Exploring resilient safety culture through structural equation modeling

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Abstract

Resilient safety culture (RSC) model earlier developed by authors is defined and categorized into three groups: behavioral (B), psychological (P), and managerial (M) capabilities. These groups are further sub-divided based on various subconstructs and indicators as found in the literature. There are total of 10 subconstructs and 42 indicators. This paper studies the interactions between the constructs to understand their interactions with each other. Thus, structural equation model of resilient safety culture was developed. Prior to structural equation modeling, a measurement scale analysis was conducted to assess overall reliability. It was found that behavioral capability is a complex phenomenon and is dependent on both psychological and managerial capability. This study thus helps in understanding the interactions between constructs and help the organizations make a better strategy how to enhance the resilience in their safety culture.

Keywords

Safety, Resilience safety culture, Structural equation model, Exploratory factor analysis, Confirmatory factor analysis

1.0 Introduction

RSC model was generated as seen in earlier studies (A Garg & Mohamed, 2018; Arun Garg, Tonmoy, & Mohamed, 2019). Resilient safety culture is a new concept which has been proposed in order to cover the weaknesses of safety culture. It is a safety culture with resilience, learning, continuous improvements and cost effectiveness (Shirali et al. 2016). Resilient safety culture is based on three factors: 1) Psychological/cognitive capability 2) Behavioral capabilities and 3) Managerial/contextual capabilities to anticipate, monitor, respond and learn in order to manage risks in a resilient organization.

Anticipating means knowing what to expect that is "how to anticipate more developments, threats and opportunities in the future, such as potential changes, disturbances, pressures and their consequences. Monitoring means knowing what to look for that means "how to monitor something that is a threat or can become a threat in the near future. Monitoring must include both what happens in the environment and what happens in the system itself that is system performance. Responding means knowing what to do that is "how to respond to the regular and irregular disruptions and disturbances through implementing a full and ready set of responses or through adjusting normal functions". Learning means knowing what has happened that means "how to take lessons from experiences, in particular how to learn useful lessons from the experiences of success and failures" (Trinh and Feng 2019).

The psychological/ cognitive resilience or capabilities of an organization that enables an organization to notice shifts, interpret unfamiliar situations, analyze options and figure out how to respond. Psychological resilience relates to sustaining pressures in a company environment. It is a personality trait. Behavioral resilience of an organization comprises of established behaviors and routines that enable an organization to learn more about the situation, implement new routines and fully use its resources. Managerial / contextual resilience is combination of interpersonal connections, resource stocks and supply lines that provide a foundation of quick actions (Lengnick-Hall, Beck, and Lengnick-Hall 2011).

In this section, the sub constructs and constructs were assessed to determine its overall reliability. Factor analysis was performed on each scale to uncover and confirm factor structures. Exploratory factor analysis (EFA) is conducted to uncover the appropriate factor structures of the model construct as well as to assess the common method variance. Confirmatory factor analysis (CFA) is employed to confirm and refine the identified structure of each model construct to ensure its reliability, validity and uni-dimensionality.

The data for this study is pilot study which was done on multiple sites in Kuwait in oil and gas industrial sector. The survey was in English and it was personally handed over and the survey questions explained well to all the participants. The participants were employees of the companies irrespective of their designation or gender or experience.

1.1 Scale Reliability

There are 10 different subconstructs from C1-C10 used in the questionnaire to measure the constructs proposed in the conceptual mode and there are 4 constructs (P, B, M and RSC). Please see appendix 1 for detailed explanation. To ensure that such set of measurement scales consistently and accurately captured the meaning of model constructs, an analysis of scale reliability was performed through an assessment of internal consistency and item-total correlations.

1.1.1 Internal consistency

Internal consistency refers to degree to which responses are consistent across the variables within a single measurement scale (Kline 2015). It is measured by Cronbach's alpha coefficient. Cronbach's Alpha is an index of consistency. Questionnaires are often used by researchers to measure personal characteristics that are not directly observable. The questionaries developed to measure the constructs are typically comprised of multiple items with each addressing slightly different aspect of the construct. It is the first measure calculated to assess the alpha coefficient around 0.9 is excellent, 0.8 to be very good and 0.7 to be adequate. Values of 0.6 to 0.7 are lower limit of acceptability (Jr et al. 2009). The values range from 0.696 to 0.821 above the lower limit of 0.6.

1.1.2 Item-total correlations

The item-total correlation refers to the correlation of a variable with the composite score of all the variables forming the measure of the construct (Lu, Lai, and Cheng 2007). If all the variables share common core of same construct, the score of each variable and entire construct should be correlated (Churchill 1979). In SPSS, the value of item-total correlation is corrected. The value of the corrected item-total correlation of less than 0.3 indicates that the variable is measuring something different (Pallant 2007). None of the variables is less than 0.3 so these variables are kept.

1.2 Exploratory factor Analysis (EFA)

Following the scale reliability assessment, Exploratory factor analysis (EFA) was employed to reduce the large number of variables into smaller, more manageable set of factors (Jr et al. 2009). In EFA, R factor or Q factor analysis can be used. R factor is most common type of analysis where analysis identifies a set of dimensions that area latent in large set of variables. It is thus adopted since the main objective of this analysis is to summarize the variables into set of new composite dimensions or factors rather than condensing the individual respondents into groups. The EFA is useful in preliminary analysis about the relations of the variables to underlying constructs.

1.2.1 Factorability of data

The suitability of data is factorized in terms of the intercorrelation between variables. This is known as factorability. The Kaiser-Meier -Olkin-index (KMO) and Bartlett's test of sphericity are generally used to determine the factorability of such matrix. The KMO is between 0.5 to 0.827 for subconstructs and 0.89 to 0.895 for constructs which is above 0.5 (minimum acceptable standard)(Jr et al. 2009) . The 139 survey cases in this study was more than 100 sample size which is the acceptable minimum limit and exceeds five times the number of variables which is the minimum requirement. The Bartlett's test of sphericity statistic for each sub-construct was highly significant and is less than 0.001 level which indicates that there are adequate relationships between the variables. This confirmed the factorability of EFA for each sub-construct (Jr et al. 2009; Pallant 2007).

1.2.2 Factor extraction and rotation

To produce a good solution, the EFA follows two steps. First is the factor extraction and the other is factor rotation and interpretation (Pallant 2007). To perform the factor extraction, the principal component analysis which is an extraction method is used for defining the factors. Once the factors are extracted, it was then possible to determine the degree to which the variables load onto factors, which was done by examining the factor loadings. Factor rotation was employed to achieve simpler and more meaningful solutions. Varimax orthogonal rotation was a good method to use since it is simple and common method. A specific criterion is used after factor rotations to justify the significance of the factor loadings. To ensure that variable in each factor had practical significance, the recommended cut off factor loading of 0.5 was used (Jr et al. 2009). The results of EFA are presented below.

1.2.3 EFA results

The EFA was performed for each subconstruct C1 to C10 using SPSS along with on P, B and M construct. The scree test identified 1 factor which accounted for 50% of total variance for P (variable was significant, as the factor loading was 0.5 or greater). Therefore, the one factor derived from the 9 indicators of P is P11. Table 1 shows the rotated factor loadings for P construct.

Table 1: Rotated factor loadings for P construct

Variable description	**Rotated component**		
Component (P11)	**1**	**2**	**3**
Sense of purpose	0.698		
Strong core value	0.768		
Prevailing vocabulary	0.659		
Highly visible moral purpose	0.788		
Having Attitude	0.705		
Mindset	0.704		
Ingenuity to develop new skills	0.757		
Common language	0.627		
Situation specific interpretations	0.637		

The scree test identified 1 factor which accounted for 43.89% of total variance for B. Therefore, the four-factor derived from the 15 indicators of B is B11 (5 variables, component 1), B12 (4 variables, component 2), B13 (4 variables, component 3), B14 (2 variables, component 4). Table 2 shows the rotated factor loadings for B construct.

Table 2: Rotated factor loadings for B construct

Variable description	**Rotated component**			
Component	**1**	**2**	**3**	**4**
Disciplined creativity	.128	.043	**.801**	.137
Combine originality and initiative	.036	.108	**.844**	.018
Ability to follow different course of action	.152	-.124	.378	**.760**
Engaging in non-conforming repertoires	.103	.438	.195	**.657**
Have varied and complex action inventory	.351	**.514**	.048	.413

Have diverse competitive actions	.343	**.582**	.108	.482
Development of useful practical habits	**.548**	.053	-.051	.403
Develop habits of investigation	**.703**	.408	.170	.023
Develop habits of collaboration	**.751**	.227	.029	.167
Develop habit of flexibility	**.807**	.032	.027	.070
Creating robust responses	**.814**	.112	.043	-.008
Ability to spot an opportunity	-.117	.172	**.541**	.413
Developing new competencies	.246	**.795**	.257	-.029
Unlearning obsolete information	.073	**.794**	.134	.068
Benefit from situations that emerge	.041	.306	**.688**	.191

The scree test identified 1 factor which accounted for 39.69% of total variance for M. Therefore, the three-factor derived from the 18 indicators of M is M11 (5 variables, 1 component), M12 (1 variable, component 2), M13 (5 variables, component 3). Cross functional collaboration is less than 0.5 so deleted. Table 3 shows the rotated factor loadings for M construct.

Table 3: Rotated factor loadings for M construct

Variable description	**Rotated component**		
Component	**1**	**2**	**3**
Respectful interactions within organization	**.711**	.115	.133
Face to face honest interaction	**.726**	.316	.228
Disclosure oriented intimacy	**.632**	.378	.099
Exchanging resources	.236	-.033	**.729**
Sharing tacit information	.428	.170	**.631**
Cross-functional collaboration	.485	.413	.113
Forging relationships	.064	.036	**.729**
Relationships with strategic alliances	.275	.123	**.742**
Bond with various environmental agents	**.512**	.494	.060
Promote organizational slack	**.589**	.453	.148
Communicating without getting ignorant label	-.068	.556	**.670**
Communicating without getting incompetent label	.383	**.709**	.135
Communicating without getting negative label	.234	**.847**	.079
Communicating without getting time water label	.274	**.772**	.056
Sharing decision making	**.646**	.329	.306
Creating organization structure	**.664**	.246	.243
Members have discretion and responsibility	**.691**	.047	.127
Replying on self-organization	**.595**	.376	.249

Based on the eigen value, scree test and the a priori criterion, the constructs P (psychological capability), B (behavioral capability) and M (managerial capability) were represented with various factors (total 8).

1.3 Confirmatory Factor Analysis (CFA)

The EFA done in the last section uncovered number of factors and confirmed that the reliability of the measurement scales that structured the model constructs. To adequately assess construct validity and one-dimensionality, confirmatory factor analysis (CFA) which is subset of structural equation modelling is done. The CFA is a way of testing how well the a priori factor structure and its respective pattern of loadings match with the actual data. EFA provides preliminary factor structure for each construct, so CFA is employed to strengthen the concept.
To accurately calculate the model parameters and fit indices, an appropriate estimation method is required. Maximum likelihood (ML) is the most widely used estimation method. This method requires an assumption of the univariate and multivariate normality. Sample size of 139 was substantial for conducting an EFA but is small for CFA since at least 200 is minimum that is required. Data characteristics justified the use of model fit indices chi-square/df, Goodness of fit index (GFI), Tucker Lewis index (TLI), Incremental fit index (IFI), comparative fit index (CFI) and Root mean square error of approximation (RMSEA). For the model to be acceptable fit, the following criteria need to be satisfied.

1) Chi-square/df <3 ((Jr et al. 2009; Kline 2015)
2) GFI, TLI, CFI, IFI >0.9 (Garson 2015)
3) RMSEA<0.08 (Garson 2015; Jr et al. 2009)

1.3.1 CFA results

Assessing construct validity using CFA involves examination of convergent and discriminant validity. The CFA was performed on each construct using AMOS which is extension of SPSS. The covariance matrix is used as the input data set. The factor loading, t value and significance level of each variable provide a measure for the convergent validity, the value of R-square gives a measure with which to assess the reliability of the variables, the value of the correlation between factors provide an indication of the discriminant validity.
The CFA for P construct is Chi square= 50.96, df=27, chi-square/df=1.88<3, GFI= 0.925, TLI=0.93, CFI= 0.947, IFI=0.948 >0.9 and RMSEA=0.08 <0.08
The CFA for B construct is presented is Chi square= 164.37, df=86, chi-square/df=1.911 <3, GFI= 0.872, TLI=0.871, CFI= 0.894, IFI=0.897 and RMSEA=0.081
The CFA for M construct is presented is Chi square= 232.6, df=116, chi-square/df=2.005 <3, GFI= 0.844, TLI=0.878, CFI= 0.896, IFI=0.898 and RMSEA=0.085
The TLI and CFI should be 0.9 or higher , we find that they are close to 0.9 we shows satisfactory fit.

The CFA results confirmed the factor structures derived from the EFA. The assessment of the scale reliability showed that the measurement scales which were used to capture the meaning of the model constructs were reliable. The item correlation of all the variables were substantial indicating that each variable adequately measured its underlying construct. The EFA was conducted of each individual construct to uncover the factor structures.

2.0 Model assessment

This section presents the detailed procedure undertaken to assess the conceptual model following the confirmed validity, reliability, and uni-dimensionality of the model constructs. The section presents the technique to evaluate the sequential assessment of two main components: the measurement model and the structural model. The data used is the same survey which was used earlier in previous sections. The following is the proposed conceptual model (table 4) presented broadly depicts the possible relationships connecting the constructs. It has three hypotheses.

Table 4: Research hypothesis for constructs

Hypothesis	Description
H1	Psychological capability positively influences behavioral capability
H2	Managerial capability positively influences behavioral capability
H3	Managerial capability positively influences psychological capability

2.1 Structural Equation Modelling Overview

SEM is an extension of a multivariate technique such as regression analysis which allows the use of multiple indicators to measure unobserved variables for example constructs while taking to consideration the measurement errors when statistically analyzing data (Jr et al. 2009). It is employed to determine whether a theoretical model (a priori) is valid and validating and evaluating linear relationships among set of observed and unobserved variables (Shah and Goldstein 2006). The model used in SEM analysis is combination of measurement model and structural model. The former depicts the relationships between variables and the constructs which can be used to determine whether the construct is accurately measured. The latter represents the relationship between constructs only. The first step in the SEM analysis is to look at the measurement model and establish validity and unidimensional and then test the structural model to see the relationships between the constructs.

2.2 Measurement model assessment

2.2.1 Measurement model assessment criteria

The measurement model was assessed using the CFA technique conducted similarly to that performed in the earlier places. The assessment of the model fit, the convergent and discriminant validity and the uni-dimensionality were based on the following criteria:

1) Model fit indices: chi square/df <3, GFI, TLI, CFI, IFI >0.9 and RMSEA <0.08 ((Garson 2015; Jr et al. 2009; Kline 2015))
2) Convergent validity: Factor loadings >0.5, t values >1.96 where $p<0.05$ and R square > 0.5 ((Jr et al. 2009; Koufteros 1999))
3) Discriminant validity: correlation coefficients for each pair of constructs less than 0.85 ((Kline 2015))
4) Uni-dimensionality: fit indices of the factor model, specified as unidimensional, satisfy the above model fit criteria. (Koufteros 1999)

The reliability of the model was assessed using more accurate measure of composite reliability and average variance extracted rather than traditional Cronbach's alpha approach. Composite reliability refers to the degree to which a set of two or more variables share in their measurement of a construct (Koufteros 1999). A high composite reliability indicates all the variables measure the same construct. A composite reliability greater than 0.6 is desirable.

2.2.2 Measurement model results

The model exhibited an acceptable level of fit with chi square=1396.98, df=769, chi-square/df= 1.817, GFI= 0.681, TLI=0.773, CFI=0.787, IFI=0.791, RMSEA=0.077. All indicators have greater loadings than 0.5. The TLI, CFI, IFI and GFI should be greater than 0.9 but since chi-square/ df is less than 3 and RMSEA is less than 0.08, the model fit indices are accepted. The model fit indices such as TLI, CFI range from 0 to 1 and greater the range better the model fit.

2.3 Structural Equation Modelling

Once the validity and uni-dimensionality of the measurement model is established, the structural model was assessed to examine the relationships between its constructs. The structural model was specified by replacing the double headed arrows representing correlations between the constructs to casual single headed arrows. They represent the hypothetical relationships as represented by the conceptual model. The structural model assessment procedure included an examination of model fit indices and standardized path coefficients to provide a basis of the accept and reject the hypothetical relationships. The hypothetical relationships to be supported, the standard path coefficient need to be significant at $p<0.05$ level and greater than 0.3 to be considered meaningful.

2.3.1 Results of the structural equation modelling

Table 5 shows the results. The model exhibited an acceptable fit where chi square = 1396.98, df= 769, chi square/df= 1.81, GFI= 0.681, TLI= 0.773, CFI=0.787, IFI= 0.791, RMSEA= 0.077. All the three results were statistically significant with 0.399 to 0.814. It should be noted that TLI and CFI do not vary much with sample size. However, these measures are less variable with larger sample sizes. The RMSEA is larger with smaller sample sizes. Table 5 shows that the managerial capability construct has very strong influence on the psychological capability construct and so all the hypothesis was true and positive.

Table 5: Structural model results

Path (Hypothesis)	Standardized path coefficient	t-value	Hypothesis testing results
P to B (H1)	0.491	3.133	supported
M to B (H2)	0.449	2.767	supported
M to P (H3)	0.859	8.167	supported

Conclusion and Discussions

Based on the results, it can be concluded that the hypothesis is true. The managerial capability influences the psychological capability a lot as compared to behavioral capability. The psychological capability influences the behavioral capability as well, but the behavioral capability is a complex phenomenon where it is getting influenced by psychological as well as managerial capability.

What can be inferred from the results is that managerial capability talks about the systems in place along with rules and regulations along with the management of the safety system, this characteristic of RSC helps make a perception in worker's mind about a robust system in an organization which is the psychological capability, this leads to workers practicing safe behaviors thus behavior capability gets influenced by psychological capability.

This study would benefit from additional validation of the SEM model with larger sample sizes to enhance the robustness and applicability of the findings. Future research can explore the model's applicability in different cultural or industrial settings which could provide deeper insights into the universality of the proposed relationships within the RSC model. Also, the quantitative approach adopted in this study provides a solid foundation for understanding the interrelations within the RSC model, incorporating qualitative data could enrich the findings which can be part of the future research as well.

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Appendix 1

Indicator #	Constructs (SCG)	Safety culture attribute (SCA)	EFA factor	Sub constructs
1	P	Sense of purpose	P11	Conceptual Orientation (C1)
2		Strong core value		
3		Prevailing vocabulary		
4		Highly visible moral purpose		
5		Having Attitude		Constructive Sensemaking (C2)
6		Mindset		
7		Ingenuity to develop new skills		
8		Common language		
9		Situation specific interpretations		
10	B	Disciplined creativity	B13	Learned resourcefulness (C3)
11		Combine originality and initiative	B13	
12		Ability to follow different course of action	B14	Counterintuitive agility (C4)
13		Engaging in non-conforming repertoires	B14	
14		Have varied and complex action inventory	B12	
15		Have diverse competitive actions	B12	

16		Development of useful practical habits	B11	Practical habits (C5)
17		Develop habits of investigation	B11	
18		Develop habits of collaboration	B11	
19		Develop habit of flexibility	B11	
20		Creating robust responses	B11	
21		Ability to spot an opportunity	B13	Behavioural preparedness (C6)
22		Developing new competencies	B12	
23		Unlearning obsolete information	B12	
24		Benefit from situations that emerge	B13	
25	M	Respectful interactions within organization	M11	Deep social capital (C7)
26		Face to face honest interaction	M11	
27		Disclosure oriented intimacy	M11	
28		Exchanging resources	M13	
29		Sharing tacit information	M13	
30		Cross-functional collaboration		
31		Forging relationships	,M13	Broad resource network (C8)
32		Relationships with strategic alliances	M13	
33		Bond with various environmental agents	M11	
34		Promote organizational slack	M11	
35		Communicating without getting ignorant label	M13	Psychological safety (C9)
36		Communicating without getting incompetent label	M12	
37		Communicating without getting negative label	M12	
38		Communicating without getting time water label	M12	
39		Sharing decision making	M11	Diffused power and accountability (C10)
40		Creating organization structure	M11	
41		Members have discretion and responsibility	M11	
42		Replying on self-organization	M11	

P= Psychological capability, B=Behavioral capability, M=Managerial capability