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DATA ENVELOPMENT AND RIDGE REGRESSION ANALYSIS OF PAIRED COMPARISON LOGLINEAR CANONICAL MODEL OF EVALUATING QUALITY CIRCLES.

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ABSTRACT

This paper discusses the mathematical programming approach to assess relative efficiencies within a group of Decision Making Units (DMUs) which are known as Data Envelopment Analysis (DEA) and Ridge Regression Analysis in evaluating Quality Circles (QCs)

Keywords: Data Envelopment Analysis (DEA), Ridge Regression and Quality Circles (QCs)

INTRODUCTION

This paper is concerned with the data envelopment analysis (DEA) and ridge regression analysis of paired comparison loglinear canonical model of evaluating quality circles (QCs). Further, by using this method the factors contributing to the success of QCs will be determined.

Many papers have been written on DEA (*see literature survey*). Mathiyalakan and Chung (1996) have established the viability of using DEA to analyse performance of QCs in an organisation. In another analysis, the best practice in corporate-stakeholder relations was developed by Bendheim *et al.* (1998) by using the DEA technique.

As far as DEA is concerned, there is a need to develop a model which can incorporate DEA and ridge regression of evaluating QCs. DEA developed by Charnes *et al.* (1978), provides a complex methodological advance over simpler methods of assessing performance, one that permits simultaneous multidimensional assessment. As such, it provides a significant advantage for researchers using single dimensional assessment techniques where the nature of activity and data is inherently multidimensional (Bendheim *et. al* 1998)

As noted by Roll *et al.* (1991), DEA has received considerable attention from QCs practitioners and researchers since the technique has been approached. It has been applied in organisations such as airforce maintenance units, higher learning institutes, hospitals, and profit and non-profit organisations. Ghani (1988) noted that "ridge regression is one of the possible methods used in estimating the parameters of the paired comparison loglinear model for experiments. The model that will be suggested is the combination of DEA and ridge regression analysis of paired comparison loglinear canonical.

LITERATURE SURVEY

As noted by Heizer and Render (1991), a great emphasis on quality improvement programme will result in the increase in revenues and decrease in costs. Modarres and Ansari (1989), relate quality to industrial productivity. Mathiyalakan comments on the evaluation of a quality improvement to ensure it does not drain its resources. Mathiyalakan classified techniques of evaluating quality into statistical and non-statistical. In the early stage, quality is measured on the production process to ensure that the system has a low defect rate. Statistical tools such as scatter diagrams, Pareto charts, frequency histograms and control charts and diagrams are used to measure quality. These tools as argued by Mathiyalakan have their weaknesses as they do not directly highlight the role of production workers. Mathiyalakan suggested the inclusion of the measurement of worker attitudes and behaviours as a non-statistical technique besides the checklist approach and cause and effect diagrams.

Many scholars commented on the evaluation of QCs Reiker and Sullivan (1981) cited that QCs program should not be subject to special measurement (i.e., evaluation), they added QCs should be treated as a normal part of organisation elements. Donovan and Jury (1983) and Beardsley and Malmquist (1983) have similar objections on QCs evaluation. They commented that QCs evaluation ends up not being done even where QCs recognise the practical and strategic value of systematic program evaluation, their time is consumed with the work of launching and maintaining circle activities. Lack of management support, the cost of complexity of evaluation, the difficulty of quantifying benefits and inappropriateness of premature evaluation are reasons stated by Seybolt and Johnson (1985) for not evaluating QCs.

In spite of the above objections on the QCs evaluation, Wood *et al.* (1983) stressed the importance of QCs evaluation to avoid the adoption, disappointment and discontinuation cycle. The evaluation is necessary to provide evidence on how the program is progressing, how members of the organisation are being affected, and what can be learned to improve the program. Seaton (1984) stated that the evaluation brought about improvements in QCs in his organisation. Thompson (1982) and Tortorich *et al.* (1981), have similar opinions in QCs evaluation and regard evaluation as a process that provides insights as how to improve the QCs. In Honeywell Inc., the systematic evaluation for QCs helps in winning management support and it was found to be crucial to the survival and growth of company QCs. This comment was noted by Donovan and Van Horn (1980). Seybolt and Johnson give similar reasons as Donovan and Van Horn, they suggested evaluation is necessary in order to justify program expenses, to determine problems in QCs, to provide feedback and information on involvement and participation of QCs.

Beardsley and Malmquist; Gibson (1983); Ingle (1982) and Zahra *et al.* (1983) cited the importance of evaluation for QCs survival and improvement of the program. They added it is crucial to encourage a more general utilisation of evaluation for both QCs and problem-solving groups to maintain and enhance the effectiveness in organisations.

DEA, as noted by Roll is a systematic approach for measuring relative efficiencies within a group of decision making units (DMUs), which utilise several inputs to produce a set of outputs. Developed by Charnes, it extends the classical engineering approach to non-engineering environments such as non profit or public sector organisations. Comparisons of DEA to other efficiency measurement approaches have been carried out by Bowlin *et al.* (1985). Many scholars utilised DEA technique in efficiency research. Ruggiero (1996b) uses a semi parametric method based on DEA and canonical regression and reported that there was 83% technical efficiency in 636 New York state school districts. A conceptual basis was derived by Fare *et al.* (1989) for analysing inefficiency in the public sector using DEA. Another scholars, Vitaliano and Toren (1994) studied inefficiency for New York Nursing Houses. Byrnes and Valdams (1993) also provided a report on inefficiency in California hospitals using DEA. In maintenance, a study on road maintenance inefficiency by Deller and Halstead (1994) in a group of New England states using DEA indicates 40% inefficiency. Lynch and Ozcan (1994) uses DEA to construct an index of technical efficiency in their research on hospital closure. These indices together with data on hospital utilisation, competition, hospital size, and utilisation by medicaid and medicare patients are variables used in hypothesis testing by means of a logistic regression analysis.

Dinc and Haynes (1999) utilised the modified shift share model and DEA to investigate regional economic structure, sectoral productivity, and relative efficiency. They applied it in two states, California and Ohio to assess and compare the foundations of economic performance. Bendheim evaluates the company best practices with respect to five primary stakeholders at an industry level of analysis by using DEA technique. Mathiyalakan applied the DEA approach in evaluating QCs. Their primary purposes are to determine the effectiveness-efficiency relationship of QCs in an organisation.

The paired comparison method as cited by Peterson and Brown (1998), yields an individual respondent's preference order among elements of a choice set by presenting the element in pairs and asking the respondent to choose the preferred element in each pair. This will result to the more reliable estimates due to the repeated measures for each elements as compared with the contingent valuation which is only based on the single-point estimates.

Ridge regression used earlier by Hoerl (1959) is for describing the behaviour of second-order response surfaces. Hoerl and Kennard (1970a, b) have developed a number of procedures for obtaining biased estimators of regression analysis. This procedure is also known as ridge regression as the underlying mathematics is similar to the method of ridge regression.

As suggested by Ghani, in determining the treatment worth parameter for paired comparison experiments with mixture, the treatments are compared subjectively. The parameters can be represented as a loglinear canonical regression model. Ghani recommended the application of ridge regression analysis for the experiments with and without ties to fit the regression model.

THE MATHEMATICAL MODEL

Andrews and McLone (1980) described mathematical modelling as the art of applying mathematics to a real-life situation. A good model recognises the relevant features of a problem by means of judicious choice and has a well-defined mathematical structure from which the quantities of practical interest can be derived.

Giordano *et al.* (1997) defined a mathematical model as a mathematical construct design to study a particular real-world system or phenomenon. This includes graphical, symbolic, simulation and experimental constructs. They emphasise problem identification, assumptions making (i.e. identify and classify the variables; and determining interrelationships between the variables and sub-models), model solving, model verifying (i.e. does it address the problem, does it make common sense, and test it with real-world), model implementation and model maintenance when performing the construction of a model. The mathematical model that is suggested will follow the above emphasised criteria.

DEA that is suggested is a mathematical programming developed by Charnes for assessing the efficiency of a number of decision-making unit, with respect to a variety of inputs and outputs. In DEA, the efficiency of units with the same goals will be compared. Charnes, and Beasly (1990), note that the DEA model can be easily transformed into a linear programming model and it is based on the concept of

$$h_j = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \quad (1)$$

linearity. The following formulation is one of the standarad forms for DEA. Assume that there are n DMUs to be evaluated.

Each consumes different amount of i inputs and produces r different outputs,that is DMUj consumes x_{ji} amounts of input to produce y_{ir} amounts of output. It is assumed that these input, x_{ji}, and output y_{ir} are nonnegative and that each DMU has at least one positive input and output value. The productivity of a DMU can be written as,

In this formulation, u and v are the weights assigned to each input and output. By using mathematical programming, DEA optimally assigns the weights, subject to the following constraints:

- the weights for each DMU are assigned subject to the constraint that no other DMU has an efficiency greater than 1 if it uses the same weights, implying that efficient DMUs will have a ratio value of 1; and
- the derived weights, u and v, are not negative.

The objective function of DMUk is the ratio of the total weighted output divided by the total weighted input:

$$Maximise \ h_k = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \quad (2)$$

subject to:

$$\frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \leq 1 \; for \;\; j = 1 \ldots n. \qquad (3)$$

$$v_i \geq 0 \; for \; i = m \; and \; u_r \geq 0 \; for \; r = 1s.$$

Another component in the model is paired comparison. In paired comparison objects or treatments $A = \{a_1, \ldots, a_n\}$ are compared with each other in pairs. Let y_{ij} denote the observed response when the pair (a_i, a_j) is presented. The simplest case is the dichotomous response where $y_{ij} = 1$ denotes dominance of a and $y_{ij} = 2$ denotes dominance of a_j. A tie is declared if there is no preference that can be determined. It is assumed for the various repetitions of all pairs are stochastically independent and the order of presentation of treatments within a pair does not influence the response.

The model developed by Ghani will be extended to suit with QCs evaluation. Ghani (1994) uses the model of analysis categorical data proposed by Grizzle *et al.* (1969) in analysing paired comparison experiment with mixtures based upon Bradley-Terry and Rao-Kupper models. The technique is based upon generalised least squares method applied to a linear model resulting from a transformation of observed cell counts.

Once the model has been developed as explained in the earlier part, the model is suggested to be verified by using data collected from the QCs. The *LINDO* and *TORA* packages for mathematical programming and the *SPSS for windows* package for statistical analysis are suggested to be utilised to analyse this data. Furthermore, if there is a need for special programming, *FORTRAN 95* is recomended.

CONCLUSION

The model that is suggested among other things incorporate the DEA, ridge regression and paired comparisons of evaluating Qcs. Further, it also helps to determine the factors that contribute to the success of QCs.

The model strengthens the DEA by means of incorporating ridge regression of paired comparisons loglinear canonical model. The model will benefit organisations in evaluating the QCs. The contribution to the advancement of the academic world is also expected.

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