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A trust-based performance measurement modeling using DEA, T-norm and S-norm operators

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Abstract—**In today's highly dynamic economy and society, the performance evaluation of Decision Making Units (DMUs) is of high importance. This study presents an efficient model for analyzing the outputs of performance measurement methodologies by means of trust, which provides explicit qualitative scales instead of representing pure numerical data. The efficiency rate of the current, previous and coming years, as well as the average efficiency and standard deviation, are the five inputs for this model. These efficiency rates are calculated using Data Envelopment Analysis (DEA). The approach uses time series forecasting to predict the future efficiency rate. Furthermore, the implemented Auto Regressive (AR) model includes an Auto Correlation Function (ACF) for input selection. The model utilizes T-norms and S-norms as the final modeling tools. To illustrate the applicability of the proposed model, we apply it to a data set of DMUs. Ultimately, modified trust values for these DMUs are determined using the proposed approach.**

Keywords - Performance assessment, Trust, T-norm and S-norm operators, Time series modeling, Auto regressive model

I. INTRODUCTION

Interaction based on trust between two parties is a fundamental concept, since trust provides appropriate circumstances in which to select a partner who best meets individual requirements. In some cases, users (trusting agent) may rely on measured values provided about a trusted agent by others in similar situations rather than communicating directly. In practice, two closely related concepts trust and security might be difficult to distinguish. The difference is that security prepares a safe environment in which the parties can exchange anything in a safe space without impairment, whereas trust is the level of confidence that the trusting gent has in the trusted partner which helps him to choose a trustee partner [1].

Distrust signifies not trusting any a given party too much in a situation of high risk. Dissatisfaction with services provided in the past results in distrust, either through direct relation or based on others' experience. Trust is a crucial ingredient in any bilateral relationship and is a broadly-implemented concept that can be found in many areas including business, sociology, and computing.

According to Chang et al. [1, 15], trust is the belief that the trusting agent has in the trustee partner's (trusted agent) capability, skill and willingness to fulfill a mutually agreed service in a given context and in a given timeslot.

The process of measuring the efficiency of any organization (such as power station, hospital, factory, bank etc...) that utilizes multiple inputs and as a consequence generates outputs is complicated. A non-parametric approach in such situations is proposed by Charnes et al to calculate efficiency. This methodology is known as data envelopment analysis (DEA) [2]. DEA is a linear programming approach to measure the efficiency of a number of decision-making units (DMUs) in a situation where the production process contains a structure of several inputs and outputs. This paper enhances and builds upon our previous work in this area [14]. Building on our previous work, in this paper, we make use of DEA for performance assessment, and the developed methodology is applied on real data sets on performance of DMUs.

The outline for the remainder of the paper is as follows: The body of literature pertaining to the problem is briefly reviewed in Section 2. Section 3 describes our proposed methodology for trust determination for the assessment of performance. The application of the methodology to the data set pertaining to a case study is presented in Section 4. Section 5 presents the discussion, and the final section of the paper, Section 6, presents the conclusions and suggestions for future work.

II. LITERATURE REVIEW

The related literature contains two particular areas: "performance assessment" and "trust". One of the most significant techniques for evaluating the performance of DMUs is to define a baseline for efficiency. To determine and depict the boundaries of such efficiency, several techniques have been proposed. These methodologies can be classified into two categories, parametric and nonparametric methods [3]. These methods are mainly used for the calculation of efficiency. In the parametric methodology, both deterministic and stochastic boundary functions are estimated. The nonparametric method includes data envelopment analysis (DEA) as well as free disposal hull which make use of a mathematical programming method [4].

A wide variety of trust and reputation models have been developed in the last few years [5-8]. A brief

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review of relevant studies in this area, relative to our work, is given below.

A trust and reputation model called FIRE which incorporates several information sources to provide an exhaustive evaluation of an agent's expected performance in open systems is proposed by Huynh et al [8]. Interaction trust, role-based trust, witness reputation, and certified reputation are integrated in this model to propose trust metrics in most situations.

Raza et al [9] propose a technique for predicting the trust value of an interaction is [9]. The proposed methodology contains a set of metrics that comprises of maturity, distance and density (MD2), which are capable of considering different features of the confidence level in the predicted trust value. A trust-based credit scoring methodology which uses a model based on ANN to categorize potential customers according to different classes was proposed by Mirtalaei et al [10]. To illustrate the superiority and applicability of the proposed methodology as a result of the spectrum of trust levels, it was applied to a credit-card dataset gathered from the UCI repository.

The majority of works consider only mathematical modeling rather than qualitative methods in the case of performance assessment. Very few approaches in the literature take into account trust-based performance assessment. In addition, most of the trust models include frameworks for trust prediction, modeling and classification. To the best of our knowledge, there have been very few works about the practicability and use of trust as a technique for performance assessment.

III. PROPOSED METHODOLOGY

The procedure of the proposed methodology contains four main steps, each including a number of sub-steps. Fig. 1 shows the structure of this approach.

Step 1. Data collection

This step contains two sub-steps: selecting appropriate inputs and gathering related data and implementing DEA on these sub-steps.

Step 1.1. Selecting appropriate inputs

During this stage, the decision maker has to decide which inputs are to be used for performance assessment. It is important to note that the trust value of the DMU's (output of our proposed method) is dependent on the selected inputs. In this paper, we make use of energy consumption data, which includes total electricity consumption (sold), total natural gas consumption (including supplemental gaseous fuels) and total consumption of all petroleum products, as input parameters for performance measurement of DMU's. We selected this data as input as they are publicly available. Correspondingly, the trust assessment that we obtain, using our proposed method are linked to these input. It is important to note that the trust assessments of DMU's might vary if a different set of input parameters are selected as input parameters.

Step 1.2. DEA Implementation

We first use this data to calculate the efficiency rate for each of the DMUs, using Data Envelopment Analysis (DEA).

Step 2. Model input provision

We consider five main features of DMU performance in this study for the purpose of implementing trust modeling. These five inputs are the respective efficiency rates of the current, previous and following year (predicted), and the average efficiency and standard deviation of efficiency for each DMU. It should be noted that time series modeling is used to calculate the predicted value because the efficiency rate of the following year of a timeslot is unknown.

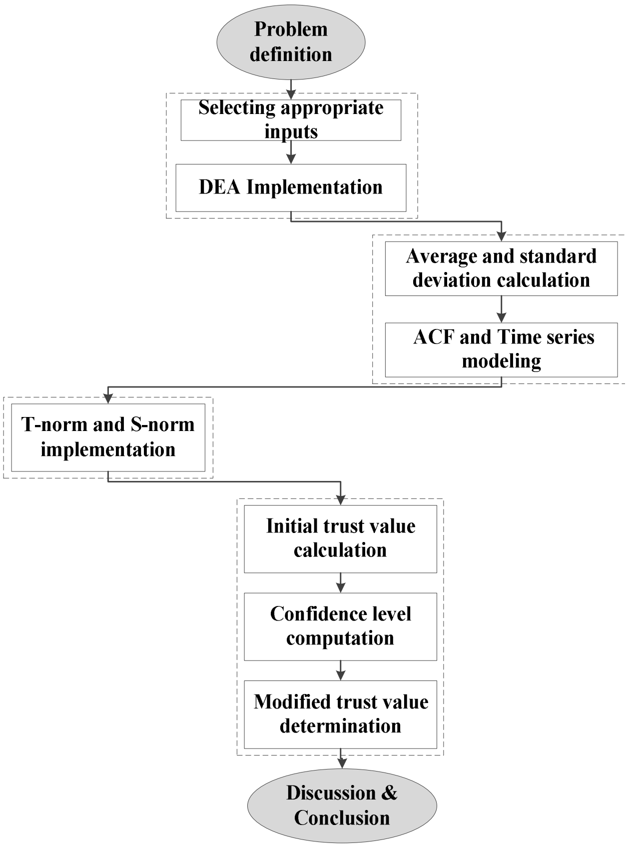

Fig. 1. Overview of the proposed methodology.

As pointed by Velicer et al [11], a time series is a sequence of data points, which data point representing an observation. The sequences of observations in a time series are usually carried out at periodically recurring intervals of time. Time series analysis comprises methods for analyzing time series data to extract meaningful statistics and other characteristics, and provides tools for selecting a model that can be used to forecast future events [11].

In time series forecasting, the autocorrelation function (ACF) plays an important role in data analysis and aims to identify the extent of the lag in an autoregressive model [16]. ACF shows how a given time series and a lagged version of itself are similar over successive time intervals in a mathematical form; the function is the same as determining the correlation between two different time series, with the exception that the same time series is used twice: once in its base form and once lagged by one or more time intervals. The range of the resulting number computed for ACF can vary from +1 to -1[16].

Step 3. T-norm and S-norm implementation

This step is the core of our methodology and is used to model trust in a performance assessment area. Given that the three input variables are different variations of trust values, logically the combination of these values would result in a trust value. In the current study all the three variables have same weight, but it should be noted, that it is possible that differential weights be assigned to these variables. We propose using triangular norm (T-norm) and T-conorm (also called S-norm) as the fusion functions for their flexibility and diversity when performing calculations. These operators are the extension of traditional logical conjunction and disjunction in fuzzy logic. The S-norms and T-norms are a family of operators, and it is possible to assign different weights when using them. In our future work, we intend to model the preferences or characteristics of people as weights. In this study, we used minimum, product, Lukasiewicz, Nilpotent minimum and Hamacher as T-norm formulas and Maximum, Probabilistic sum, Bounded sum, Nilpotent maximum and Einstein sum as S-norm formulas. The S-norms and T-norms used are shown in Figures 2 and 3. Let E_t denote the efficiency rate of the current year, E_{t-1} the efficiency rate of the previous year, E_{t+1} the efficiency rate of the following year, E_{avg} the average efficiency rate and finally, std denote the standard deviation. The values obtained from this step are Modified Efficiency (M.E) rates. Fig. 4 shows how modified efficiency rates are calculated.

Minimum	Min $\{a, b\}$
Product	$a.b$
Lukasiewicz	Max $\{\, 0,\ a+b-1 \,\}$
Nilpotent minimum	$\begin{cases} Min\ (a,b) & a+b>1 \\ 0 & otherwise \end{cases}$
Hamacher	$\begin{cases} 0 & a=b=0 \\ \frac{a.b}{a+b-a.b} & otherwise \end{cases}$

Fig. 2. T-norms and their formulae.

Maximum	Max $\{a, b\}$
Probabilistic sum	$a+b-a.b$
Bounded sum	Min $\{\, a+b\ , 1\}$
Nilpotent maximum	$\begin{cases} Max\ (a,b) & a+b<1 \\ 1 & otherwise \end{cases}$
Einstein sum	$\frac{a+b}{1+a.b}$

Fig. 3. S-norms and their formulae.

$$Modified\ Efficiency\ rate = Average\ \left(T(F_2, E_t), S(F_2, E_t)\right)$$

Fig. 4. T-norm and S-norm calculation.

Step 4. Trust value calculation

This step contains two sub-steps as follows:

Step 4.1. Initial trust value calculation

In this step, we utilize the modified efficiency rates (M.E) determined in step 3 in order to calculate the trust value. It should be noted that our proposed methodology uses an interval of 60-100 percent efficiency rate. Fig. 5 indicates the procedure for calculating the trust value.

Step 4.2. Confidence level computation and determining modified trust value

In this step we build upon the idea presented by Raza et al [9]. Three metrics are defined in this study for the computing the confidence level that will be used to calculate the modified trust value including maturity, tendency and density. The possible values that could be assigned to any of these metrics are 1, 2 or 3; 1 is the lowest value, 2 is the moderate value, and 3 is the highest value.

Maturity (M): Maturity is an indicator that represents the total life span of an entity for which efficiency rates are available [9].

Tendency (Te): Tendency refers to the time related to the largest data; i.e. for each set of data, we find the k-th largest data (k=1… j) and then determine the year to which the data belongs [9].

Density (D): Density is the metric that compares the median and the mean of the data set. It delineates whether or not our data set contains many low rates. Suppose the median is larger than mean value; this shows that there are a number of data whose values are so low that they have decreased the value of the mean value [9]. The procedure for modified trust value (MTV) calculation is described in Fig. 6.

Trust value determination

If $\mathrm{M.E} < 60$ then trust value=0 meaning absolutely untrustworthy

If $60 \le \mathrm{M.E} < 65$ then trust value=1 meaning very untrustworthy

If $65 \le \mathrm{M.E} < 75$ then trust value=2 meaning untrustworthy

If $75 \le \mathrm{M.E} < 85$ then trust value=3 meaning partially trustworthy

If $85 \le \mathrm{M.E} < 95$ then trust value=4 meaning very trustworthy

If $95 \le \mathrm{M.E} \le 100$ then trust value=5 meaning very trustworthy

Fig. 5. Initial trust value calculation.

Confidence level determination Maturity (M): Determine the number of timeslots for which the data are in hand (T) If $T \leq 15$ then M=1 If $15 < T \leq 30$ then M=2 If $T > 30$ then M=3 Tendency (Te): j= 0.4*T For k=1,…,j Determine the k-th largest efficiency rate n= the number of j data which belong to t=T/2…T If $n < j/2$ then Te=1 If $n = j/2$ then Te=2 If $n > j/2$ then Te=3 Density (D): Calculate mean and median of each DMU If mean<median D=1 If mean=median D=2 If mean>median D=3 Confidence level: c level= M+Te+D / Max(M+Te+D) Modified trust value (MTV): MTV= c level* Initial trust value

Fig. 6. Modified trust value determination.

The final interpretation of the modified trust value (MTV) is shown in Table 1.

Table 1. Scale of modified trust value.

Scale number	Semantics	Value
1	Very untrustworthy	$0 \leq \text{MTV} < 1$
2	Untrustworthy	$1 \leq \text{MTV} < 2$
3	Partially trustworthy	$2 \leq \text{MTV} < 3$
4	Trustworthy	$3 \leq \text{MTV} < 4$
5	Very trustworthy	$4 \leq \text{MTV} \leq 5$

IV. THE CASE STUDY

We will present the calculations and results obtained according to our methodology proposed in Section 3. We apply our methodology on a data set of DMUs. For each DMU this data set has the total consumption of electricity, natural gas and all petroleum products from 2000 to 2010. In our case study, we use these parameters as inputs of the DEA, and the CO_2 emissions as the output. The efficiency rates of DMUs have been calculated based on the framework described in Step 1.2 and are presented in Table 2. The modified trust values after calculation are provided in Table 3.

V. DISCUSSION

Several distinct observations can be made from an analysis of the results. A comparison of the initial trust value and the modified trust value shows that the modified trust value is less than (or equal to) the initial trust value. The reason for this is that in order to calculate the modified trust value, we modulate the initial trust value with the confidence level. As previously mentioned, the confidence level is calculated by taking three metrics into account, including maturity, tendency and density, and the confidence level always takes values less than or equal to one. Therefore, it is clear that the modified trust value will be lower than (or equal to) the initial trust value.

In addition, we conducted experiments over five different sets of various T-norms and S-norms to take into account the role of personality in trust value calculation. According to the results for these five sets of T-norms and S-norms, we see that the values obtained by the first three sets are equal, whereas the values for the fourth and fifth groups are greater, while Nilpotent has the highest results. Table 4 reports the incident numbers of each trust value range for these five sets of T-norms and S-norms.

Another important point to note is the link between the input factors and the obtained trust assessment (output of our method). The purpose of this paper is only to demonstrate the working of our method as a means for performance assessment. It is the job of the decision maker to select appropriate input factors for performance assessment. As mentioned previously, the input factors that were used in this study were selected because they were publicly available for DMU's. However, it is likely that making use of different set of input factors would vary the performance assessment.

Table 2. Efficiency rates obtained by means of DEA implementation.

	Time slot										
DMUs	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
DMU1	0.856	0.862	0.856	0.856	0.847	0.847	0.843	0.84	0.843	0.844	0.836
DMU2	0.949	0.948	0.949	0.947	0.945	0.938	0.942	0.944	0.948	0.948	0.950
DMU3	0.894	0.889	0.889	0.884	0.874	0.871	0.865	0.858	0.857	0.863	0.874
DMU4	0.919	0.921	0.920	0.918	0.920	0.917	0.915	0.916	0.914	0.916	0.912
DMU5	0.367	0.352	0.382	0.374	0.342	0.331	0.320	0.310	0.303	0.311	0.353
DMU6	0.904	0.894	0.895	0.893	0.890	0.882	0.882	0.876	0.875	0.872	0.878
DMU7	0.935	0.935	0.935	0.933	0.931	0.929	0.934	0.931	0.936	0.935	0.936
DMU8	0.982	0.981	0.981	0.980	0.982	0.981	0.983	0.982	0.982	0.985	0.985
DMU9	0.649	0.641	0.628	0.617	0.604	0.589	0.588	0.587	0.592	0.584	0.583
DMU10	0.790	0.795	0.789	0.787	0.778	0.770	0.772	0.770	0.774	0.768	0.763
DMU11	0.981	0.980	0.979	0.978	0.977	0.977	0.977	0.976	0.979	0.979	0.980
DMU12	0.967	0.968	0.969	0.970	0.968	0.968	0.967	0.965	0.964	0.965	0.966
DMU13	0.712	0.716	0.712	0.712	0.709	0.69	0.706	0.697	0.693	0.703	0.709
DMU14	0.808	0.815	0.809	0.804	0.805	0.799	0.805	0.799	0.800	0.809	0.806
DMU15	0.921	0.921	0.920	0.92	0.918	0.913	0.913	0.907	0.903	0.904	0.907
DMU16	0.919	0.922	0.920	0.918	0.920	0.920	0.919	0.914	0.913	0.912	0.915
DMU17	0.869	0.866	0.856	0.860	0.855	0.852	0.857	0.852	0.851	0.855	0.857
DMU18	0.675	0.710	0.699	0.707	0.695	0.692	0.687	0.678	0.682	0.692	0.679
DMU19	0.973	0.970	0.969	0.971	0.970	0.971	0.973	0.973	0.973	0.974	0.974
DMU20	0.892	0.891	0.886	0.881	0.885	0.881	0.893	0.889	0.891	0.890	0.892
DMU21	0.880	0.877	0.877	0.872	0.873	0.869	0.877	0.871	0.872	0.875	0.874
DMU22	0.764	0.769	0.765	0.761	0.762	0.753	0.770	0.770	0.776	0.784	0.789
DMU23	0.874	0.874	0.872	0.869	0.869	0.863	0.866	0.861	0.856	0.864	0.865
DMU24	0.906	0.903	0.905	0.907	0.905	0.903	0.902	0.896	0.897	0.897	0.891
DMU25	0.866	0.862	0.863	0.863	0.863	0.855	0.858	0.853	0.851	0.858	0.857
DMU26	0.973	0.977	0.975	0.975	0.974	0.972	0.971	0.969	0.969	0.970	0.973
DMU27	0.955	0.955	0.954	0.953	0.953	0.952	0.951	0.948	0.945	0.945	0.945
DMU28	0.946	0.945	0.945	0.943	0.938	0.933	0.929	0.928	0.927	0.927	0.933
DMU29	0.982	0.983	0.982	0.977	0.976	0.976	0.978	0.978	0.976	0.978	0.979
DMU30	0.816	0.813	0.813	0.810	0.807	0.796	0.807	0.794	0.792	0.802	0.806
DMU31	0.950	0.949	0.951	0.950	0.949	0.946	0.945	0.943	0.942	0.942	0.944
DMU32	0.670	0.669	0.672	0.668	0.662	0.653	0.675	0.661	0.664	0.669	0.679
DMU33	0.808	0.810	0.808	0.810	0.803	0.801	0.809	0.802	0.800	0.804	0.799
DMU34	0.981	0.979	0.979	0.979	0.979	0.978	0.978	0.977	0.975	0.976	0.974
DMU35	0.691	0.704	0.708	0.704	0.702	0.693	0.711	0.698	0.698	0.715	0.718
DMU36	0.881	0.878	0.881	0.875	0.875	0.862	0.856	0.855	0.850	0.852	0.854
DMU37	0.912	0.917	0.920	0.919	0.916	0.914	0.914	0.911	0.908	0.910	0.917
DMU38	0.730	0.729	0.728	0.722	0.716	0.707	0.719	0.707	0.703	0.705	0.709
DMU39	0.987	0.985	0.986	0.986	0.988	0.986	0.987	0.986	0.985	0.984	0.985
DMU40	0.883	0.886	0.881	0.883	0.875	0.875	0.877	0.877	0.877	0.877	0.876
DMU41	0.988	0.988	0.986	0.986	0.987	0.986	0.986	0.984	0.981	0.981	0.981
DMU42	0.842	0.841	0.840	0.839	0.839	0.834	0.837	0.835	0.836	0.847	0.841
DMU43	0.014	0.014	0.013	0.013	0.014	0.014	0.014	0.014	0.013	0.014	0.013
DMU44	0.949	0.950	0.950	0.949	0.948	0.945	0.941	0.937	0.936	0.937	0.939
DMU45	0.831	0.832	0.831	0.824	0.816	0.811	0.820	0.810	0.815	0.815	0.814
DMU46	0.833	0.852	0.865	0.861	0.857	0.852	0.851	0.848	0.843	0.838	0.849
DMU47	0.949	0.948	0.947	0.949	0.948	0.947	0.945	0.944	0.944	0.949	0.949
DMU48	0.871	0.872	0.870	0.869	0.867	0.860	0.866	0.863	0.862	0.867	0.872
DMU49	0.973	0.971	0.971	0.969	0.970	0.969	0.967	0.964	0.962	0.961	0.962

Table 3. Modified trust value.

DMUs	Min Max	Product Probabilistic	Lukasiewicz Bounded	Nilpotent	Hamacher Einstein	Output
DMU1	1.67(U)	1.67(U)	1.67(U)	2.22(PT)	2.22(PT)	Untrustworthy
DMU2	1.33(U)	1.33(U)	1.33(U)	1.67(U)	1.67(U)	Untrustworthy
DMU3	2.22(PT)	2.22(PT)	2.22(PT)	2.22(PT)	2.22(PT)	Partially trustworthy
DMU4	2.22(PT)	2.22(PT)	2.22(PT)	2.78(PT)	2.22(PT)	Partially trustworthy
DMU5	0.00(VU)	0.00(VU)	0.00(VU)	0.00(VU)	0.00(VU)	Very untrustworthy
DMU6	2.22(PT)	2.22(PT)	2.22(PT)	2.22(PT)	2.22(PT)	Partially trustworthy
DMU7	1.33(U)	1.33(U)	1.33(U)	1.67(U)	1.33(U)	Untrustworthy
DMU8	3.89(T)	3.89(T)	3.89(T)	3.89(T)	3.89(T)	Trustworthy
DMU9	0.56(VU)	0.56(VU)	0.56(VU)	1.67(U)	1.11(U)	Very untrustworthy
DMU10	1.67(U)	1.67(U)	1.67(U)	2.22(PT)	1.67(U)	Untrustworthy
DMU11	1.67(U)	1.67(U)	1.67(U)	1.67(U)	1.67(U)	Untrustworthy
DMU12	2.78(PT)	2.78(PT)	2.78(PT)	2.78(PT)	2.78(PT)	Partially trustworthy
DMU13	0.67(VU)	0.67(VU)	0.67(VU)	1.33(U)	1.00(U)	Very Untrustworthy
DMU14	1.67(U)	1.67(U)	1.67(U)	2.22(PT)	1.67(U)	Untrustworthy
DMU15	1.33(U)	1.33(U)	1.33(U)	1.67(U)	1.33(U)	Untrustworthy
DMU16	1.33(U)	1.33(U)	1.33(U)	1.67(U)	1.33(U)	Untrustworthy
DMU17	2.22(PT)	2.22(PT)	2.22(PT)	2.22(PT)	2.22(PT)	Partially trustworthy
DMU18	0.67(VU)	0.67(VU)	0.67(VU)	1.00(U)	0.67(VU)	Very untrustworthy
DMU19	2.78(PT)	2.78(PT)	2.78(PT)	2.78(PT)	2.78(PT)	Partially trustworthy
DMU20	1.33(U)	1.33(U)	1.33(U)	1.33(U)	1.33(U)	Untrustworthy
DMU21	1.33(U)	1.33(U)	1.33(U)	1.33(U)	1.33(U)	Untrustworthy
DMU22	2.33(PT)	2.33(PT)	2.33(PT)	3.11(T)	2.33(PT)	Partially trustworthy
DMU23	2.22(PT)	2.22(PT)	2.22(PT)	2.22(PT)	2.22(PT)	Partially trustworthy
DMU24	1.33(U)	1.33(U)	1.33(U)	1.33(U)	1.33(U)	Untrustworthy
DMU25	2.22(PT)	2.22(PT)	2.22(PT)	2.22(PT)	2.22(PT)	Partially trustworthy
DMU26	1.67(U)	1.67(U)	1.67(U)	1.67(U)	1.67(U)	Untrustworthy
DMU27	1.33(U)	1.33(U)	1.33(U)	1.67(U)	1.67(U)	Untrustworthy
DMU28	2.22(PT)	2.22(PT)	2.22(PT)	2.78(PT)	2.22(PT)	Partially trustworthy
DMU29	2.78(PT)	2.78(PT)	2.78(PT)	2.78(PT)	2.78(PT)	Partially trustworthy
DMU30	1.00(U)	1.00(U)	1.00(U)	1.33(U)	1.00(U)	Untrustworthy
DMU31	1.33(U)	1.33(U)	1.33(U)	1.67(U)	1.33(U)	Untrustworthy
DMU32	0.67(VU)	0.67(VU)	0.67(VU)	1.00(U)	0.67(VU)	Very untrustworthy
DMU33	1.67(U)	1.67(U)	1.67(U)	2.22(PT)	1.67(U)	Untrustworthy
DMU34	1.67(U)	1.67(U)	1.67(U)	1.67(U)	1.67(U)	Untrustworthy
DMU35	1.56(U)	1.56(U)	1.56(U)	3.11(T)	2.33(PT)	Untrustworthy
DMU36	2.22(PT)	2.22(PT)	2.22(PT)	2.22(PT)	2.22(PT)	Partially trustworthy
DMU37	2.22(PT)	2.22(PT)	2.22(PT)	2.78(PT)	2.22(PT)	Partially trustworthy
DMU38	1.11(U)	1.11(U)	1.11(U)	2.22(PT)	1.67(U)	Untrustworthy
DMU39	1.67(U)	1.67(U)	1.67(U)	1.67(U)	1.67(U)	Untrustworthy
DMU40	2.22(PT)	2.22(PT)	2.22(PT)	2.22(PT)	2.22(PT)	Partially trustworthy
DMU41	1.67(U)	1.67(U)	1.67(U)	1.67(U)	1.67(U)	Untrustworthy
DMU42	1.67(U)	1.67(U)	1.67(U)	2.22(PT)	2.22(PT)	Untrustworthy
DMU43	0.00(VU)	0.00(VU)	0.00(VU)	0.00(VU)	0.00(VU)	Very untrustworthy
DMU44	1.33(U)	1.33(U)	1.33(U)	1.67(U)	1.33(U)	Untrustworthy
DMU45	1.67(U)	1.67(U)	1.67(U)	2.22(PT)	1.67(U)	Untrustworthy
DMU46	1.00(U)	1.00(U)	1.00(U)	1.33(U)	1.33(U)	Untrustworthy
DMU47	1.33(U)	1.33(U)	1.33(U)	1.67(U)	1.67(U)	Untrustworthy
DMU48	1.33(U)	1.33(U)	1.33(U)	1.33(U)	1.33(U)	Untrustworthy
DMU49	1.67(U)	1.67(U)	1.67(U)	1.67(U)	1.67(U)	Untrustworthy

Very untrustworthy (VU), Untrustworthy (U), Partially trustworthy (PT), Trustworthy (T), Very trustworthy (VT)

Table 4. Incident numbers of each trust value range for five sets of T-norms and S-norms.

Trust value range	Lukasiewicz Bounded	Nilpotent	Hamacher Einstein
Very untrustworthy	6	2	4
Untrustworthy	28	24	27
Partially trustworthy	14	20	17
Trustworthy	1	3	1
Very Trustworthy	0	0	0
Sum	49	49	49

Table 4 (Continued). Incident numbers of each trust value range for five sets of T-norms and S-norms.

Trust value range	Lukasiewicz Bounded	Nilpotent	Hamacher Einstein
Very untrustworthy	6	2	4
Untrustworthy	28	24	27
Partially trustworthy	14	20	17
Trustworthy	1	3	1
Very Trustworthy	0	0	0
Sum	49	49	49

VI. LIMITATIONS, CONCLUSIONS AND FUTURE RESEARCH

This paper has presented a model for trust determination to evaluate the performance of DMUs. The use of historical data, current values, and prediction, along with the mean and dispersion factors, has established an exhaustive methodology for trust value determination which is made more reliable by involving the concept of confidence level. The proposed model provides explicit qualitative scales instead of representing purely numerical data, and a case study illustrates the applicability of the proposed approach. In the context of the dataset used in this work, it is important to note that the trust assessment that we obtain, based on our methodology, is linked to the input parameters. As mentioned previously, in this paper, the input parameters that we use are publicly available for the DMUs. Using a different set of parameters for these DMUs might result in a different trust assessment.

Our future work is to include decision makers' individual preferences in the model to identify the most appropriate T-norm and S-norm model based on which the trust value will be determined. Implementing ANN instead of time series to predict the next year's efficiency rate when the data set is large enough is a suitable technique. As a part of our future research, we would like to include a wide range of variable as input to the DEA. We would additionally like to investigate the impact of varying input factors on trust assessments. Lastly, applying a Z-number methodology [13] to calculate the probability of a computed trust value seems to be a worthwhile topic to explore as a part of our future work.

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