta \eta') \Lambda_y' + E(\varepsilon \varepsilon') \\ &= \Lambda_y (\Gamma \Phi \Gamma' + \Psi) \Lambda_y' + \Theta_\varepsilon \end{aligned} \quad (7)$$

$$\begin{aligned} \Sigma_{xx}(\theta) &= E(xx') \\ &= E(\Lambda_x \xi + \delta)(\xi' \Lambda_x' + \delta') \\ &= \Lambda_x E(\xi \xi') \Lambda_x' + E(\delta \delta') \\ &= \Lambda_x \Phi \Lambda_x' + \Theta_\delta \end{aligned} \quad (8)$$

$$\begin{aligned} \Sigma_{yx}(\theta) &= E(yx') \\ &= E(\Lambda_y \eta + \varepsilon)(\xi' \Lambda_x' + \delta') \\ &= \Lambda_y E(\eta \xi') \Lambda_x' \\ &= \Lambda_y \Gamma \Phi \Lambda_x' \end{aligned} \quad (9)$$

$$\begin{aligned} \Sigma_{xy}(\theta) &= E(xy') \\ &= \Lambda_x \Gamma \Phi \Lambda_y' \end{aligned} \quad (10)$$

Then, the model implied covariance matrix can be written as:

$$\Sigma(\theta) = \begin{bmatrix} \Sigma_{yy}(\theta) & \Sigma_{yx}(\theta) \\ \Sigma_{xy}(\theta) & \Sigma_{xx}(\theta) \end{bmatrix} = \begin{bmatrix} \Lambda_y (\Gamma \Phi \Gamma' + \Psi) \Lambda_y' + \Theta_\varepsilon & \Lambda_y \Gamma \Phi \Lambda_x' \\ \Lambda_x \Gamma \Phi \Lambda_y' & \Lambda_x \Phi \Lambda_x' + \Theta_\delta \end{bmatrix} \quad (11)$$

It is seen that the elements of this matrix contains all the unknown parameters in the model.

### 5.3 Model Identification

In order to estimate the parameters model, the model should be identified. To judge the identification of a model, there are several rules we can follow: t-Rule, Two-step Rule, Recursive Rule, Order and Rank Conditions. In our study, we choose t-Rule.

$$T\text{-rule: } t \leq (1/2)(p+q)(p+q+1). \quad (12)$$

Identification is demonstrated by showing the unknown parameters are functions only of identified parameters and these functions lead to unique solutions. More specifically, Suppose  $\Sigma$  is known. The identification problem is whether  $\theta$  is uniquely determined from  $\Sigma$ . If all parameters in  $\theta$  are identified, we say that the model is identified. Let  $p$  and  $q$  be the number of y-variables and x-variables respectively, let  $t$  be the number of free parameter in  $\theta$ .

In our model,  $p$  is 25,  $q$  is 5 and  $t$  is 75. It is satisfied with t-Rule, so our model is identified.

Model identification is a complex problem in SEM. Many scholars explored into this field and tried to find a uniform method to identify a model in general way. However, there is no consensus now. Different reasons caused the model not satisfied with identification. When we use LISREL to analyze, if the model cannot be fitted, we would back to see why it is not identified.

### 5.4 Model Estimation

#### 5.4.1 Maximum Likelihood (ML)

After we assure the identification of our model, we should estimate the unknown parameters in the model. The basis hypothesis for the model estimation is:

$$\Sigma = \Sigma(\theta) \quad (13)$$

However, we can't get the implied covariance matrix  $\Sigma$  in real case so the sample covariance matrix  $S$  is treated as the estimation of it.  $\Sigma(\theta)$  is based on the different parameter. Our purpose is minimizing the difference between  $\Sigma(\theta)$  and  $S$ . We define a fit function  $F(S, \Sigma(\theta))$  to measure the difference between  $\Sigma(\theta)$  and  $S$ . Parameter estimation is finding a solution  $\hat{\theta}$  for  $\theta$ , to minimize the fit function:

$$F_{ML} = \log |\Sigma(\theta)| + tr[S \Sigma^{-1}(\theta)] - \log |S| - (p+q) \quad (14)$$

ML method is for estimation in this study. It assumes that the observed variables have multi-normal distribution. Our data are ordinal, and these data with many categories, such as 5-point Likert-type scales of agreement, are usually treated as "continuous." If they are non-normal, then

data analytic techniques for non-normal continuous variables should be used. (Newsom, SEM, 2005) In our study, we checked the normality of all the observed variables (see Figure 4), if P-Value > 0.05, the variable has normal distribution. It is clear that not all of the observed variables satisfied with normal distribution. As seen in Figure 4, 23 observed variables satisfied with normal distribution. Therefore, even ML is widely used in SEM, it is not suitable for our study. If we adapt the ML estimation, the standard errors and chi squares will be wrongly estimated. Therefore we should find another method to estimate the parameters

Test of Univariate Normality for Continuous Variables

Variable	Skewness		Kurtosis		Skewness and Kurtosis	
	Z-Score	P-Value	Z-Score	P-Value	Chi-Square	P-Value
JS1	-6.855	0.000	1.610	0.107	49.587	0.000
JS2	-1.735	0.083	-0.037	0.970	3.012	0.222
JS3	-1.989	0.047	-0.863	0.388	4.702	0.095
JS4	-2.795	0.005	-1.851	0.064	11.236	0.004
JS5	-1.727	0.084	-0.321	0.748	3.086	0.214
TC1	-1.036	0.300	1.259	0.208	2.657	0.265
TC2	-1.471	0.141	-0.154	0.878	2.187	0.335
TC3	-1.745	0.081	0.662	0.508	3.482	0.175
TC4	-1.727	0.084	-0.131	0.896	2.999	0.223
TC5	-1.490	0.136	0.401	0.689	2.381	0.304
TC6	-1.254	0.210	0.978	0.328	2.528	0.283
SC1	-2.971	0.003	-2.168	0.030	13.532	0.001
SC2	-2.296	0.022	-1.489	0.137	7.489	0.024
SC3	-1.031	0.303	-0.472	0.637	1.285	0.526
SC4	-1.428	0.153	-1.624	0.104	4.677	0.096
SC5	-1.080	0.280	-0.302	0.763	1.258	0.533
SC6	-1.104	0.270	-0.379	0.705	1.362	0.506
SC7	-1.712	0.087	0.126	0.900	2.947	0.229
WC1	-2.889	0.004	-1.520	0.129	10.655	0.005
WC2	-1.173	0.241	2.111	0.035	5.835	0.054
WC3	-0.188	0.851	-0.697	0.486	0.521	0.771
WC4	-1.072	0.284	-0.996	0.319	2.141	0.343
PM1	-0.948	0.343	-0.077	0.938	0.905	0.636
PM2	-3.354	0.001	-2.514	0.012	17.571	0.000
PM3	-0.062	0.950	-2.720	0.007	7.400	0.025
PM4	-1.241	0.215	-0.212	0.832	1.584	0.453
SR1	-0.114	0.909	-3.094	0.002	9.583	0.008
SR2	-0.792	0.428	-1.245	0.213	2.179	0.336
SR3	-1.546	0.122	-0.551	0.581	2.693	0.260
SR4	-1.550	0.121	-1.866	0.062	5.887	0.053

**Figure4** Test of Univariate Normality for Observed Variables

### 5.4.2 Robust Maximum Likelihood (RML)

To adjust the estimation to non-normality, RML can be employed. Browne (1987) formulated a Robust Maximum Likelihood (RML) method for related models. This method is available in LISREL, the associated formula is provided in Jöreskog et al (2001). To implement this method,

we need to calculate the Asymptotic Covariance Matrix (ACM) of the sample variance and covariance.

The RML fit function is as:

$$F_{ML} = (\mathbf{s} - \boldsymbol{\sigma})' \mathbf{D}' (\hat{\boldsymbol{\Sigma}}^{-1} \otimes \hat{\boldsymbol{\Sigma}}^{-1}) \mathbf{D} (\mathbf{s} - \boldsymbol{\sigma}) \quad (15)$$

Where  $\mathbf{s}$  is a vector of order  $s \times 1$  consists of which are non-duplicated elements in  $\mathbf{S}$ ,  $\mathbf{D}$  is the duplication matrix which transfer  $\mathbf{s}$  to  $\text{vec}(\mathbf{S})$ ,  $\otimes$  stands for Kronecker product. This equation could be explained as Maximum Likelihood estimated by means of iteratively reweighted least squares in which  $\hat{\boldsymbol{\Sigma}}$  is updated in each iteration. Both of these fit functions have a minimum at the same point in the parameter space, so called ML estimates. However, the minimum value of the functions is not the same.

## 6. Results

### 6.1 Model Assessment

Assessment of fit is a basic part in SEM, forming the basis for accepting or rejecting models, more usual speaking; it is about accepting one competing model over another. The output of LISREL includes matrices of the estimated relationships between variables in the model. Assessment of fit essentially calculates how similar the predicted data are to matrices containing the relationships in the actual data.

Formal statistical tests and fit indices have been developed for these purposes. Individual parameters of the model can also be examined within the estimated model in order to see how well the proposed model fits the data and theory.

The most common goodness of fit indices is RMSEA (Root Mean Square Error of Approximation). From the definition,

$$RMSEA = \sqrt{\frac{\max(\frac{\chi^2 - df}{N - 1}, 0)}{df}}, \quad (16)$$

If RESEA > 0.8, we will not consider the model fits the data at all, if 0.05 < RESEA < 0.08, the result is acceptable and reasonable, if RESEA < 0.05, the model indicates a good fit.

There are also other indices could be considered to access SEM

$$\text{Chi-square: } \chi^2 = \frac{d}{h} (N - 1) (\mathbf{s} - \hat{\boldsymbol{\sigma}})' \Delta_c (\Delta_c' V^{-1} \Delta_c)^{-1} \Delta_c' (\mathbf{s} - \hat{\boldsymbol{\sigma}}), \quad (17)$$

Where  $d$  is the degree of freedom,  $h = tr[(\Delta_c' V^{-1} \Delta_c)^{-1} (\Delta_c' W \Delta_c)]$ , here  $\Delta_c$  is an orthogonal complement to  $\Delta$  such that  $\Delta_c' \Delta = 0$ , and  $\Delta = \partial \rho / \partial \theta$ .  $V^{-1} = 2(D'D)^{-1} D'(\hat{\Sigma} \otimes \hat{\Sigma}) D(D'D)^{-1}$  and  $W$  is the weight matrix under the non-normal condition which will compute by LISREL if we got the asymptotic covariance matrix. (Yang-Wallentin, 2010)

$$\text{Normed Fit Index: NFI} = 1 - \frac{F}{F_i}, \quad (18)$$

Where,  $F$  is the minimum value of the fit function for the estimated model.

$$\text{Comparative Fit Index: CFI} = 1 - \frac{\tau}{\tau_i}, \quad (19)$$

Where,  $\tau = \max(nF - df, 0)$ ,  $\tau_i = \max(nF_i - df_i, nF - df, 0)$

As we discussed in Section 5, the model fits the data reasonably is a basement for analysis of structural model. Therefore, we explore the relationship between the six factors using structural model. In the full model we hypothesis Job Satisfaction could influence other five factors, and the hypothesis of the model is  $\Sigma(\theta) = \Sigma$ . RML method is used to estimate unknown parameters in the model.

Index	Suggested Limit	Value
$\chi^2$	As small as possible	573.88
Df		400
RMSEA	< 0.08	0.055
NFI	>0.90	0.96
CFI	>0.90	0.99

**Table 6** Goodness of Fit Indices of the Initial Model

We check the significant of all parameters and find there is one path of the structural model is non-significant. From Table 6, RMSEA = 0.055, which means our model is reasonable but not good. Therefore, we could improve the initial model.

## 6.2 Model Modification

From the output of LISREL, we find a suggestion that a few error correlations should be set free. Adding these correlations could have impact on the model improvement. Error correlation is as an unanalyzed association, which means that the specific nature of the shared "something" is unknown. Correlated error terms in measurement models represent the hypothesis that the unique variances of the associated indicators overlap; that means, they measure something in common other than the latent constructs that are represented in the model. The variables have related errors are:

“SC6” and “SC4”, “WC1” and “SC1”, “WC2” and “SC2”, “PM3” and “TC6”, “JS2” and “JS1”, “JS3” and “JS1”, “JS4” and “JS1”, “JS4” and “JS3”.

Back to the SAQ, those pairs indeed have relationships in reality SC4 and SC6 reflect a same problem that whether atmosphere of discussion is free in Operating Room, SC4 is from the negative side otherwise SC6 is from the positive. SC2 and WC2 have strong causal relationship. If all the necessary information for diagnostic and therapeutic decisions is routinely available to working stuff (WC2), the medical errors would be handled appropriately in this clinical area. For SC1 and WC1, there is also causal relationship between them. As a work stuff in an operating room, if he/she find trainees are not adequately supervised, he/she would not feel safe being treated as a patient. TC6 is a description that the physicians and nurses here work together like as a well-coordinated team, and it leads to the levels of staffing in this clinical area are sufficient to handle the number of patient (PM3).

The rest pairs all belong to Job Satisfaction. JS1 has relationships with JS2, JS3 and JS4, JS4 has connection with JS3. JS1: I like my job. JS2, JS3, JS4 explain why I like my job sufficiently. For JS4, I am proud to be working on this operation department is the result according to JS3.

## 6.3 Results of Modified Model

From Table 7, we can find that all the coefficients in our model with the absolute value of  $T > 2$  which means all the coefficients are significant. All the estimated parameters and T values for measurement model are listed in Table7.

Observed Variables	Parameters $\Lambda_x$	Estimates (T-value)	Observed Variables	Parameters $\Lambda_y$	Estimates (T-values)
JS1	$\lambda_1$	1.00 <sup>c</sup>	TC1	$\lambda_6$	1.00 <sup>c</sup>
		-			-
JS2	$\lambda_2$	0.38 (9.70)	TC2	$\lambda_7$	0.59 (9.98)
JS3	$\lambda_3$	0.27 (10.94)	TC3	$\lambda_8$	0.55 (12.34)
JS4	$\lambda_4$	0.68 (11.00)	TC4	$\lambda_9$	1.69 (11.05)
JS5	$\lambda_5$	0.23 (8.80)	TC5	$\lambda_{10}$	0.64 (12.17)
			TC6	$\lambda_{11}$	0.58 (12.96)
			SC1	$\lambda_{12}$	1.00 <sup>c</sup>
					-
			SC2	$\lambda_{13}$	0.36 (11.81)
			SC3	$\lambda_{14}$	0.43 (11.96)
			SC4	$\lambda_{15}$	0.49 (11.33)
			SC5	$\lambda_{16}$	0.62 (13.51)
			SC6	$\lambda_{17}$	0.51 (13.62)
			SC7	$\lambda_{18}$	0.46 (9.12)
			WC1	$\lambda_{19}$	1.00 <sup>c</sup>
					-
			WC2	$\lambda_{20}$	0.37 (6.61)
			WC3	$\lambda_{21}$	0.68 (8.95)
			WC4	$\lambda_{22}$	1.39 (9.24)
			PM1	$\lambda_{23}$	1.00 <sup>c</sup>
					-
			PM2	$\lambda_{24}$	1.34 (7.58)
			PM3	$\lambda_{25}$	0.60 (5.31)
			PM4	$\lambda_{26}$	1.11 (10.39)
			SR1	$\lambda_{27}$	1.00
					-
			SR2	$\lambda_{28}$	1.19 (8.08)
			SR3	$\lambda_{29}$	1.52 (8.43)
			SR4	$\lambda_{30}$	1.15 (8.17)

**Table7** RML Estimates of Modified Measurement Model

Note: c = constrained to equal 1 indicates that the variable with coefficient 1 is chosen as reference variable.

For Job Satisfaction, JS4 was the most significant, then JS2, JS3, JS5, JS1.

For Teamwork Climate, TC4 is much more effective than other measurements.

For Safety Climate, SC1 to SC6 value the largest influence. SC7 is less effective comparatively.

For Working Condition, WC1 is most effective. So people think orientation of new employees in operating department is an important index to measure the Working Condition. WC4, WC2, WC3 follows.

For Perception of Management, PM1 has the largest impact on PM. PM4, PM2, PM3 follows.

For Stress Recognition, SR3 is most influence, when the working stuffs feel less effective at work when they fatigued, they may more recognize the Stress. The following measurements are SR2, SR4 and SR1.

	JS
TC (T - value)	0.49 (8.13)
SC (T - value)	0.62 (8.04)
WC (T - value)	0.36 (7.84)
PM (T - value)	0.24 (7.34)
SR (T - value)	-0.036 (-1.35)

**Table 8** RML Estimates of Modified Structural Model

For structural model, the paths from Job Satisfaction to Working Condition, Teamwork Climate, Safety Climate and Perception of Management are significant. For TC, SC, WC and PM, JS has positive influence on them which help us prove the first and the second research questions in Section 3. However, the path from Job Satisfaction to Stress Recognition is not significant under the significance level 0.05 (see table 8). Therefore, our third question is not fully answered by our model. From the correlation matrix of the latent variables, Job Satisfaction is highly correlated with Teamwork Climate and Working Condition (0.99, 0.93 respectively), Perception of Management (0.92) and Safety Climate (0.89) are as follows. The correlation between Job Satisfaction and Stress Recognition is small (- 0.10). To further express the hypothesis three is not fully demonstrated.

For the correlation matrix, we also find that there are still strong correlation between Teamwork Climate, Working Condition and Perception of Management.

	TC	SC	WC	PM	SR	JS
TC	1.00					
SC	0.89	1.00				
W	0.93	0.84	1.00			
PM	0.92	0.82	0.86	1.00		
SR	-0.10	-0.09	-0.10	-0.10	1.00	
JS	0.99	0.90	0.94	0.92	-0.10	1.00

**Figure 5** Correlation Matrix of Latent Variables

Index	Suggested Limit	Value
$\chi^2$	As small as possible	498.86
Df		392
RMSEA	< 0.08	0.034
NFI	>0.90	0.96
CFI	>0.90	0.99

**Table 9** Goodness of Fit Indices of the Modified Full Model of SAQ

From Table 9, we can find the modified model is better than the intimal one. The chi-square is much smaller; RMSEA is 0.034 which means the model is pretty good. GFI, NFI and CFI are all increased in the new model.

## 7. Conclusion

Based on the result of SEM model we discussed above, we find some conclusions. Firstly, all the measurements within SAQ—operating room version are valid and reliable. Secondly, Job Satisfaction is strongly associated with Teamwork Climate, Safety Climate, Working Conditions and Perception of Management but less associated with Stress Recognition.

For our model, RMSEA, NFI, CFI are almost satisfied with the critical values from Table 9, although the measurement models are reasonable, the structural model does not fit the data very well. There is one main coefficient not significant (from JS to SR). There are some possible reasons as follows:

1. The sample size is small. Although our research is based on 283 respondents, compared to empirical study, it is not enough. With larger sample set, we may reach more satisfactory results.

2. Our model is under the hypothesis that Job Satisfaction could influence the other five factors. Since social phenomenon are complex and resulted in many uncertain elements and SAQ is not perfect enough and safety culture is a complex concept, other variables such as staff turnover, length of stay should be considered. What's more there are only 30 items scaled the latent variables in SAQ, even these factor loadings are reliable, some of them might not explain the latent variable sufficiently.

From our study, the Operating Room version of SAQ is a valid and reliable instrument for measuring the safety attitudes of working stuff in Sweden. Identifying factors influencing the safety culture in Operating Room is vital, since it can be supportive when making decisions to improve the safety climate at Operating Room. In our model, Job Satisfaction is a very important factor in this questionnaire, it take positive influence on Teamwork Climate, Working Condition, Safety Climate, Perception of Management. However, it seems not work on Stress Recognition.

According to the feedback of the questionnaire, the SAQ of Operating Room has not fully developed and there is still considerable room for improvement. Some of the items need to be redesigned which is another future work for this paper.

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# Appendix

Estimating and Testing a CFA Model on SAQ

Observed Variables: JS1 JS2 JS3 JS4 JS5 TC1

TC2 TC3 TC4 TC5 TC6 SC1

SC2 SC3 SC4 SC5 SC6 SC7

WC1 WC2 WC3 WC4 PM1 PM2

PM3 PM4 SR1 SR2 SR3 SR4

Covariance Matrix from File 0515.cov

Asymptotic Covariance Matrix from File 0515.acm

Sample Size: 237

Latent Variables: JS TC SC WC PM SR

Relationships:

$JS1 = 1*JS$

$JS2 JS3 JS4 JS5 = JS$

$TC1 = 1*TC$

$TC2 TC3 TC4 TC5 TC6 = TC$

$SC1 = 1*SC$

$SC2 SC3 SC4 SC5 SC6 SC7 = SC$

$WC1 = 1*WC$

$WC2 WC3 WC4 = WC$

$PM1 = 1*PM$

$PM2 PM3 PM4 = PM$

$SR1 = 1*SR$

$SR2 SR3 SR4 = SR$

Options: AD=OFF SS

Method: Robust Maximum Likelihood

Path Diagram

End of Problem

Estimating and Testing modified a Full Model on SAQ

Observed Variables: JS1 JS2 JS3 JS4 JS5 TC1

TC2 TC3 TC4 TC5 TC6 SC1

SC2 SC3 SC4 SC5 SC6 SC7

WC1 WC2 WC3 WC4 PM1 PM2

PM3 PM4 SR1 SR2 SR3 SR4

Covariance Matrix from File 0515.cov

Asymptotic Covariance Matrix from File 0515.acm

Sample Size: 237

Latent Variables: JS TC SC WC PM SR

Relationships:

$$JS1 = 1*JS$$

$$JS2 JS3 JS4 JS5 = JS$$

$$TC1 = 1*TC$$

$$TC2 TC3 TC4 TC5 TC6 = TC$$

$$SC1 = 1*SC$$

$$SC2 SC3 SC4 SC5 SC6 SC7 = SC$$

$$WC1 = 1*WC$$

$$WC2 WC3 WC4 = WC$$

$$PM1 = 1*PM$$

$$PM2 PM3 PM4 = PM$$

$$SR1 = 1*SR$$

$$SR2 SR3 SR4 = SR$$

$$TC SC WC PM SR = JS$$

set the error of covariance of SC6 and SC4 free

set the error of covariance of WC1 and SC1 free

set the error of covariance of WC2 and SC2 free

set the error of covariance of PM3 and TC6 free

set the error of covariance of JS2 and JS1 free

set the error of covariance of JS3 and JS1 free

set the error of covariance of JS4 and JS1 free

set the error of covariance of JS4 and JS3 free

Options: AD=OFF SS

Method: Robust Maximum Likelihood

Path Diagram

End of Problem

Confirmatory Factor Analysis:

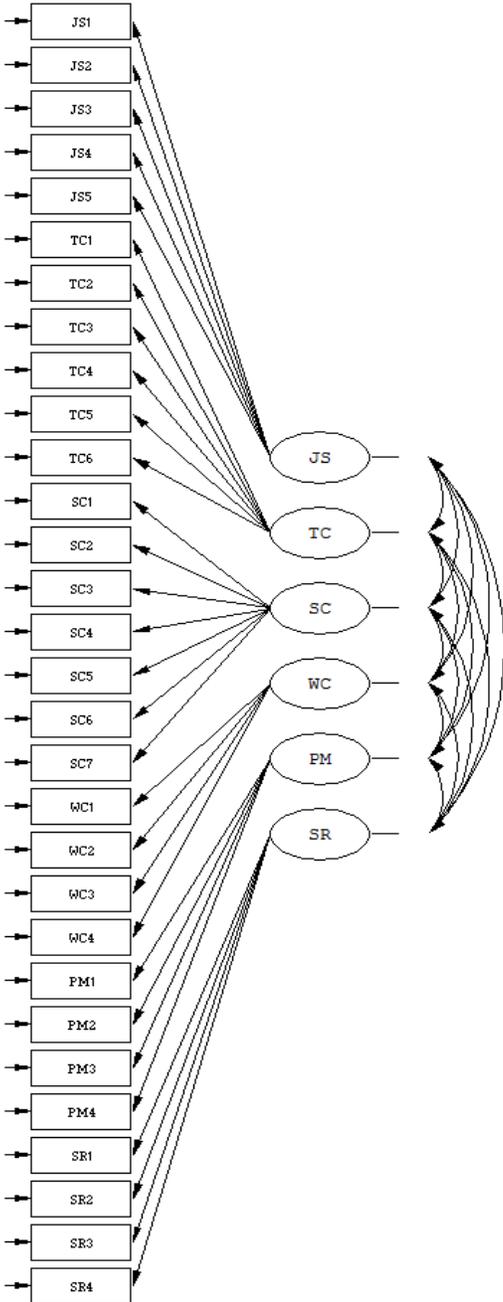


Figure 6 Path Diagram of CFA