

Performance Evaluation of Geological Disaster Relief Operations in China using SBM-DEA Methodology

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1 Performance evaluation of geological disaster relief operations in 2 China using SBM-DEA methodology

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11 **Abstract:** Geological disasters have caused enormous damage to human beings and the
12 economy in China. Chinese government pay great effort on geological disaster relief.
13 Usually, the efficiency of the disaster rescue is the first priority to be considered.
14 Taking the historical analysis of China's geological disaster rescue as the main line ,
15 in this paper, we developed a slacks-based measure data envelopment analysis (SBM-
16 DEA) model to evaluate the performance of 18 geological disasters relief during 2015-
17 2019 in China, which are used to examine the performance of the geological disasters
18 rescue activities. The results show that though the capabilities of geo-disaster relief is
19 continuous improvement from 2015 to 2019, China's geological disasters rescue
20 system is still at the primary stage. Especially, the efficiency of landslide rescue
21 operation is pretty low. We analysis the factors influencing the efficiency and provide
22 several suggestions for capacity improvement of geo-disasters rescue.
23

24 **Key words:** Geological disasters; Rescue efficiency; SBM model; Redundancy
25

26 1. Introduction

27 China is an geological disaster-prone country, China has one of the most serious
28 geological disaster damage statistics and casualty rates in the world. According to
29 Emergency Events Database (EM-DAT) statistics, during 2008-2018 , 150 thousand
30 geological disasters took place and caused more than 7000 casualties. There are more
31 than 280 thousand potential geological hazards which thread about 15 million people^[1].
32 so the Chinese government pay great effort on the prevention and rescue of the
33 geological disaster^[2].

34 Tremendous progress has been made in response to many challenges resulting from
35 geo-disaster. However, geo-disaster rescue is complicated, and great emphasis should

36 be placed on its efficiency to achieve the best results. Chinese government can mobilize
37 the whole country to deal with the great disaster and make maximum efforts to reduce
38 casualties. Meanwhile, several disaster relief operations show that China are
39 experiencing an increasing number of overreaction problem in disaster relief^[3]. Recent
40 case show that there are more rescue teams and heavy machineries deployed than the
41 requirement at the scene of the disaster, which is a waste of rescue resource and caused
42 chaotic of the situation^[4]. So, accurate resource deployment is important for disaster
43 relief. Under the premise of ensuring rescue resource supply, the rescue efficiency
44 should be improved. The performance evaluation of the geological disasters rescue
45 operations should be conducted, and lessons should be learned to improve the rescue
46 performance.

47 The objective of this paper is to develop a benchmarking framework for geological
48 disaster rescue operations. The remaining parts of the paper are as follow. Section 2
49 summarize some literature on disaster rescue performance. Section 3 presents the SBM-
50 DEA method and history data for evaluating the geo-disaster rescue performance.
51 Section 4 presents the empirical results and policy implications. Conclusions are given
52 in Section 5.

53 **2. literature review**

54 The traditional method of disaster relief performance analysis is usually to set the
55 factors of search and rescue, medical rescue, transportation recovery, logistics supply
56 and emergency evacuation, and get the comprehensive index by its calculation of its
57 index ^[5] weighting method. However, this method is sensitive to the selection of the
58 weights of each sub-index, and the weighting method is subjective, which affects the
59 analysis results.

60 Data envelopment analysis (DEA) is a well-known method for measuring
61 efficiency among decision making units (DMUs). More than 40 years ago, Charnes et
62 al ^[6] proposed the CCR model that allows for the translation of fractional linear
63 measures of efficiency into a linear programming model. DEA exists because of its

64 unique ability to measure the efficiency of multiple-input and multiple-output DMUs
65 without the need to assign weights to inputs and outputs in advance different DEA
66 models [7], [8]. DEA has applications in many fields including education [9], banking [10],
67 [11], manufacturing [12], and others [13-17].

68 DEA can be used as a decision analysis tool in several fields because it does not
69 focus on finding universal relationships among all units evaluated in the sample. DEA
70 allows each unit in the data to have its own production function and then assesses the
71 efficiency of that single unit by comparing it with the efficiency of other units [18].

72 A large number of studies on the efficiency of disaster response are based on
73 earthquake, hurricane and flood disasters, mainly on humanitarian organizations and
74 medical institutions. Research on geological disasters has focused on process
75 documentation [19], causal mechanisms [20], [21], risk and loss assessment [22]-[24], disaster
76 prediction [25], stabilization and remedial measures- [26], etc., of landslides and mudflows,
77 and qualitative analysis of factors influencing disaster relief efficiency and suggestions
78 for improvement of relief efficiency.

79 Current research findings on disaster response efficiency include three main areas:

80 First, the analysis of factors affecting rescue efficiency. It mainly includes the
81 rescue process, methods and different roles in disaster events, the impact of information
82 and communication networks [27], the location of supplies and post-disaster relief funds
83 [28] and the geographical location of the affected country [29] on the rescue efficiency;
84 Wei J (2016) studied the impact of economic, political, cultural, geographical location
85 and disaster type on the rescue efficiency based on the perspective of emergency supply
86 chain [30]; Gao L explored the disaster relief capacity of Heilongjiang province in the
87 context of government input in the past decade to study the factors affecting the relief
88 capacity [31].

89 Second, from the resource allocation perspective. Acimovic J (2016) established a
90 two-stage stochastic optimization model based on actual material stockpile data to
91 evaluate the relief response capability of disaster relief agencies in the United States [32].

92 Taking the "Wenchuan earthquake" as an example, Sun Huali (2019) introduced a
93 timeliness evaluation function to evaluate the execution efficiency of key links by
94 considering the relationship between the amount of medical resources invested and the
95 rescue work efficiency, and proved the existence of an optimal value for the same
96 resource ratio through theoretical derivation ^[33].

97 Third, from the relief supply chain perspective. Zobel C (2016) used the DEA
98 method to evaluate relief efficiency by building an input-output matrix and considered
99 data envelopment analysis and dynamic frontier analysis as the two most important
100 methods ^[34]. Abidi H (2014) ^[35] and Blecken A (2010) ^[36] pointed out that the evaluation
101 of humanitarian relief efficiency is very lacking, and Schulz S (2009) proposed
102 principles for selecting evaluation indicators for the efficiency of the post-disaster
103 logistics operations of the International Red Cross and Red Crescent ^[37]. Üstün A (2015)
104 used the DEA method to evaluate the efficiency of humanitarian organizations' disaster
105 relief in the 1999 earthquake in Turkey ^[38], and Guan G (2016) used the Wenchuan
106 earthquake as an example of efficiency performance in terms of analyzed the synergy
107 of the rescue supply chain ^[39], Leng Q (2018) used DEA-SBM model to calculate the
108 efficiency of 86 natural disaster rescues by international organizations during 2001-
109 2017, and Tobit regression was used to analyze the influencing factors ^[40]. Lin W (2019)
110 constructed an ArcGIS-based maritime rescue efficiency evaluation model from
111 calculated the maritime rescue efficiency of Japan and Korea in specific sea areas of
112 the Middle East Sea ^[41]. Expert scholars have made some progress in exploring the
113 efficiency of disaster relief using DEA models ^{[42], [43]}.

114 Combined with the existing research results, the following research aspects still
115 need to be improved: (1) Most of the research scope of geological hazards is focused
116 on earthquake hazards, while there is little research on landslide and debris flow hazards.
117 (2) In geological disaster rescue, it is important to improve rescue efficiency by
118 evaluating the inputs and outputs of rescue efficiency, constructing a rescue efficiency
119 evaluation index system, and finding out the relationship between disaster procedures

120 and rescue inputs. (3) There is a lack of research results and relevant case data on the
 121 evaluation of rescue efficiency of major geological disasters, and the research on rescue
 122 efficiency is mainly based on a single disaster or a single organization, which needs to
 123 effectively improve the efficiency of disaster relief.

124 This paper analyzes the "input-output" indexes of 18 major geological disaster
 125 rescue cases of landslides and mudslides that occurred in China from 2015-2019, and
 126 constructs a rescue efficiency evaluation model based on the "rescue-disaster" index,
 127 conducted a study of geological disaster rescue efficiency.

128 3. Methodology and Data Collection

129 3.1 Slacks-based measure of efficiency (SBM) DEA model

130 DEA includes both radial and non-radial models. The radial model is represented
 131 by the CCR (Charnes-Cooper-Rhodes) model ^[44]. The treatment results respond to the
 132 changes in the input or output ratio. However, not all inputs (outputs) are scaled in the
 133 actual modeling. It ignores the slack variables and the efficiency may be overestimated.

134 Non-radial DEA methods can overcome such limitations, such as SBM, the SBM
 135 model proposed by Tone (2001) (see also Pastor et al., 1999) ^[45]. It has three variations:
 136 input, output and non-oriented, and the un-oriented model has to have both input and
 137 output orientations. Following, the SBM model is introduced to estimate geological
 138 disaster rescue operation efficiency ^[46].

$$\begin{aligned}
 \rho = \min & \frac{1 - \frac{1}{m} \sum_{i=1}^m \frac{s_i^-}{x_{io}}}{1 + \frac{1}{q_1 + q_2} \left(\sum_{r=1}^{q_1} \frac{s_r^+}{y_{ro}} + \sum_{t=1}^{q_2} \frac{s_t^{b-}}{b_{ro}} \right)} \\
 \text{s.t.} & \begin{cases} x_o = X\lambda + S^- \\ y_o = Y\lambda - S^+ \\ b_o = B\lambda + S^{b-} \\ \lambda \geq 0, S^- \geq 0, S^+ \geq 0, S^{b-} \geq 0 \end{cases} \quad (1)
 \end{aligned}$$

140 ρ is called SBM input efficiency, x_{io} is the input; y_{ro} is the output; q_1 is the desirable
 141 output, q_2 is the undesirable output, m means the inputs number; s^- is the inputs slacks,
 142 s^+ is the desirable output slacks, s^{b-} is the undesirable output slacks. λ is a non-
 143 negative multiplicative vector of production possibility sets. Equation (1) defines the

144 non-radial, non-directional measure of the SBM model. When, this implies that all slack
 145 variables are zero and the DMU is undesirable for the output case. Because the objective
 146 function is not linear, the available Charnes-Cooper transformation method will
 147 optimize the problem to a linear model (Tone, 2001) [45].

$$\begin{aligned}
 & \rho = \min \left(t - \frac{1}{M} \sum_{i=1}^m \frac{S_i^-}{x_{i0}} \right) \\
 & \left\{ \begin{aligned}
 & 1 = t + \frac{1}{q_1 + q_2} \left(\sum_{r=1}^{q_1} \frac{S_r^+}{y_{r0}} + \sum_{j=1}^{q_2} \frac{S_j^{b-}}{b_{j0}} \right) \\
 & tx_0 = X\lambda - S^- \\
 & ty_o = Y\lambda - S^+ \\
 & tb_o = B\lambda + S^{b-} \\
 & \lambda \geq 0, S^- \geq 0, S^+ \geq 0, S^{b-} \geq 0
 \end{aligned} \right. \quad (2)
 \end{aligned}$$

149 Using the linear solution model (2), the optimal solution can be obtained. It directly
 150 considers the deficiencies of inputs and outputs in the efficiency measure and has the
 151 advantage of capturing the entire inefficient aspect, which is suitable for analyzing the
 152 efficiency considering non-ideal outputs.

153 3.2 Inputs and outputs selection for rescue performance evaluation

154 As needed, a list of performance indicators suitable for measuring the performance
 155 of geo-hazard relief operations is proposed, either individually or as part of a multi-
 156 objective model. These indicators are represented through a framework based on the
 157 simplest possible action: input, output, and efficiency indicators. Among them,
 158 efficiency indicators refer to the ability to produce the maximum output with the
 159 minimum input. Three inputs and two outputs are assumed for a geological disaster
 160 relief operation:

$$161 \quad \text{efficiency} = \frac{u_1 \cdot \text{input}_1 + u_2 \cdot \text{input}_2 + u_3 \cdot \text{input}_3}{v_1 \cdot \text{output}_1 + v_2 \cdot \text{output}_2}$$

162 The inputs and outputs of geological disaster rescue operation performance are
 163 sought in Figure 1: the three input factors are rescue teams, rescue time and rescue
 164 heavy machinery; the two output outcomes are the number of people affected by the
 165 disaster, the total number of people searched and rescued. This model demonstrates the
 166 main features of the DEA rescue operation evaluation domain, from which more
 167 comprehensive models can be designed.

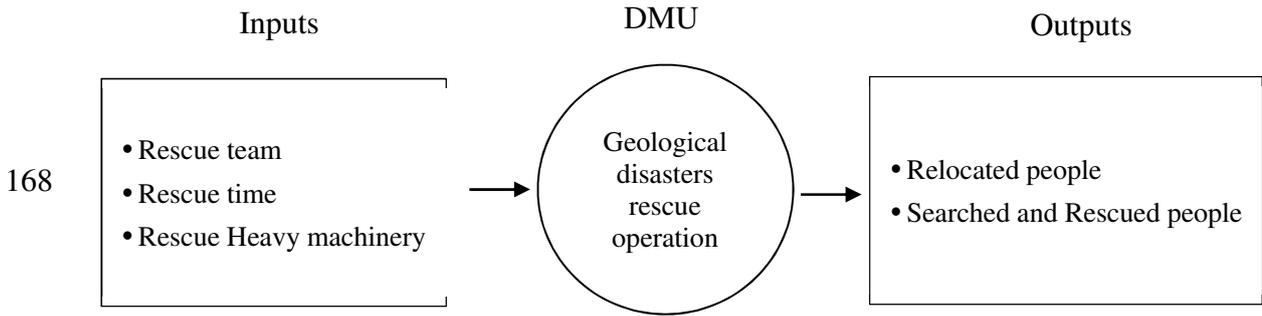


Fig1 Inputs and Outputs of a Geological disasters rescue operation

169 Efficiency is defined as the ratio of output to total input. The concept of effective
 170 boundary provides a formal representation of efficiency. Compared with other low-
 171 efficiency DMUs, a set of optimal decision-making units (DMUs) are more effective.
 172 DMU can represent different geological disaster rescue operations. The efficiency
 173 metric can measure the efficiency of the DMU's rescue output given its input (rescue
 174 resources).

175 **3.3 Data collection**

176 Top 18 worst geological disasters during 2015-2019 in China were selected. Data for
 177 each rescue operation is obtained from ministry of emergency management of PRC,
 178 <https://www.mem.gov.cn/>. Table 1 shows a description of the collected data is shown
 179 in Table 1.

180 Table 1

181 Descriptive statistics for the collected data.

	Mean	Standard deviation	Minimum	Maximum
Rescue team(person)	5586	912.40	333	39729
Rescue time(day)	5.83	4	2	18
Rescue Heavy machinery(suit)	150.83	158.93	14	693
Relocated people(person)	6211.94	11892.41	90	47200
Searched and Rescued people(person)	28.44	26.24	0	103

182

183 **4. Empirical Results and Discussion**

184 **4.1 analysis of the rescue operation performance and performance fluctuations**

185 The model was run through DEA-Solver software and by calculation, the
 186 performance of only 6 out of 18 Geo-hazard rescue operations was effective, where the
 187 maximum efficiency score was 1.302 and the minimum 0.413, with a mean value of

188 0.671. This means that an average unit of input can be reduced by 33%. Table 2
 189 summarizes the descriptive statistics of the results.

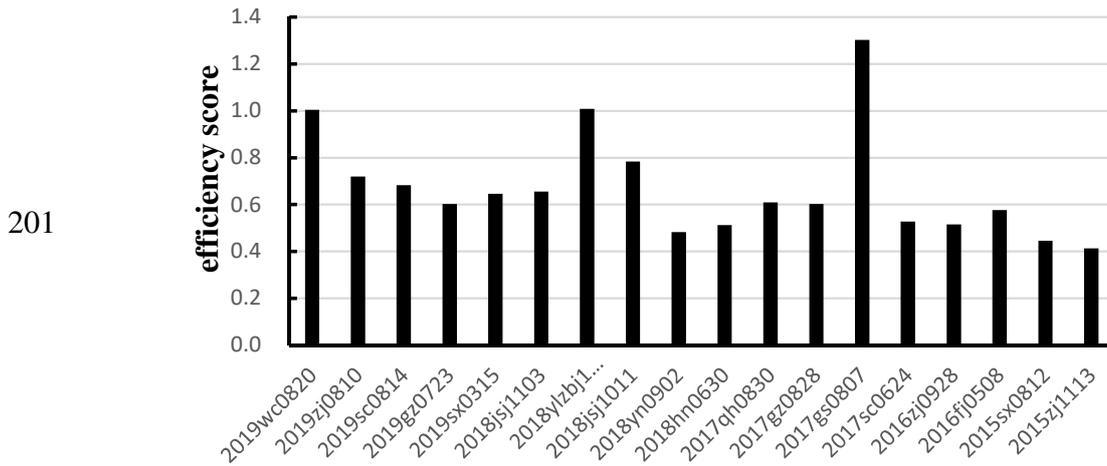
190 Table 2
 191 Descriptive statistics for DEA results.

Total number of DMUs	18
Number of efficient DMUs	6
Number of inefficient DMUs	12
Scores average	0.671
Scores standard deviation	0.228
Maximum score	1.302
Minimum score	0.413

192
 193 The calculated results show the performance of each rescue operation. Compared
 194 with other rescue operations, the efficiency scores of three rescue operations,
 195 2019wc0820, 2018ylzjb1017, 2017gs0807, were greater than 1.0 ranked at the
 196 efficiency frontier and can be described as excellent efficiency performance. Table 3
 197 shows the efficiency scores and rankings of the 18 rescue operations.

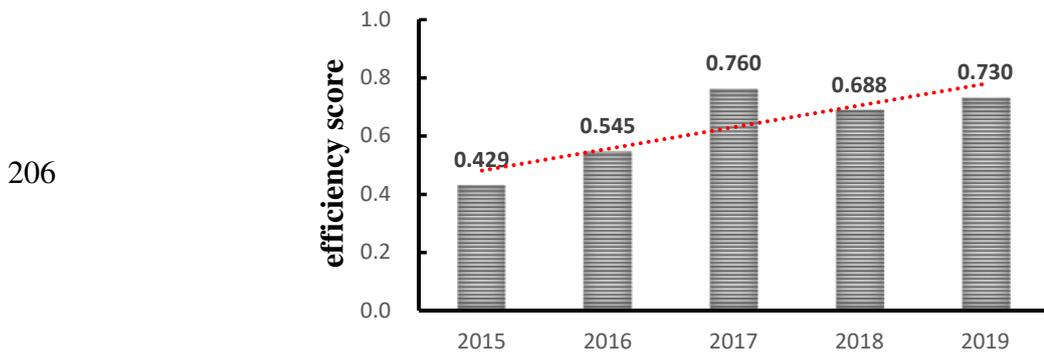
198
 199 Table 3
 200 Efficiency scores and ranks of geological disaster rescue operations.

No.	Year	Location	DMU	Geological disaster	Score	Rank
1	2019	Sichuan	2019wc0820	Debris flow	1.003	3
2	2019	Zhejiang	2019zj0810	Barrier lake	0.719	5
3	2019	Sichuan	2019sc0814	Debris flow	0.682	6
4	2019	Guizhou	2019gz0723	Landslide	0.602	11
5	2019	Shanxi	2019sx0315	Landslide	0.646	8
6	2018	Sichuan	2018jsj1103	Landslide	0.655	7
7	2018	Tibet	2018ylzjb1017	Barrier lake	1.008	2
8	2018	Sichuan	2018jsj1011	Barrier lake	0.783	4
9	2018	Yunnan	2018yn0902	Debris flow	0.482	16
10	2018	Hunan	2018hn0630	Landslide	0.512	15
11	2017	Qinghai	2017qh0830	Landslide	0.608	9
12	2017	Guizhou	2017gz0828	Landslide	0.602	10
13	2017	Gansu	2017gs0807	Debris flow	1.302	1
14	2017	Sichuan	2017sc0624	Landslide	0.527	13
15	2016	Zhenjiang	2016zj0928	Landslide	0.514	14
16	2016	Fujian	2016fj0508	Debris flow	0.575	12
17	2015	Shanxi	2015sx0812	Landslide	0.446	17
18	2015	Zhejiang	2015zj1113	Landslide	0.413	18



202 Figure2 efficiency scores of 18 rescue operations

203 Figure 2 shows there are 12 rescue operations had lower efficiency scores than the
 204 scores average. 67% of the rescue operations under the average, China's geological
 205 disasters rescue system is still at the primary stage, the overall level is not high.



207 Figure 3 the trend of the geological disaster rescue operation performance 2015-
 208 2019 in China

209 However, figure 3 shows the efficiency score averages from 2015 to 2019 is
 210 continuous improvement. The overall trends in geological disaster rescue performance
 211 is getting better and better. Which indicates that China has paid more and more attention
 212 to the geological disaster management in recent years. Especially, since the
 213 establishment of the Ministry of Emergency Management (MEM) in China, the ability
 214 to prevent and resolve major risks and the ability to engage in disaster and disaster relief
 215 has been greatly improved since 2019. MEM is very helpful to improve emergency
 216 resources and optimize rescue productivity.

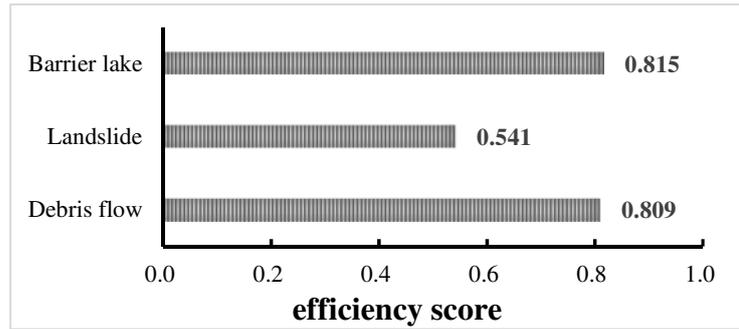


Figure4 the rescue operation efficiency of different geological disasters

Figure4 shows the three rescue operation performance of different types of geological disasters. Barrier lake's rescue operation efficiency average score 0.815 is the largest among the three kinds of geological disasters. Debris flow and Landslide rescue operation efficiency ranked second and third, with their scores of 0.809 and 0.541, respectively. Landslide search and rescue is the most difficult rescue mission among the three kinds of geological disasters. Landslides are usually classified by type of movement such as sliding, flow, spreading, tipping or falling, and by type of rock, debris or earth material. They usually involve a complex sequence of events - including rotational, translational and flow mechanisms - and are also referred to as debris-avalanche flows. Sometimes there are more than one type of movement, and the temporal and spatial relationships of the movements can be complex.

Besides, second landslide often caused huge rocks to fall onto the scene, which made it more difficult for heavy machinery to get to the rescue site. so, landslide rescue operation is more dangerous and complex than other geological disaster rescue, which decreases the rescue operation efficiency. In the future, China should put priority on improving its landslide search and rescue capacity.

4.2 Factors influencing geological disaster rescue operation performance

The variables s_j^- and s_k^+ are called slacks, because they indicate lack of performance. For example, although DMUA completely controls a point with $(x_1', x_2', x_3', y_1', y_2')$ as the coordinate, this can be interpreted by $(s_1^-, s_2^-, s_3^-, s_1^+, s_2^+)$, compared with the

241 performance of DMUA, the performance at this point is insufficient. Based on the
 242 efficiency score and the best value, we can calculate slack values, which indicate the
 243 direction of improvement. If we know the functional form of the relationship between
 244 various performance indicators, we can use optimization techniques to estimate the
 245 effective frontier.

246 Table 4 Summary of input and output slacks

DMU	Score	Inputs						Outputs		
		S_1^-		S_2^-		S_3^-		S_1^+	S^{b-}	
2019wc0820	1.003	0.077	0.96%	0.000	0.00%	0.000	0.00%	0.000	0.00%	0
2019zj0810	0.719	0.348	-4.27%	0.602	-43.45%	0.000	0.00%	1.506	16.94%	0
2019sc0814	0.682	0.000	0.00%	2.080	-71.95%	0.608	-10.67%	0.630	6.22%	0
2019gz0723	0.602	0.000	0.00%	0.704	-50.76%	0.419	-8.90%	2.254	33.14%	0
2019sx0315	0.646	0.326	-5.10%	1.183	-66.00%	0.000	0.00%	1.244	18.19%	0
2018jsj1103	0.655	1.957	-21.25%	1.575	-68.39%	0.000	0.00%	0.633	7.02%	0
2018ylzbj1017	1.008	0.000	0.00%	0.000	0.00%	0.087	2.40%	0.000	0.00%	0
2018jsj1011	0.783	2.357	-28.45%	0.098	-14.21%	0.000	0.00%	0.692	9.61%	0
2018yn0902	0.482	0.219	-2.07%	0.346	-24.93%	0.000	0.00%	6.495	88.81%	0
2018hn0630	0.512	0.000	0.00%	0.516	-46.95%	0.121	-3.20%	2.979	62.68%	0
2017qh0830	0.608	3.017	-47.17%	0.354	-51.07%	0.507	-19.23%	0.000	0.00%	0
2017gz0828	0.602	1.496	-19.69%	1.467	-70.54%	0.000	0.00%	1.125	16.06%	0
2017gs0807	1.302	2.747	39.77%	0.115	16.56%	0.000	0.00%	0.807	-8.77%	0
2017sc0624	0.527	0.000	0.00%	0.381	-34.68%	0.763	-14.46%	3.518	58.59%	0
2016zj0928	0.514	0.950	-10.35%	1.120	-57.54%	0.000	0.00%	3.676	50.45%	0
2016fj0508	0.575	0.382	-4.16%	0.725	-45.03%	0.000	0.00%	3.659	45.29%	0
2015sx0812	0.446	0.736	-10.38%	1.665	-72.31%	0.000	0.00%	3.256	62.56%	0
2015zj1113	0.413	0.000	0.00%	1.250	-60.10%	0.032	-0.61%	5.305	93.01%	0

247 Table 4 show the input and output slacks of geological disaster rescue operations.
 248 The DEA analysis of relative efficiency provides useful information on the strengths
 249 and weaknesses of each DMU and contributes to the improvement of the efficiency
 250 level of the "best" DMUS. The main reasons which caused the inefficiency of the rescue
 251 operations include overreaction and shortage of in professional rescue facilities.
 252 China's political system and its pattern of crisis management are different from western
 253 countries. China's government has strong capacity of mass mobilization in short time
 254 when crisis outbreaks. However, one of the most common things we've noticed is the
 255 government always overreacting to the disasters. From the table 4, we can see the

256 inefficient rescue operations have the problem of resource redundancy. About 20%-30%
257 rescue team and 30% rescue time can be reduced. Besides, about 15% rescue heavy
258 machinery can be reduced. In geological disaster rescue operation, most rescue sites are
259 limited and confined, though many heavy rescue machinery are deployed, only several
260 can work at the same time.

261 **4.3 Policy implications aiming at improving geo-disaster rescue performance**

262 For the purpose of improvement of Geological disaster rescue efficiency in China,
263 the following suggestions can be provided:

264 (1) Search and rescue techniques and standards on geological disasters should be
265 developed to support the emergency rescue operations. China can dispatch sufficient
266 rescue teams to the impact areas after geological disasters happened. However, the
267 rescue techniques of the rescuers in geological disasters are still inadequate. China has
268 established special standards and methodology for earthquake rescue operations which
269 making humanitarian coordination and response more effective, timely, and coherent.
270 There are no standards in geological disaster search and rescue in China. Experts should
271 be bring together to share knowledge and develop standards to strength the
272 effectiveness and Coordination of rescue operation in geological disasters. As the
273 government authority, the Ministry of Emergency Management should establish
274 minimum standards and procedures for special rescue teams, as well as training,
275 preparation, classification and operational specifications for emergency rescue, and
276 provide guidance on geological disaster search and rescue methods.

277 (2) Multifunctional integrated rescue machinery should be designed for geological
278 disaster search and rescue. Construction machinery such as excavator and dump truck,
279 have become one of the most important rescue equipment for debris removing and road
280 rehabilitation in geological disaster search and rescue. Generally, several kinds of
281 construction machinery should work together in the disaster field. But most workspaces
282 are confined and limited. Only one construction machinery operate onsite while others
283 waiting outside. The working efficiency of construction machinery are very low. So,
284 it's necessary to design minimal and multifunctional integrated rescue machinery for

285 geological disaster search and rescue. Quick grab-pass and Multi-purpose wheeled
286 vehicle will significant increase search and rescue efficiency.

287 (3) In China, there should be greater coordination between the various individual,
288 state, county, provincial and national agencies involved in geological disaster relief
289 operations.

290 In the giant debris flow disaster which caused more than 1700 casualties in Zhouqu
291 county, Gansu province at 2010, there are more than 9 relief headquarters in the disaster
292 field. The staffs of the headquarters comes from different departments including central
293 government, local government, military, police, enterprises. Different agencies initiated
294 different emergency response level from their own views, which led to disorder and
295 confusion in the early response. After a disaster, a rapid, coordinated and effective
296 response not only minimizes the loss of life and property, but also promotes early
297 recovery. Agencies and functions must have a clear understanding of their respective
298 roles, responsibilities, and specific actions that must be taken. Coordination and
299 synergy between agencies at all levels is enhanced through standard operating
300 procedure setting, information system sharing, and coordination mechanism
301 establishment.

302 **5.Conclusions**

303 In this study, SBM-DEA is used as a possibility to evaluate geohazard methods from
304 the perspective of rescue operation efficiency. The advantages and disadvantages of the
305 geohazard rescue operation efficiency perspective are analyzed, and possible directions
306 for improvement are proposed. SBM-DEA analysis scores of geological disaster rescue
307 operation performance on a scale of 0-1.4. The analysis identifies rescue operations
308 2019wc0820, 2018ylzbj1017, and 2017gs0807 as efficient frontier units. Compared to
309 the rest of the rescue operations, these three rescue operations are relative efficient,
310 which serve as the benchmark for the disaster emergency response. These three efficient
311 rescue operations can be utilized as role models, from which lessons and experiences
312 can be learned in order to improve the future geological disaster rescue operation

313 efficiency.

314 After identifying several factors that drive the performance of disaster relief
315 operations for disaster management studies, the SBM-DEA model was used to analyze
316 and derive relevant and valid information. Due to the data collection date, only three
317 input variables and two output variables were considered as a case study, and the range
318 of optional variables could be further increased to be more extensive in further studies.
319 An attempt was made to correlate the variability of rescue operation performance with
320 certain explanatory variables to verify the consistency of the study findings.

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323 **Ethical Statement:** I certify that this manuscript is original and has not been
324 published and will not be submitted elsewhere for publication while being considered.
325 And the study is not split up into several parts to increase the quantity of submissions
326 and submitted to various journals or to one journal over time. No data have been
327 fabricated or manipulated (including images) to support your conclusions. No data, text,
328 or theories by others are presented as if they were our own.

329 The submission has been received explicitly from all co-authors. And authors whose
330 names appear on the submission have contributed sufficiently to the scientific work and
331 therefore share collective responsibility and accountability for the results.

332 **Conflict of Interest:** The authors declare that they have no conflict of interest. This
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336 **Reference**

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