An Investigation of the Joint Rescue Capability of Emergency in City Group in the Northern Frontier of China

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Abstract: The risk of emergency in the city group is becoming increasingly prominent. In this study, the importance of determining the influencing factors by using a structural equation model is assumed to be related to the emergency rescue capability of the city group. Firstly, by using existing literature and discussions, and questionnaires designed for a number of experts and local emergency department staff. 513 questionnaires were collected and 24 key factors affecting emergency evacuation capability were identified. Secondly, the hypothetical structural equation model of influencing factors and its relationship with emergency rescue ability were proposed. Finally, the relationship between the influencing factors and its influence on the emergency rescue ability was analyzed. Results suggest that most of the influencing factors have a significant impact on the capability of rescue under chemical fire accident. The results of this study can be used to improve the level of chemical fire accident rescue in a risk event in an existing frontier city group in the north of China.

1. Introduction

In recent years, natural disasters (earthquakes, floods, hurricanes) and man-made accidents (terrorist attacks, chemical leakages, fire, and explosion have occurred frequently in the urban areas of China. These major disaster accidents can cause vast damage to a large-scale urban area in a short time, leaving many casualties behind [1-9]. With the acceleration of urbanization process and constant expansion of city size in China in recent 10 years, the difference in population density between urban agglomerations formed by more than three cities and surrounding cities is expanding, the cross-boundary crisis is easy to cross the geographical boundary and the function boundary in the process of large-scale regional disaster formation. It also has a high speed of spread and the great damage potential [10]. The cross-boundary crisis will affect many administrative regions and the diffusion process of the situation will escalate rapidly and complexly [11] . Emergency resources allocation is the key link of emergency rescue, assistant, and management in city groups [3, 12, 13].However, the accidental public events in city groups are usually characterized by superposition, union and risk coupling [14]. Specialized emergency units for specific types of disasters are often distributed across multiple organizations and lack synergy. As a result, they cannot cope with the complex public incident effectively [15].

2. Hypotheses of model development

Several questions were included in the main contents, three about the construction status of emergency education and training, three about the construction status of emergency rescue, two about the construction status of monitoring, three about the construction status of resource security, three about the construction status of information security, two about the construction status of decision-making analysis, three about the order and two about how to improve the construction status. There are many factors affecting the emergency rescue capability of the city group (ERCOCG). For example, the evaluation index of the ERCOCG does have a direct influence on the validity of the evaluation result. Therefore, it is of vital importance to design a reasonable system of the evaluation index. Pre-disaster monitoring together with early warning is the precondition of emergency rescue to evacuate the personnel and complete the resettlement work in the disaster.

3. Case study

3.1 Study area introduction

Located in the north of China, Hohhot-Baotou-Ordos region including the cities and towns of those urban circles lies in the central area of the mid-western Inner Mongolia Autonomous Region with a zigzag distribution [16-19].

With the development of the city group, major public safety problems occurred frequently. What's worse, energy and chemical industries have developed in these three cities, thus they gave rise to frequent accidents of various kinds in heavy and large industrial enterprises[20,21]. On January 21, 2014, the relevant departments of the clean solvent oil plant in Ejin Horo Banner, Ordos's city, Inner Mongolia autonomous region mobilized the fire department of Hohhot Baotou and Ordos city to support the accident.

3.2 Questionnaire design

In this paper, the survey was conducted in Hohhot, Baotou, and Ordos with government emergency management staff (20%), fire commanders (30%), firefighters (20%) and safety management personnel of chemical enterprises (30%) involved. The crisis response departments and experts related were consulted to revise the comments and recommendations. In addition, the five-level Likert scale was adopted to measure the variables of every question. The contents can be mainly divided into three categories, namely, the questionnaire guide, the personal situation of the respondents and the related problems about the ERCOCG. Staff from three cities emergency offices were elected as respondents to finish 528 questionnaires, but in fact, 513 pieces collected were valid. SPSS 23.0 statistical analysis software package, exploratory factor analysis, and validation factor analysis were carried out by the software of SPSS Amos.

3.3 Confirmatory factor analysis

By examining, KMO (Kaiser-Meyer-Olkin measure of sampling adequacy) was 0.783, greater than 0.5. The significant level of Bartlett sphericity test was 0.000, which showed it was suitable for factor analysis. The cumulative explained variance reached 61.044%. Cronbach's α was greater than 0.60.

4. Results analysis

4.1 Initial structure model

Emergency rescue capability, which is difficult to be measured directly, could be taken as a latent variable and be measured by some observed variables using a SEM model. This analysis was based on data from the first survey. Because there were many items in the external factor scale, an item analysis was conducted firstly to delete the items which had no significant difference.

4.1.1 Reliability and validity test

According to the fit indexes, Chi-square value χ = 130.119, $\chi^2/df = 0.790$ < 2.00, which reached 0.05 significance level. The results of CFI = 1> 0.90, RMSEA = 0.054＜0.06 was obtained by calculating the datum of the questionnaire through the use of Amos software. The factor loading ranges from 0.75 to 0.90 which showed the standard error is small and all parameters are important.

4.1.2 Correlation between emergency rescue capability and latent factors

The relationship between emergency rescue capability and other latent factors was tested by correlation analysis. In addition, if the correlation reached a significant level, the linear relationship was meaningful. Thus, the regression analysis could be used for interpretation. SPSS 23.0 software was used to explore the relationships. Emergency rescue capability was significantly and positively correlated with the capability of command and decision-making (r=0.998), the capability of recovery after the disaster (r=0.99), the capability of summarizing(r = 0.861) and capability of information transfer (r=0.853). Correlation variables are positively correlated, and in the regression analysis, these variables are involved.

4.2 Effect of observing factors on emergency rescue capability

Analysis of latent variables was directly influenced by SPSS software analysis for emergency rescue capability. The multicollinearity of independent variables of command and decision-making capability was diagnosed. As shown in Table 5, the Tolerance of all variables (TOL) entering the regression equation was 0.997, less than 1. The Variance Inflation Factor (VIF) was 1.003, less than 10. Most of the observed variables were randomly distributed above and below zero and most randomly fell between [-2, 2], which means that sample observations meet the normality and homogeneity of variance assumption. Since there were no multicollinearity, heteroscedasticity and serial correlation in the regression equation, the results of regression analysis were of great importance. The value of Durbin-Watson was 1.897, close to 2, which means there was no serial correlation between sample residuals.

Table 1. Multiple linear regression analysis of communication skill and decision-making on emergency rescue capability

Independent variable		B	SE	Beta(β)	t	Sig.	TOL	VIF
Command and decision-making capability	Constant	2.965	0.446		6.647	0.000		
	● Communication skill	0.180	0.085	0.171	2.130	0.035	0.997	1.003
	● Decision making	0.045	0.085	0.043	0.535	0.593	0.997	1.003
R=0.712 R^2=0.507 DR^2=0.507 F=4.439								

Table 2. Multiple linear regression analysis of independent variable

Independent variable		B	SE	Beta(β)	t	Sig.	TOL	VIF
Information transfer capability	Constant	2.641	0.531		4.971	0		
	Communication Networks	0.041	0.085	0.04	0.475	0.636	0.903	1.107
	Service and Device Configuration	0.087	0.09	0.081	0.96	0.339	0.912	1.096
	Applications and information flow	0.177	0.091	0.158	1.942	0.054	0.986	1.014
R=0.625 R^2=0.425 DR^2=0.424 F=3.844								
Capability of summarize	Constant	3.444	0.361		9.541	0		
	Extracting lessons learned	0.021	0.092	0.019	0.23	0.818	1	1
	Identifying specific implications	0.014	0.034	0.034	0.418	0.676	1	1
R=0.550 R^2=0.302 DR^2=0.301 F=0.055								
Recovery capability after the disaster	Constant	3.999	0.488		8.187	0		
	Self-reliance	0.083	0.095	0.072	0.876	0.383	0.968	1.033
	Shared responsibility	0.081	0.087	0.076	0.932	0.353	0.998	1.002
	Policy implementation	0.019	0.025	0.061	0.74	0.46	0.969	1.032
R=0.516 R^2=0.266 DR^2=0.265 F=0.397								

Similarly, with information transfer capability, the capability of summarizing and recovery capability after the disaster of the latent variable of multivariate linear regression analysis. As shown in Table 1 and Table 2. The Tolerance of all variables (TOL) entering the regression equation was less than 1. The Variance Inflation Factor (VIF) was less than 10. The results analyzed by regression analysis method had substantive significance.

The multiple correlation coefficients (R) of the four latent variables are 0.712, 0.625, 0.550, and 0.516. The squared multiple correlation coefficients (R2) are respectively: 0.507, 0.425, 0.302, and 0.266. The normalized regression coefficients of four latent variables are positive, which shows that the four factors had a positive impact on emergency response capability.

5. Discussion

In this paper, the SEM model of the emergency rescue capability of the city group is mainly composed of two aspects. As is manifested in Fig. 1, there is a certain relationship among monitoring and early warning capability, resource support capability, education and training capability, Emergency collaboration strategy. The path coefficients are 0.637, 0.863, 0.708 and 0.359 respectively. The greater the value it elaborates, the greater the impact it may have.

The keynote of improving emergency reliability is to improve the cooperation capability which responses organizations consistently. Table 2 shows that the standard estimates of the path coefficients between the cooperative capability, the reliability of the emergency response and the coordination of the emergency organization system is 0.453. According to the results of SEM structural analysis, the enhancement of organizational cooperation capability can also be realized by improving organizational structure, organizational operation mechanism, organizational culture and organizational leadership cultivating ability.

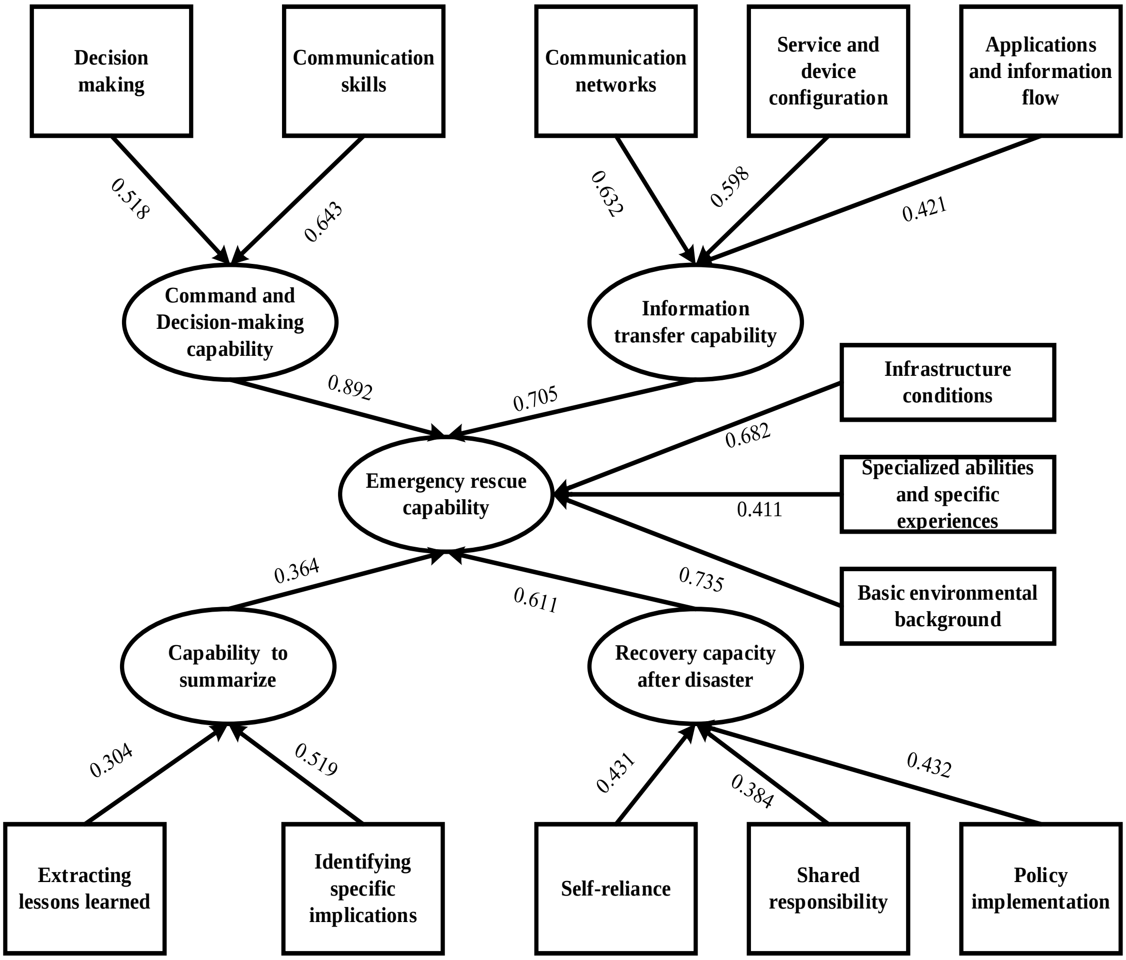

Figure 1. Hypothetical structural equation model and its estimated results

6. Conclusion

Based on the evaluation indexes of the ERCOCG, this paper puts forward the theoretical hypothesis of the relationship between these evaluation indexes. The theoretical hypothesis of construction is tested by using a structural equation model. The direct impact coefficients of the command and decision-making ability and emergency rescue ability reach 0. 892, higher than the direct impact of the other three factors.

Emergency rescue of city groups should set out from the most influential factors and seize the key factors. Therefore, it is necessary to accurately grasp the causal relationship between all the evaluation indicators and the relationship between key factors and other factors of the accurate positioning, which will help enhance the emergency rescue capability of city groups and promote governmental reform of new departments.

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References

[1] Rawls C G, Turnquist M A. Pre-positioning of Emergency Supplies for Disaster Response [J]. Transportation Research Part B, 2010, 44 (4): 521-534.

[2] Caunhye A M. Location-allocation models for casualty response planning during catastrophic health events [J], 2014.

[3] Wang L, Song J, Shi L. Dynamic emergency logistics planning: models and heuristic algorithm [J]. Optimization Letters, 2015, 9 (8): 1533-1552.

[4] Ai F, Comfort L K, Dong Y, et al. A dynamic decision support system based on geographical information and mobile social networks: A model for tsunami risk mitigation in Padang, Indonesia [J]. Safety Science, 2015, 90: 62-74.

[5] Santos R, Mosse D, Znati T, et al. Design and implementation of a Witness Unit for opportunistic routing in tsunami alert scenarios [J]. Safety Science, 2016, 90: 75-83.

[6] Boonmee C, Arimura M, Asada T. Facility location optimization model for emergency humanitarian logistics [J]. International Journal of Disaster Risk Reduction, 2017, 24: 485-498.

[7] Anaya-Arenas A M, Renaud J, Ruiz A. Relief distribution networks: a systematic review [J]. Annals of Operations Research, 2014, 223 (1): 53-79.

[8] Cao H, Tian L, Li S, et al. An integrated emergency response model for toxic gas release accidents based on cellular automata [J]. Annals of Operations Research, 2017, 255 (1-2): 617-638.

[9] Duque P a M,Dolinskaya I S,Sörensen K. Network Repair Crew Scheduling and Routing for Emergency Relief Distribution Problem [J]. European Journal of Operational Research, 2015, 248 (1): S0377221715005408.

[10] Zhang H. Collaboration in Emergency Response in China: Evolution from the Wenchuan Earthquake, May 12, 2008 to the Lushan Earthquake, April 20, 2013[M]. 2015.

[11] Pescaroli G, Alexander D. Critical infrastructure, panarchies and the vulnerability paths of cascading disasters [J]. Natural Hazards, 2016, 82 (1): 175-192.

[12] Wang D, Qi C,Wang H. Improving emergency response collaboration and resource allocation by task network mapping and analysis [J]. Safety Science, 2014, 70 (70): 9-18.

[13] Lu Y, Xu J. The progress of emergency response and rescue in China: a comparative analysis of Wenchuan and Lushan earthquakes [J]. Natural Hazards, 2014, 74 (2): 421-444.

[14] Cao J, Zhu L, Han H, et al. Modern Emergency Management [M]. 2018.

[15] Zhang J H, Sun X Q, Zhu R, et al. Solving an emergency rescue materials problem under the joint reserves mode of government and framework agreement suppliers [J]. Plos One, 2017, 12 (10): e0186747.

[16] Guo P, Duan T, Song X, et al. Evaluation of a sequential extraction for the speciation of thorium in soils from Baotou area, Inner Mongolia [J]. Talanta, 2007, 71 (2): 778-783.

[17] Sun L P, Yin J F. Study on Sustainable Construction and Improvement of Dwellings in Huhhot and Baotou Area of Middle Inner Mongolia [J]. Advanced Materials Research, 2013, 689: 149-152.

[18] Zhou H, He J, Zhao B, et al. The distribution of PM 10 and PM 2.5 carbonaceous aerosol in Baotou, China [J]. Atmospheric Research, 2016, 178-179: 102-113.

[19] Liu X, Gao T, Wang X. Inner Mongolia [J], 2018.

[20] Mukherjee A, Bhattacharya P, Shi F, et al. Chemical evolution in the high arsenic groundwater of the Huhhot basin (Inner Mongolia, PR China) and its difference from the western Bengal basin (India)[J]. Applied Geochemistry, 2009, 24 (10): 1835-1851.

[21] Wang J, Brown D G, Agrawal A. Climate adaptation, local institutions, and rural livelihoods: A comparative study of herder communities in Mongolia and Inner Mongolia, China [J]. Global Environmental Change, 2013, 23 (6): 1673-1683.