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Grey Relation Analysis Methodology and its Application

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ABSTRACT

Grey Relation analysis was developed by Deng and most widely used model of Grey system. Model is applied between known and unknown information, which is grey in nature. Condition with clearly defined information is named as white and no information as black, in between as Grey. The grey theory is applied in various filed including manufacturing, process and service operations. The theory is also applied in selection process which involves multiple selection attributes. The paper focuses on fundamentals of method, steps required to follow and various applications of method. This paper will be of assistance to the researchers and industries to understand basics of theory and to know its application in real life problems.

1. Iintroduction

In 1982 Deng established Grey System theory, which focused on decision making with partial information known and partial unknown. The information between known and unknown information is called as grey information. Grey System theory is applied for complex problem subjected to complex data. Grey relation analysis is quantitative and systematic approach, subsystem of grey system theory and most widely used in solving complex system (Xion et. al., 2012). GRA can be used in financial, logistic and also to optimize process.GRA method can effectively used for problems with multiple criteria's and their exists complicated relationship between criteria's (Geum et. al., 2011) . It can also be used effectively to determine optimum process parameter influencing two or more response variables (Patel et.al.,2014). Multi criteria problems can effectively handled using Grey Relation analysis (Patil et. al.,2017).

2. Grey Relation Analysis Steps

Steps in Grey Relation Analysis includes

- Defining problems and response variables or quality characteristics.
- Data collection.
- Normalizing data for smaller the better or larger the better quality characteristics.
- Find grey relation coefficient for normalized data.
- Calculate grey relation grade.
- Select optimum level based on grade value.

For larger the better quality characteristic, normalized value (X_i) is given by

$$X_i = \left(\frac{x_i - x_{min}}{x_{max} - x_{min}}\right)$$

For smaller the better quality characteristic, normalized value (X_i) is given by

$$X_i = \left(\frac{x_{max} - x_i}{x_{max} - x_{min}}\right)$$

Where$(x_i)_{max}$ and $(x_i)_{min}$ are the maximum and minimum values of the original sequence x_i.

Grey Coefficient, γ_i is given by

$$\gamma_i = \left\{\frac{(\delta_i)max + (\delta_i)min}{(\delta_i)max + (\delta_i)}\right\}$$

Where, Delta value, δi .is given by

$$\delta_i = (X_i)_{max} - X_i$$

3. Applications

Grey Relation analysis was successfully used to tag factors governing selection of web service. Analysis was applied on 365 web services considering nine factors. Study was carried out for ten minutes for three days. Study concluded influencing factors on web services selection as best practice, compliance, availability, success ability, reliability, latency, response time (Xion et.al., 2012).

Grey relation was used in conjunction with Taguchi's approach on wire cut EDM process. The listed process factors influencing EDM were current, pulse ON time and pulse OFF time. The two levels were decided and nine trials were conducted to verify surface roughness and kerf width. Both quality characteristics are of type smaller the better, analysis pointed out current and pulse off time required to maintain at low level whereas pulse on time at high level to optimize quality characteristic (Khan et. al., 2015).

Quality of air is essentially important for survival on earth. There are various factors responsible for pollution and other factor to maintain health ecosystem. The study was carried out in China to investigate factors influencing environmental conditions. Grey Relation application in research established industrial pollution and life energy consumption are influential on pollution, where as green project helps to improve quality of air (Pan, 2011).

Grey relation was applied to study feasibility of recycled polypropylene. The quality characteristics considered for study were tensile strength at break, percentage elongation at break, density and vicat softening point. Process factor influencing quality characteristics includes virgin to recycled ratio, injection temperature, pressure and speed. Confirmation results of research concluded low level of injection pressure, low level of injection temperature, high level of injection speed and 95:05 virgin to recycled material is best to qualify product (Battacharya and Bepari, 2014)

Water pressure, wire feed and wire tension at level 3, pulse off time at level 2 and pulse on time and servo voltage at level 1 is optimum combination for wire electrical discharge machining process on AISI304. To determine optimum levels Grey relation analysis was used along with Taguchi's L27 orthogonal array (Mathew and Babu, 2014).

Capital investment firm evaluation is essential to minimize risk associated and maximize returns. These two governing quality characteristics of firm depend upon management ability, operational ability, market ability, exits obtain and investment cost. Firm evaluation was done by five experts using grey relation analyses to get optimal firm (Zhang, 2012).

Feed rate, flow rate and concentration of electrolyte are important machining variable of electrochemical drilling process. Material removal rate, surface roughness, overcut, profile errors are desired performance characteristics of electrochemical drilling process. Grey Relation was used to find more influencing variable on performance characteristics and feed rate was found to have more influencing variable (Manikandan et.al., 2017)

Squeeze cast process study was carried out considering squeeze pressure, die temperature and pouring temperature as variable. Casting density and surface finish were considered as process quality characteristics. For, variable factors three levels were defined and experimental trials using L9 orthogonal array was conducted to find best setting of variable factors (Patel et.al., 2014)

Grey Relation analysis was used to know customer satisfaction level for car sale enterprise. Customer satisfaction controls sales and profit of organization. Score of customer satisfaction was calculated for year 2008, 2009 and 2009. Factors considered were after sales service, service charge, special maintenance, maintenance quality, spare part quality and customer care (Cenglin, 2012).

Taguchi's L27 orthogonal array was used to determine factors influencing hot machining process. Machining was done on stainless steel using carbide tool and variables identified were cutting speed, feed rate, depth of cut and work piece temperature. Using grey relation levels of factors were determined influencing material removal rate and surface roughness (Ganta and Chakrandhar, 2014).

Grey relation was integrated with fuzzy AHP to decide best car from shortlisted cars. Method was applied to quantitative criteria's which includes price, service station location, mileage, power , torque and displacement. Grey relation assisted ranking considering all quantitative criteria's (Patil et.al., 2017)

Grey Relation analysis can also be used in credit risk analysis. Four different companies were considered for study and with various decision making attributes credit risk associated, was determined (Wu, 2017)

Other application of grey relation analysis in multi criteria was to select safety officer in construction organization. Fourteen criteria's were considered and nine short listed candidates were interviewed. Interview analysis was carried out using Grey Relation analysis (Rajprasad, 2018)

Integrated Fuzzy Logic and grey relation analysis was demonstrated on optimization multi response electrical discharge machine process. Integrated approach was used to optimize surface roughness and material removal rate considering three process parameters namely voltage factor, peak current and duty factor (Winarni and Indratho, 2018)

Grey relation analysis with fuzzy synthetic discrimination was employed to study the oxidation resistance of eight varieties of peach fruit during early and late stages of fruit development (Zhang et.al., 2018)

Influencing factors on Quality of calcined petroleum coke were studied using grey relation analysis. Six influencing factors on real density and powder resistivity were studied (Huang et.al., 2018)

Integrated affective design and grey relation analysis was used to develop product design process. Optimal process strategy was selected using grey relation analysis. Higher quality with short lead time to sustain competition was main aim behind study (Liu and Tong, 2018)

Data envelopment analysis and grey relation analysis was integrated to determine efficiency of public hospitals. Thirty hospitals were selected for evaluation with number of examination in emergency service, bed occupancy rate and number of operation as output variable. Influencing input variables considered were number of beds, surgeons, practitioners and annual expenditure as input variable. Study concludes out of thirty hospitals, sixteen were found efficient (Uckun et. al., 2017)

Complex electricity power generation problem is selected to demonstrate effectiveness of grey relation approach. Considering social and environment criteria, power sources like coal, gas, nuclear, wind, hydro, oil, solar, biomass were ranked (Malekpoor et. al., 2018)

Taguchi technique coupled with grey relation was used to optimize resin finishing. Multiple response like crease recovery angle, tearing strength, whiteness index were considered. Parameter affecting response for study, included resin concentration, polythene softener, catalyst, curing temperature and curing time (Perez et. al., 2018)

4. Conclusion

Grey relation analysis has wide applications in analyzing complex problems. This paper lists down few applications of grey relation analysis. The application of grey relation analysis in paper includes web service selection, defining hospital efficiency, car sale, electric discharge process improvement, deciding recycle of material, capital investment, car selection, employee selection, deciding quality of fruit, petrol and also defining product design. From study it is clear that Grey relation can be applied to optimize any process or any service. The approach can also be effectively applied in selection process as well improving quality of process, product or service. Service or process optimization can even be done if there are more than one quality characteristics deciding process or service nature. Listed application also demonstrates method effectiveness for processes which are governed by two or more quality characteristics, with few smaller the better type and few larger the better type response.

Grey relation analysis approach is based on similar or dissimilar relation between various variables of process. The method also provides information for prediction and decision making. The method can also be applied in multi criteria decision making. It also assists in ranking alternative's in decision making. So, study concludes grey relation as one of good option for decision making in complex problems.

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