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SELECTION OF SAFETY OFFICERS IN AN INDIAN CONSTRUCTION ORGANIZATION BY USING GREY RELATIONAL ANALYSIS

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ABSTRACT

Stakeholders are responsible for implementing the occupational health and safety provisions in an organization. Irrespective of organization, the role of safety department is purely advisory as it coordinates with all the departments, and this is crucial to improve the performance. Selection of safety officer is vital job for any organization; it should not only be based on qualifications of the applicant, the incumbent should also have sufficient exposure in implementing proactive measures. The process of selection is complex and choosing the right safety professional is a vital decision. The safety performance of an organization relies on the systems being implemented by the safety officer. Application of multi criteria decision-making tools is helpful as a selection process. The present study proposes the grey relational analysis(GRA) for selection of the safety officers in an Indian construction organization. This selection method considers fourteen criteria appropriate to the organization and has ranked the results. The data was also analyzed by using technique for order Preference by Similarity to an Ideal solution (TOPSIS) and results of both the methods are strongly correlated.

Keywords: Safety officer, Occupational health, GRA, Selection criteria,TOPSIS

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1. INTRODUCTION

The role of safety officers is imperative for any type of organizations to avoid accidents. The objectives of safety policy and management's commitment towards occupational health and safety issues can be implemented effectively only by the efforts of the safety officers. Majority of the construction organizations in India are forced to employ safety officers based on their previous experience without considering qualifications.

The important safety activities such as hazard identification and risk assessment, imparting trainings , implementing engineering controls, conducting investigations, developing safety culture and standard operating procedures is a daunting task due to lack of qualified safety officers. Majority of the Indian construction organizations are relying on external agencies to impart safety trainings to employees due to inadequate competency levels of safety officers, employed with them.

This is persisting even in higher cadres of safety department in Indian construction industry. The results of the study conducted in Sri Lanka emphasized the need for appointment of full time safety officers to improve safety performance (KANCHANA, et al., 2014). Lack of expertise and knowledge on part of the safety officers in implementing hierarchy of accident prevention controls is a major concern to the construction organizations.

A study conducted in India suggest that perception of safety officers from construction steel and refractory industries has positive influence on factors such as injury avoidance, work practices, standardisation, healthcare and risk management (BERIHA, et al., 2011). The role of safety officer is significant in improving safety performance and the selection of safety officer is an important decision for any organization.

Some organizations adopt expensive and time-consuming processes for selecting the suitable personnel, while others complete the recruitment process faster with less expense using traditional methods of selection based on criteria like expertise and qualifications. The traditional methods yeild results based on subjective judgment of decision makers, which makes the accuracy of the results questionable.

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In order to select the most suitable personnel, combining the 'Subjective Judgment' and 'The Objective Analysis' approaches is the need of the hour in the current business environment (PRAMANIK; MUKHOPADHYAYA, 2011). It is observed from the literature that various methods are proposed for personnel selection, to assist the organizations in this key decision making process. Most of these methods are multi criterion decision making methods (MCDM).

Liang and Wang presented a fuzzy MCDM algorithm for personnel selection (LIANG; WANG, 1994). Gibney and Shang have advised the use of the analytical hierarchy process (AHP) in the personnel selection process (GIBNEY; SHANG, 2007). Dağdeviren proposed a hybrid model, which employs analytical network process (ANP) and modified technique for order preference by similarity to ideal solution (TOPSIS) for supporting the personnel selection process in the manufacturing systems (DAGDEVIREN,2010).

Robertson and Smith presented reviews on personnel selection studies and investigated the role of job analysis and other contemporary models of work performance, and set of criteria used in personnel selection process (ROBERTSON; SMITH, 2001).

Managers in an organization make decisions in a static and stochastic environment. Right decisions are possible in a stochastic environment, which is closer to the reality and can be solved by applying grey relational analysis (GRA) (MARKABI; SABBAGH, 2014).

The solution of the problems with qualitative and quantitative data under complex criteria, uncertainty and insufficient data or information in decision making process is solved by using GRA (IRFAN, et al., 2016). GRA is one of the popular methods to analyze various relationships among the discrete data sets and make decisions in multi attribute situations and also useful to making decisions in complex business environment (SUNITHA; RUBEN, 2017).

The comparative analysis of different methods of personnel selection may help in finding out their accuracy, appropriateness, suitability, fairness and practical efficiency (ROUYENDEGH; ERKAN, 2012). In the present study, GRA was adopted to select safety professionals in Indian construction organizations and the results of the selection process were compared by using TOPSIS.

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2. CONSTRUCTION SAFETY OFFICER

The building and other construction workers act 1996 is the comprehensive legislation to regulate the employment and conditions of service of building and construction workers and to provide them safety, health and welfare measures. It is clearly mentioned in the building and other construction workers act, 1996 that every construction organization wherein five hundred or more building workers are ordinarily employed shall appoint safety officers (GOI, 1996). The act also specifies that the number of safety officers required is based on the strength of workers, qualifications of safety officers and; roles & responsibilities.

The responsibilities of a construction safety officer as per the act are to conduct safety inspections, investigate all fatal and other selected accidents; maintenance of records with regard to accidents and occupational diseases; advise purchase department and ensure quality personal protective equipment confirming to Indian standards; promoting the functioning of safety committees; implementing motivational schemes; design and conducting safety training and educational programmes; framing safety rules and advise the supervisors in implementing safe operating procedures. Safety officers shall not be permitted to perform any work which is not relevant or detrimental to the performance of the roles and responsibilities.

3. METHODOLOGY

3.1. Grey relational analysis and applications

The information that is either incomplete or undetermined is called Grey. The Grey system provides multidisciplinary approaches for analysis and abstract modelling of systems for which the information is limited, incomplete and characterized by random uncertainty (SIFEN; FORREST, 2007). GRA has been extensively adopted by researches in various selection processes. The application of GRA in various field are presented in Table 1.

Table 1: Applications of GRA

Area of application	Reference
Vendor evaluation	TSAI, et al., 2003
Supplier selection	YANG; CHEN, 2006
Material selection	CHAN; TONG, 2007
Performance of power plants	XU,et al., 2011

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Supplier selection	RAJESH; RAVI,2015]
Green supplier selection	HASHEMI,et al., 2015
Personnel selection	NILSEN,2016
Facilility layout	KUO, et al.,2008
Site selection	BIRGUN; GUNGOR,2014

3.2. Step by step procedure

Step 1: Collection of data and forming decision matrix

The decision matrix D_a is formed with m alternatives and n criteria is shown in Equation (1).

$$D_a = \begin{bmatrix} p_1(1), p_1(2),.....p_1(n) \\ p_2(1), p_2(2),....p_2(n) \\ .... \\ .... \\ p_m(1), p_m(2),....p_m(n) \end{bmatrix} \quad (1)$$

Where, p_a (k) is the value of a^{th} alternative with respect to b^{th} criterion.

Step 2: Normalization of the decision matrix

The standardized formula is suitable for the benefit or maximization is shown in Equation (2).

$$p_a^*=[p_a(b)–\min p_a(b)] / [\max p_a(b)–\min p_a (b)] \quad (2)$$

The normalized formula for minimization criteria is shown in Equation 3.

$$p_a^*=[\max p_a(b)–p_a(b)] /[\max p_a (b) – \min p_a (b)] \quad (3)$$

The medium – type, or nominal-the-best (the nearer to a certain standard value the better), if the target value is p_{oc} (b) and max p_a (b) and max pa (b) ≥ poc (b) ≥ min p_a (b), normalization formula is shown as equation (4).

$$p_a^*=[| p_a(b)-p_{oc}(b)|] / [\max p_a (b) - p_{oc} (b)] \quad (4)$$

Step 3: Developing reference series

The reference value the b^{th} criterion p_o^* (b) is determined by considering the maximum normalized value of each criterion by using the Equation (5).

$$p_o^*(b)=\max\{p_a(b)\} \quad (5)$$

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Step 4: Developing the difference matrix

The absolute difference of the compared series and the referential series should be obtained by using the following Equation (6).

$\Delta_{oa}(b) = | p_o^*(b) - p_a^*(b) |$ and the maximum and the minimum difference should be found. (6)

Step 5 : Calculation of grey relation coefficient

$$\gamma_{oa}(b)=[(\Delta_{min}+ \zeta\, \Delta_{max})/(\Delta_{oa}(b)+ \zeta\, \Delta_{max})] \quad (7)$$

ζ is distinguishing coefficient and usually the value is considered by the decision makers as 0.5 as this value offers stability and distinguishing effects (ÖZCELIK; ÖZTURK,2014).

Step 6: Calculation of degree of grey coefficient (r_{oa})

If the criteria weights are equal, then degree of grey coefficient is calculated by using Equation (8).

$$r_{oa} = (1/n) \sum_{b=1}^{n} \gamma_{oa}(b) \quad (8)$$

If the weights of the criteria are different then grey coefficient is calculated by using Equation (9).

$$r_{oa} = \sum_{b=1}^{n} \gamma_{oa}(b)\, w(b) \quad (9)$$

w(b)is the weight of the j^{th} criteria and sum of w(b) is one.

Step 7: Final selection and ranking

The selection and ranking of alternatives is according to the degree of grey coefficient and the alternative with highest grey coefficient will be the best alternative.

3.3. Technique for order preference by similarity to an ideal solution (TOPSIS)

TOPSIS is a multi criteria decision making tool. The principle of TOPSIS aims at devising an alternate solution, which should be nearest to the positive ideal solution and far away from the negative ideal solution. The ideal solution is formed

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as a composite of the best performance values in the decision matrix by any alternative for each attribute. The negative ideal solution is the composite of the worst performance values. The positive ideal solution is a solution that maximizes the benefit criteria and minimizes cost criteria and vice versa in case of the negative ideal solution. TOPSIS was adopted to ascertain the ranking of sectors based on safety performance. TOPSIS has been applied in various areas of research, and few applications are presented in Table 2.

Table 2: Application of TOPSIS

Area of Application	Authors
To provide decision methods for project managers in construction organizations, which can be applied in other organizations also in project selection issues.	PRAPAWAN, 2015
To measure and compare the financial performance of firms trading in stock exchange.	BERNA,2012
To compare multi criteria decision making tools to rank banks in Serbia.	DRAGSIA,et al.,2013
To evaluate and select best location for implementing the urban distribution centre.	ANJALI, et al.,2011
To identify the factors influencing successful implementation of safety management system.	HADI, et al.,2011
To improve the process of supply chain management in a manufacturing company.	ROGHANIAN, et al.,2014
To propose a method for supply chain risk evaluation.	SUN, et al., 2015
To propose a method to assist contractors to make a better decision on project selection.	YONG – TAO et al.,2010
To identify best alternative basing on noise emitted from electrical machines.	PIJUSH, et al., 2012
To explore new directions in telecom service quality in India.	AMIT; INDU,2013
To search for optimal tenderer in E –tendering.	WANG, et al., 2015

3.3.1. TOPSIS procedure

The sequence of steps involved in TOPSIS procedure is detailed below:

Step 1: Arrange the attributes influencing safety performance.

Step 2: Construction of the decision matrix.

Step 3: Standardized evaluation matrix

Step 4: Construct weighted normalized decision matrix

Step 5: Construct weighted normalized matrix

Step 6: Calculation of separation of each alternative from the positive and negative ideal solutions

Step 7: The relative closeness index

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Step 8: Allocation of rankings

4. SELECTION OF SAFETY OFFICER – A CASE STUDY

A major construction organization in India was planning to recruit a safety officer with five years of experience in handling safety aspects in metro rail construction. The client was particular about qualifications of safety officer as per the BOCW Act, 1996 and communicated the fourteen criteria relating to the occupational heath and safety to be fulfilled by the safety officers. The requirements of client in selection of safety officer are presented in Table 3.

Table 3: Criteria for selection of safety officer

R_1 Command over language	R_8 Planning and organizing resources
R_2 Exposure in risk assessment	R_9 Capable to work independently
R_3 Developing safe working procedures	R_{10} Steps to improve safety performance
R_4 Competency in imparting trainings	R_{11} Knowledge in OHS
R_5 Conducting mock drills	R_{12} Safety performance appraisal
R_6 Conducting accident investigations	R_{13} Initiatives to improve safety culture
R_7 Team work	R_{14} Knowledge in applicable legislations

Accordingly the organization released an advertisement in news papers and in response to the advertisement, 32 applications were received. On scrutiny of applications and after examining the relevant experience, age, qualifications; 9 applications were finalized. The 9 candidates were called for an interview to gauge the fulfillment of criteria. The panel comprising of three members; safety manager from client, safety head of contractor and an independent safety consultant; and the panel members were requested to rate each criteria on 1 to 5 scale with 1 corresponds to very low and 5 as very high.

5. RESULTS

5.1. Results of GRA

The common rating of the panel members after discussions, the final ratings were presented in the form of decision matrix and are presented in Table 4.

Table 4: Decision matrix

	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}	R_{11}	R_{12}	R_{13}	R_{14}
S1	3	5	3	3	4	3	4	2	3	4	4	3	4	3
S2	4	4	2	4	3	3	3	4	3	5	3	4	3	3
S3	3	4	4	3	4	4	4	2	3	4	4	5	3	3
S4	2	5	3	3	3	4	3	3	4	4	3	4	3	3
S5	3	4	2	3	2	3	4	3	4	4	3	4	5	4
S6	4	3	3	3	3	3	3	5	2	3	3	4	4	3
S7	3	2	3	4	5	2	3	3	3	4	4	3	4	3
S8	2	4	3	3	5	4	3	3	3	4	4	3	4	2
S9	4	4	2	3	3	5	4	4	3	3	4	2	3	4

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Ref	1	1	1	1	1	1	1	1	1	1	1	1	1	1

The normalized decision matrix was obtained by using the Equation (2) and presented in Table 5.

Table 5: Normalized decision matrix

	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}	R_{11}	R_{12}	R_{13}	R_{14}
S1	0.5	1.00	0.5	0	0.67	0.33	1.0	0	0.5	0.5	1.0	0.33	0.5	0.5
S2	1.0	0.67	0	1.0	0.33	0.33	0	0.67	0.5	1.0	0	0.67	0	0.5
S3	0.5	0.67	1.0	0	0.67	0.67	1.0	0	0.5	0.5	1.0	1.00	0	0.5
S4	0	1.00	0.5	0	0.33	0.67	0	0.33	1.0	0.5	0	0.67	0	0.5
S5	0.5	0.67	0	0	0.00	0.33	1.0	0.33	1.0	0.5	0	0.67	1.0	1.0
S6	1.0	0.33	0.5	0	0.33	0.33	0	1.0	0	0	0	0.67	0.5	0.5
S7	0.5	0.00	0.5	1.0	1.00	0.00	0	0.33	0.5	0.5	1.0	0.33	0.5	0.5
S8	0	0.67	0.5	0	1.00	0.67	0	0.33	0.5	0.5	1.0	0.33	0.5	0
S9	1.0	0.67	0	0	0.33	1.00	1.0	0.67	0.5	0	1.0	0	0	1.0
Ref	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

The difference matrix is framed by using Equation (6) and presented in Table 6.

Table 6: Difference matrix

	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}	R_{11}	R_{12}	R_{13}	R_{14}
S1	0.5	0	0.5	1.0	0.33	0.67	0	1	0.5	0.5	0	0.67	0.5	0.5
S2	0	0.33	1.0	0	0.67	0.67	1.0	0.33	0.5	0	1.0	0.33	1.0	0.5
S3	0.5	0.33	0	1	0.33	0.33	0	1.0	0.5	0.5	0	0	1.0	0.5
S4	1.0	0	0.5	1	0.67	0.33	1.0	0.67	0	0.5	1.0	0.33	1.0	0.5
S5	0.5	0.33	1.0	1	1.0	0.67	0	0.67	0	0.5	1.0	0.33	0	0
S6	0	0.67	0.5	1	0.67	0.67	1.0	0	1.0	1.0	1.0	0.33	0.5	0.5
S7	0.5	1.0	0.5	0	0	1.0	1.0	0.67	0.5	0.5	0	0.67	0.5	0.5
S8	1.0	0.33	0.5	1.0	0	0.33	1.0	0.67	0.5	0.5	0	0.67	0.5	1.0
S9	0	0.33	1.0	1.0	0.67	0	0	0.33	0.5	1.0	0	1.0	1.0	0
Ref	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

The grey relation coefficients are calculated by using Equation (7) and presented in Table 7.

Table 7: Grey relational coefficients

	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}	R_{11}	R_{12}	R_{13}	R_{14}
S1	0.5	1.0	0.5	0.33	0.60	0.43	1.0	0.33	0.5	0.5	1.0	0.43	0.5	0.5
S2	1	0.60	0.33	1.0	0.43	0.43	0.33	0.60	0.5	1.0	0.33	0.60	0.33	0.5
S3	0.5	0.60	1	0.33	0.60	0.60	1.0	0.33	0.5	0.5	1.0	1.0	0.33	0.5
S4	0.33	1.0	0.5	0.33	0.43	0.60	0.33	0.43	1.0	0.5	0.33	0.60	0.33	0.5
S5	0.5	0.60	0.33	0.33	0.33	0.43	1.0	0.43	1.0	0.5	0.33	0.60	1.0	1.0
S6	1.0	0.43	0.5	0.33	0.43	0.43	0.33	1.0	0.33	0.33	0.33	0.60	0.5	0.5
S7	0.5	0.33	0.5	1.0	1	0.33	0.33	0.43	0.5	0.5	1.0	0.43	0.5	0.5
S8	0.33	0.60	0.5	0.33	1	0.60	0.33	0.43	0.5	0.5	1.0	0.43	0.5	0.33
S9	1	0.60	0.33	0.33	0.43	1.0	1.0	0.60	0.5	0.33	1.0	0.33	0.33	1.0

The grey relation grades are computed by using Equation (9), as the weights are different for criteria under consideration. The weights are calculated by adopting analytic hierarchy process. An expert team was constituted comprising of five safety professionals having more than 20 years of experience in the domain of construction

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safety and weights are calculated rounding off to two decimal points by using analytic hierarchy process. The values of grey relational grades are presented in Table 8.

Table 8: Grey relational grades

	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}	R_{11}	R_{12}	R_{13}	R_{14}
Wts	0.07	0.15	0.10	0.11	0.07	0.07	0.05	0.05	0.05	0.06	0.06	0.05	0.05	0.06
S1	0.04	0.15	0.05	0.04	0.04	0.03	0.05	0.02	0.03	0.03	0.06	0.02	0.03	0.03
S2	0.07	0.09	0.03	0.11	0.03	0.03	0.02	0.03	0.03	0.06	0.02	0.03	0.02	0.03
S3	0.04	0.09	0.1	0.04	0.04	0.04	0.05	0.02	0.03	0.03	0.06	0.05	0.02	0.03
S4	0.02	0.15	0.05	0.04	0.03	0.04	0.02	0.02	0.05	0.03	0.02	0.03	0.02	0.03
S5	0.04	0.09	0.03	0.04	0.02	0.03	0.05	0.02	0.05	0.03	0.02	0.03	0.05	0.06
S6	0.07	0.06	0.05	0.04	0.03	0.03	0.02	0.05	0.02	0.02	0.02	0.03	0.03	0.03
S7	0.04	0.05	0.05	0.11	0.07	0.02	0.02	0.02	0.03	0.03	0.06	0.02	0.03	0.03
S8	0.02	0.09	0.05	0.04	0.07	0.04	0.02	0.02	0.03	0.03	0.06	0.02	0.03	0.02
S9	0.07	0.09	0.03	0.04	0.03	0.07	0.05	0.03	0.03	0.02	0.06	0.02	0.02	0.06

Basing on the overall performance of safety officers on various criteria according to grey relation grades are presented in Table 9. The rankings were given basing on the total grey relation grades.

Table 9: Rankings of safety officers basing on overall grade of GRA

Safety officer	Total of grades	Rank
S1	0.62	2
S2	0.60	4
S3	0.64	1
S4	0.55	7
S5	0.56	6
S6	0.50	9
S7	0.58	5
S8	0.54	8
S9	0.62	2

5.2. Results of TOPSIS

The final ranking as per TOPSIS based on the relative closeness index is presented in Table 10.

Table 10: Rankings of safety officers basing on TOPSIS

Safety officer	Relative closeness coefficient	Rank
S1	0.4607	3
S2	0.1407	4
S3	0.8741	1
S4	0.0856	7
S5	0.1022	6
S6	0.0032	9
S7	0.1057	5
S8	0.0432	8
S9	0.5821	2

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The rank correlation between the two methods is calculated and found to be 0.92 and strong correlation exists between the ranks obtained in both the methods.

CONCLUSIONS

The role of safety officer is in any organization is critical otherwise it effects the safety performance drastically. Selection of safety officer is a crucial decision making process and it depends on the scope of the work. In Indian construction organizations, traditional methods are being followed for selection of safety officers. The process of selection is based on several criteria relating to safety and application of multi criteria decision making tools in selection is useful to the organizations.

Some firms use traditional methods based on their intuitions in recruitment process while the others prefer more scientific methods. In this paper, GRA method is proposed for selection of safety officers by considering fourteen criteria to overcome the drawbacks of the traditional methods, which are based on subjective judgment of decision makers. The criteria considered in the study are equally important to improve the safety performance of an organization.

In the present study two methods are used; GRA and TOPSIS. Initially the data was analyzed by using GRA, which is simple method to apply and easy to understand. TOPSIS method was applied to compare the rankings obtained by using the GRA method and found that strong correlation exists between the two methods in final rankings. The rankings of eight safety officers who attended the selection process remain same except safety officer 1(S1). The best candidate for the safety officer position is S3, as ranking is same in both the methods. The accuracy of the rankings obtained is consistent and strong association is exists between the methods.

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