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**Fuzzy Systems Modeling of Ease of Doing Business
Indicators**

by

Mehrdad Roham, Anait R. Gabrielyan and Norman P. Archer

McMaster eBusiness Research Centre (MeRC)

**WORKING PAPER No. 25
August 2008**

**McMaster
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ABSTRACT

Ease of Doing Business (EDB) indicators are essential to the overall understanding and evaluation of national business environments, and to strategy formulations of business policy and regulations. The World Bank does an annual study of these indicators for over 170 nations, but there are many complications and uncertainties involved in their work. This paper proposes a new systematic approach that employs fuzzy set theory to generate composite EDB indicators for ranking and classification problems. In this paper, we implement the proposed approach and illustrate its process and procedures. A case study example for Canada is also presented in which EDB indicators are evaluated, linguistically identified, and ranked. This approach demonstrates the ease of using this fuzzy application, and its potential benefits for future research. We also compare ranking results, obtained from our proposed approach, with the World Bank's results.

Keywords: Fuzzy sets; Ease of Doing Business; Linguistic aggregation; Fuzzy ranking

ACKNOWLEDGEMENT

This work was supported by a grant from the Natural Sciences and Engineering Council of Canada.

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1. INTRODUCTION

Countries differ significantly in the way in which they regulate the entry of new businesses, registering property, and other business activities. Each society chooses a system of social control of business that combines market forces, dispute resolution in court, government regulation, and corrective taxes and subsidies (Djankov et al., 2003a). Ease of Doing Business indicators have been used as a communication tool to describe the overall business environment in various countries by the World Bank since 2004. Multiple Ease of Doing Business indicators can be summarized into one composite indicator “Ease of Doing Business (EDB)” (World Bank, 2003, 2004, 2005, 2006, 2007). Although EDB can help in decision making, and in reforming the business environment, both the indicators and methodology have been subject to criticism from economists and legal experts, as recently reported in du Marais (2006). The main problems cited are the weak explanatory power of the composite EDB indicator and the quality of the underlying information (Blanchet, 2006).

This study suggests another approach for calculating composite EDB indicators, employing fuzzy set theory. This is expected to be very effective in integrating various indicators which are too complicated and multifaceted to evaluate precisely. It is also conceptually easy to understand and implement, flexible, very fast and computationally inexpensive, tolerant of imprecise data and based on natural language (Al-Najjar and Alosyuf, 2003).

In real situations, data sets usually include different types of variables on different scales, i.e nominal scales (categorical or symbolic data), ordinal scales, or interval and ratio metric scales. The main approach used for different scales at the same time in data analysis is to represent the symbols numerically and/or to use intervals for numerical data. This approach unfortunately interprets interval distances as values, which are meaningless for numerically represented symbols.

Fuzzy systems are not dependent on the scales of the data they process. One of their biggest benefits for data analysis is that they can provide solutions that are interpretable in linguistic terms of the involved variables. There are also many situations in which the information cannot be assessed precisely in a quantitative form, but may be assessed in a qualitative manner (Herrera and Herrera-Viedma, 2000). In such situations, a more realistic approach may be to use linguistic assessments with linguistic variables, instead of using numerical values - that is, variables whose values are not numbers but words or sentences in a natural or artificial language (Zadeh and Kacprzyk, 1999). The other important advantage of fuzzy systems is their linguistic interpretability, whereby the results from the data-driven approach can be combined with or compared to the knowledge available from experts (van den Berg et al., 2004). In many areas, such as engineering, decision making, ranking business or economic data, data mining, artificial intelligence, medical diagnosis and fuzzy logic control, etc., linguistic information aggregation is an essential process, which has received great attention from researchers in recent times (Jamshidi et al., 1997; Zaponidis et al, 2001; Aliev et al, 2004).

Over the last few decades, various linguistic aggregation operators have been proposed, such as linguistic operators for max and min, linguistic median, linguistic weighted median, linguistic max-min weighted averaging, linguistic ordered weighted averaging (OWA) and many others. These linguistic aggregation operators have been studied and applied in a wide variety of areas, such as engineering, decision making, information retrieval, marketing, personnel management, educational grading system, supply chain management, etc. Comprehensive state-of-the-art overviews on aggregation can be found in (Calvo et al., 2002; Beliakov et al, 2007; Xu, 2008). In our research we will use the OWA operator, as it is used more widely in aggregating applications.

The purposes of this study are to illustrate how fuzzy systems can be used in linguistic aggregation for classification and ranking of Ease of Doing Business sub-indicators, to demonstrate their application in the aggregation of various indicators into the composite EDB index, to compare the resulting outcomes with World Bank results, and to propose a linguistic interpretation (classification) to all such data.

The remainder of this paper is organized as follows. The second section briefly describes the foundation of fuzzy logic and fuzzy systems. The third section proposes an algorithm for producing a composite EDB indicator. The fourth section presents a step-by-step procedure for the proposed algorithm. The fifth section reports the results of the limited empirical study and a discussion that compares our results with World Bank results. The sixth section briefly discusses system implementation. Finally, we suggest some implications of our work.

2. FUZZY LOGIC AND FUZZY SYSTEMS

Fuzzy logic, introduced by Zadeh (1965), is a precise logic of imprecision and approximate reasoning (Zadeh, 1975, 1979, 1999, 2001). Zadeh (2008) in his latest article noted that fuzzy logic may be viewed “as an attempt at formalization/mechanization of two remarkable human capabilities. First, the capability to converse, reason and make rational decisions in an environment of imprecision, uncertainty, incompleteness of information, conflicting information, partiality of truth and partiality of possibility – in short, in an environment of imperfect information. And second, the capability to perform a wide variety of physical and mental tasks without any measurements and any computations”.

When it is difficult to derive mathematical models for systems, fuzzy systems are very appropriate for uncertain or approximate reasoning. For example, incomplete or inaccurate data are fuzzy, and are often gathered from various sources. Classical nonfuzzy methods in most cases involve lengthy calculations, and depend on mathematical approximations (e.g. linearization of non-linear problems), which may lead to inaccurate or incomplete model performance and conclusions. Fuzzy logic is more preferable for data with incomplete information, and it allows knowledge to be represented in a more natural way (using fuzzy logic instead of boolean “crisp” logic)

Fuzzy system approaches also allow us to represent descriptive or qualitative expressions such as “easy” or “very difficult” and are easily incorporated with symbolic statements. These expressions and representations are more natural than mathematical equations for many human judgmental rules and statements (Munakata, 2008) and more similar to human language daily life. Fuzzy systems (FSs) are widely applied in fields like classification, knowledge based clustering, decision support, process simulation, and control (Jamshidi et al., 1997; Pedrycz, 2005). In recent years FSs have been widely used in management, finance and business (Zapounidis et al., 2001; von Altrock, 1997; Bojadziev and Bojadziev, 1997; Nedosekin, 2003). This section briefly describes the main definitions and methods that are used in the proposed approach.

2.1. FUZZY NUMBERS

Let X be a universal set. A fuzzy subset A of X is defined by a function $\mu_A(.) : X \rightarrow [0,1]$, termed its membership function. Hereafter, X is assumed to be the set of real numbers, R . Membership function specifies the grade or degree to which any element x in X belongs to fuzzy set A .

Definition (Lalla et al., 2008): A fuzzy subset A is a fuzzy number if:

a) $\forall \alpha \in [0,1]$, the set $A_\alpha = \{x \in R : \mu_A(x) > \alpha\}$, which is called α -cut of A , is a convex set, i.e., $\mu_A[\lambda x_1 + (1-\lambda)x_2] \geq \min[\mu_A(x_1), \mu_A(x_2)]$, $\forall x_1, x_2 \in R, \forall \lambda \in [0,1]$;

b) $\mu_A(\cdot)$ is an upper semicontinuous function,

c) $\text{supp}(A) = \{x \in R : \mu_A(x) > 0\}$ is a bounded set in R ,

d) $\text{height}(A) = \max_{x \in X} [\mu_A(x)] = h > 0$.

If $h = 1$, the fuzzy number is said to be normal, i.e., there exists at least one element, x_0 , such that $\mu_A(x) = 1$. If A is a crisp number with value x_0 , then its membership function is given by $\mu_A(x) = 1$, if $x = x_0$ and $\mu_A(x) = 0$ otherwise.

The operations between fuzzy numbers, such as addition, subtraction, or multiplication, become rather complicated if their membership functions are not very regularly shaped. Therefore, the trapezoidal fuzzy numbers are often used to approximate fuzzy numbers owing to their simplicity and flexibility:

$$\mu_A(x) = \begin{cases} l_A(x) = h \left(\frac{x - a_1}{a_2 - a_1} \right) & \text{for } a_1 \leq x \leq a_2 \\ h & \text{for } a_2 \leq x \leq a_3 \\ r_A(x) = h \left(\frac{a_4 - x}{a_4 - a_3} \right) & \text{for } a_3 \leq x \leq a_4 \\ 0 & \text{otherwise} \end{cases},$$

where $(a_1, a_2, a_3, a_4) \in R$, l_A is non-decreasing, and r_A is non-increasing. The two functions, $l_A, r_A : R \rightarrow [0,1]$, are termed left side and right side of the fuzzy number A , respectively. If $a_2 = a_3$, then the fuzzy number is called triangular, like the shape of its membership function. If $a_1 = a_2$ and $a_3 = a_4$, then the fuzzy number is called sometimes rectangular. If $a_1 = a_2 = a_3 = a_4$, then there is no vagueness and the fuzzy number coincides with the crisp number a .

2.2. FUZZY LINGUISTIC VARIABLES

Variables whose values are words or sentences in natural or artificial languages are called linguistic variables. To illustrate the concept of linguistic variable, assume that we want to describe the indicator "Time for Starting Business". It is a summary of the experience of many entrepreneurs and business companies in various countries, and cannot be characterized precisely. Employing fuzzy sets (usually fuzzy numbers), we can describe "Time for Starting Business" approximately. "Time for Starting Business" is a linguistic variable whose values are words like Very Low (VL), Low (L), Medium (M), High (H), Very High (VH). They are called linguistic terms or labels of the linguistic variable "Time for Starting Business" and are expressed by fuzzy sets on a universal set $U \subset R_+$ also called the operating

domain and measured in calendar days. Each linguistic term is defined by appropriate membership functions. Usually triangular, trapezoidal or bell-shapes are used for membership functions (Bojadziev and Bojadziev,1997). The trapezoidal membership function was described previously, and the membership function for each term is described in the next section during the explanation of the proposed algorithm.

2.3. FUZZY CLUSTERING

Clustering is a technique for classifying data, i.e., to divide a given dataset into a set of classes or clusters based on similarity (Bezdek and Pal, 1992; Bezdek et al, 1999). The goal is to assign data points to clusters in such a way that two feature vectors from the same cluster are as similar as possible and two feature vectors from different clusters are as dissimilar as possible (Timm et al, 2004).

Unlike classical cluster analysis, where the observation data are classified as exclusive clusters, (i.e. data points can belong to only one cluster), fuzzy cluster analysis provides clusters with gradual membership (or uncertain boundaries). Thus, a data point could belong to more than one cluster, each with some degree of membership. Each cluster is defined by a cluster center (cluster prototype) and minimized objective function. However, the cluster center is computed by the clustering algorithm and may or may not appear in the dataset (Miyamoto et al., 2008).

The most widely used and basic fuzzy clustering algorithm is the Fuzzy C-Means algorithm (FCM), proposed by Bezdek (1981). FCM is a useful tool for clustering real p-dimensional data. It attempts to find a fuzzy partition of the dataset by minimizing the following within the group least-squares error objective function, with respect to fuzzy memberships μ_{ij} and cluster center v_j :

$$J(U, V) = \sum_{j=1}^C \sum_{i=1}^N (\mu_{ij})^m \|x_i - v_j\|^2, \quad (1.1)$$

where $m > 1$ is the fuzziness index used to tune out the noise in the data, N is the number of feature vectors x_i , $C \geq 2$ is the number of clusters in the set and $d_{ij} = \|x_i - v_j\|$ is the similarity measure between a datum and a center. $U = (\mu_{ij})_{N \times C}$ is a partition matrix, in which each member μ_{ij} indicates the degree of membership between the data vector x_i and the cluster j . The values of matrix U should satisfy the following conditions:

$$\mu_{ij} \in [0,1] \quad \forall i = 1, \dots, N \quad \forall j = 1, \dots, C \quad (1.2)$$

$$\sum_{j=1}^C \mu_{ij} = 1 \quad \forall i = 1, \dots, N \quad (1.3)$$

Minimization of the cost function $J(U, V)$ is a nonlinear optimization problem, which can be minimized with the aid of the following iterative algorithm (Lampinen et al, 2005):

Step 1. Initialize the membership matrix U with random values so that conditions (1.2) and (1.3) are satisfied. Choose the appropriate exponent m and the termination criteria.

Step 2. Calculate the cluster centers V according to the equation:

$$v_j = \frac{\sum_{i=1}^N (\mu_{ij})^m x_i}{\sum_{i=1}^N (\mu_{ij})^m}, \quad \forall j = 1, \dots, C \quad (1.4)$$

Step 3. Calculate the new Euclidean distance norms:

$$d_{ij} = \|x_i - v_j\|, \quad \forall i = 1, \dots, N \quad \forall j = 1, \dots, C \quad (1.5)$$

Step 4. Update the fuzzy partition matrix U :

IF $d_{ij} > 0$ (indicating that $x_i \neq v_j$)

$$\mu_{ij} = \frac{1}{\sum_{k=1}^C \left(\frac{d_{ij}}{d_{ik}} \right)^{\frac{2}{m-1}}}, \quad \mu_{ij} = 1 \quad (1.6)$$

Step 5. STOP if the termination criteria has been met, *ELSE* go to *Step 2*.

A suitable termination criterion could be to evaluate the cost function (1.1) and to see whether it is below a certain tolerance value or if its improvement compared to the previous iteration is below a certain threshold. The maximum number of iteration cycles can also be used as a termination criterion (Lampinen et al, 2005).

2.4. THE ORDERED WEIGHTED AVERAGING (OWA) OPERATOR

An OWA operator of dimension m is a function F defined as follows

$$F : [0,1]^m \rightarrow [0,1]$$

which is associated with a weight vector $W = [w_1, \dots, w_n]$ such that,

$$w_i \in [0,1] \text{ and } \sum_{i=1}^m w_i = 1 \text{ and } F(a_1, \dots, a_m) = W \cdot B^T = \sum_{i=1}^m w_i b_i,$$

where $B = [b_1, \dots, b_m]$, and each element $b_i \in B$ is the i th largest value in the collection a_1, \dots, a_m (Yager, 1988, 1993, 1996, 1998).

The OWA operators have the properties of commutativity, monotonicity, idempotency, and boundedness (Yager, 1998). The key feature of OWA operators is the ordering of the arguments by value. Ordinary operators such as *Min*, *Max* and *simple average*, are special cases of the OWA. For example, when the situation where the weights are such that :

$$w_1 = 1 \text{ and } w_j = 0 \text{ for all } j \neq 1,$$

$$F(a_1, \dots, a_m) = \text{Max}(a_1, \dots, a_m)$$

When $w_1 = 1$, and $w_j = 0$ for all $j \neq m$,

$$F(a_1, \dots, a_m) = \text{Min}(a_1, \dots, a_m).$$

When $w_1 = w_2 = \dots = w_n = \frac{1}{m}$,

$$F(a_1, \dots, a_m) = \text{Avg}(a_1, \dots, a_m) = \frac{1}{m} \sum_{i=1}^m a_j.$$

3. PROPOSED ALGORITHM

In this section, an algorithm for fuzzy system classification modeling is proposed and demonstrated by applying it to the Ease of Doing Business classification. The proposed algorithm is composed of **seven** steps, as shown in Fig.1.

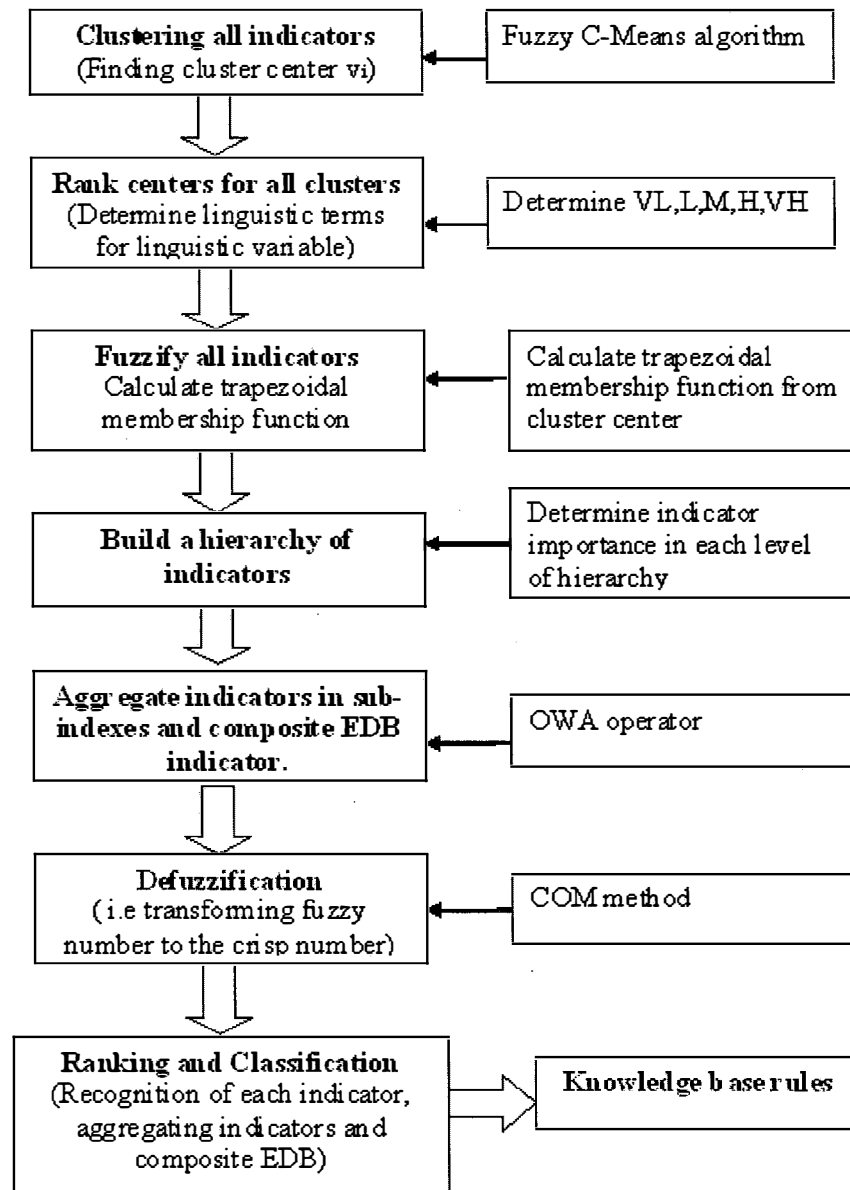


Fig.1. Proposed Algorithm for Fuzzy System Classification Modeling

Step 1: Suppose we have X_j indicators for n countries. An appropriate fuzzy cluster integrating procedure is selected to cluster the X_j indicators into $c \geq 2$ clusters in this step. The proposed method

integrates the fuzzy clustering method as a partitioning and fuzzifying procedure. Thus the fitness between data and the fuzzy clustering method will influence classification and ranking performance. In this research FCM is chosen, as it has been widely used, adapted, and generalized (Hathaway and Bezdek, 1994, 2000; Bezdek et al., 1987a, 1987b, 1999).

The FCM approach requires the user to predefine the number of clusters, denoted as c in this research. However, the determination of an optimal cluster number is still an unsettled and subjective issue. Miller (1956) pointed out that “seven plus or minus two” represents the greatest amount of information that can be dealt with by humans corresponding with the limitations of human cognition. Therefore, five clusters were chosen for our research. After applying FCM, the cluster centers for the X_j indicators, denoted as v_{ij} ($i=1,2,\dots,c$ and $j=1,2,\dots,m$), are calculated iteratively by means of the Euclidean distance. Each indicator X_j has its own cluster centers $V_{ij} = \{v_{1j}, v_{2j}, v_{3j}, v_{4j}, v_{5j}\}$.

Step 2: In this step we rank each cluster to define the clusters as ordered linguistic terms in the linguistic variables L_{ij} ($i=1,2,\dots,c$). For example, suppose we have 5 clusters whose centers are at 77.97, 127.86, 13.47, 189.97 and 44.37. Respectively, their centers are at C_3, C_4, C_1, C_5 and C_2 and they are defined as L_3, L_4, L_1, L_5 and L_2 , respectively. In this step we also determine the linguistic terms for each linguistic variable. For example, for each simple indicator we define linguistic terms $L_i = \{VL$ (Very Low), L (Low), M (Medium), H (High), VH (Very High) $\}$.

Step 3: Each indicator X_j is fuzzified by using a trapezoidal fuzzy membership function. The trapezoidal fuzzy membership function was chosen for several purposes. Firstly, it is very simple for interpreting and understanding, and secondly, for classifying countries we need ranges that include zones of absolute confidence. Trapezoidal membership function with five linguistic terms are presented in Fig.2.

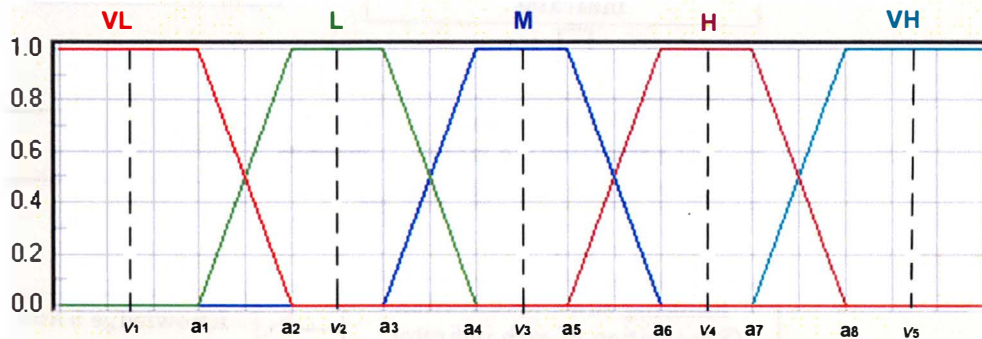


Fig.2. Trapezoidal Membership Function

As demonstrated in (Nedosekin, 2003) for fuzzifying we have to divide the range $[v_i, v_{i+1}]$ into three zones: a zone of absolute confidence, a diminished confidence zone and a zone of absolute uncertainty. The length of these three zones represent a proportion of $1:u:1$, where $u \geq 0$ expresses the depth of uncertainty. Thus, when $u = 0$ there is no diminished confidence, and the distinction between zones is hard (as in a numerical interval). For a standard five level fuzzy qualifier, $u = 2$. Thus, the choice of u is left to the choice of qualifier developers. For indicators we chose $u = 1$ and for aggregating indicators $u = 2$. Each point in the fuzzy set is calculated according to:

$$\begin{aligned}
a_1 &= v_1 + \frac{v_2 - v_1}{3}; a_2 = v_2 - \frac{v_2 - v_1}{3}; a_3 = v_2 + \frac{v_3 - v_2}{3}; a_4 = v_3 - \frac{v_3 - v_2}{3}; \\
a_5 &= v_3 + \frac{v_4 - v_3}{3}; a_6 = v_4 - \frac{v_4 - v_3}{3}; a_7 = v_4 + \frac{v_5 - v_4}{3}; a_8 = v_5 - \frac{v_5 - v_4}{3}
\end{aligned} \tag{2.1}$$

After determining each point in a fuzzy set, each trapezoidal membership function for each linguistic term can be presented as:

$$\mu_{VL}(x) = \begin{cases} 1 & \text{for } 0 \leq x \leq a_1 \\ \frac{a_2 - x}{a_2 - a_1} & \text{for } a_1 \leq x \leq a_2 \\ 0 & \text{otherwise} \end{cases}, \tag{2.2a}$$

$$\mu_L(x) = \begin{cases} \frac{x - a_1}{a_2 - a_1} & \text{for } a_1 \leq x \leq a_2 \\ 1 & \text{for } a_2 \leq x \leq a_3 \\ \frac{a_4 - x}{a_4 - a_3} & \text{for } a_3 \leq x \leq a_4 \\ 0 & \text{otherwise} \end{cases}, \tag{2.2b}$$

$$\mu_M(x) = \begin{cases} \frac{x - a_4}{a_4 - a_3} & \text{for } a_3 \leq x \leq a_4 \\ 1 & \text{for } a_4 \leq x \leq a_5 \\ \frac{a_6 - x}{a_6 - a_5} & \text{for } a_5 \leq x \leq a_6 \\ 0 & \text{otherwise} \end{cases}, \tag{2.2c}$$

$$\mu_H(x) = \begin{cases} \frac{x-a_6}{a_6-a_5} & \text{for } a_5 \leq x \leq a_6 \\ 1 & \text{for } a_6 \leq x \leq a_7 \\ \frac{a_8-x}{a_8-a_7} & \text{for } a_7 \leq x \leq a_8 \\ 0 & \text{otherwise} \end{cases}, \quad (2.2d)$$

$$\mu_{VH}(x) = \begin{cases} \frac{x-a_8}{a_8-a_7} & \text{for } a_7 \leq x \leq a_8 \\ 1 & \text{otherwise} \end{cases}. \quad (2.2f)$$

Then to any quantitative valuation of the indicator, the vector from the five values of corresponding membership functions can be shown as:

$$Z^*(x) = \{\mu_{VL}(x), \mu_L(x), \mu_M(x), \mu_H(x), \mu_{VH}(x)\}, \quad (2.3)$$

where

x is the quantitative value of the factor, and

$\mu_i(x)$ is the membership function that links it to the fuzzy set.

The sum of all components of vector $Z^*(x)$ is equal to 1 (consistency of a grey scale in Pospelov's sense (Nedosekin, 2003)). Thus from three to four values of a vector may be zero (the level belongs to a maximum of two qualitative descriptions of the membership, with a sum equal to 1).

Step 4: As proposed by World Bank reports on Doing Business (World Bank 2003, 2004, 2005, 2006, 2007), we build our hierarchy according to their recommendations. They assume that each indicator and sub-indicator are equal, not taking the weight of indicators into account. The mathematical model of Ease of Doing Business (EDB) can be presented as follows:

$$EDB = \langle G, L, F \rangle,$$

where: G - treelike hierarchy of indicators, L - a set of linguistic variables with linguistic terms, F - system of preference relations of one indicator (sub-indicator) to another indicator (sub-indicator) in one level of the hierarchy.

Thus:

$L = \{VL \text{ (Very Low)}, L \text{ (Low)}, M \text{ (Medium)}, H \text{ (High)}, VH \text{ (Very High)}\}$ for individual indicators, and
 $L = \{VE \text{ (Very Easy)}, E \text{ (Easy)}, A \text{ (Average)}, D \text{ (Difficult)}, VD \text{ (Very Difficult)}\}$ for sub-indices (aggregating indicators).

$$F = \{F_j(\varphi)F_k \mid \varphi \in (\succ, \approx)\},$$

where: \succ - the preference relation, \approx - the indifference relation.

For example, the hierarchy G on Fig.3 can be described as a focused graph without cycles, loops, or horizontal edges within the limits of one level of the range, and containing one root top:

$$G = \langle \{F_i\}, \{A_{ij}\} \rangle,$$

where $\{F_i\}$ - set of tops of sub-indicators; $\{A_{ij}\}$ - set of arches; F_0 - the root top that gives the country status as a whole.

We present here only part of the hierarchy of our indicators. The indicators and their relationships to sub-indicators will be presented in the example demonstration in Section 4.

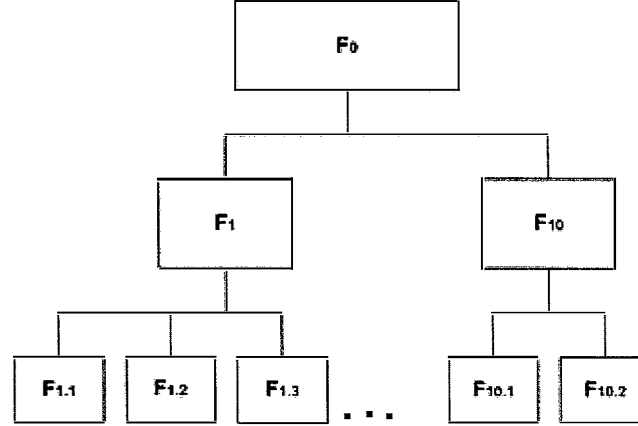


Fig.3. The Hierarchy of Indicators

We have assumed that almost all indicators in the hierarchy are equivalent. This was done for comparison purposes between our fuzzy classification system and the World Bank results. In real situations additional research is needed for determining the relative importance of each indicator. This can be done by gathering data from experts. From the example in Fig 3 we have:

$$F_0 = f(F_1, \dots, F_{10}), \quad F_1 = f(F_{1.1}, F_{1.2}, F_{1.3}), \quad F_{10} = f(F_{10.1}, F_{10.2}),$$

$$F_i = \{F_1 \approx \dots \approx F_{10}; F_{1.1} \approx F_{1.2} \approx F_{1.3}; \dots; F_{10.1} \approx F_{10.2}\}.$$

Step 5: Aggregation of several input values into a single output value is a crucial tool in many disciplines. The arithmetic mean is probably the most commonly used aggregation operator, which simply averages the input values. Weighted arithmetic means are also commonly used when the inputs have associated weights, which usually reflect the relative importance of the inputs. There is also a wide range of other averaging aggregation operators, which provide great flexibility to the modeling process. These include Ordered Weighted Averaging (OWA) operators. Yager and Kleinovich (2002) have recently shown that these operators are universal and the “best to use (in some reasonable sense)”.

Suppose we have N inputs, that should be aggregated in one output. We have also k outputs in hierarchy G . Thus we can aggregate all vectors for individual indicators $Z_k^*(x)$ in hierarchy G with weights W under the formula:

$$Z_k^*(x) = \sum_{i=1}^N w_i \times \{\mu_{iVl}(x_i), \mu_{iL}(x_i), \mu_{iM}(x_i), \mu_{iH}(x_i), \mu_{iVH}(x_i)\} =$$

$$\left\{ \sum_{i=1}^N w_i \times \mu_{iVl}(x_i), \sum_{i=1}^N w_i \times \mu_{iL}(x_i), \sum_{i=1}^N w_i \times \mu_{iM}(x_i), \sum_{i=1}^N w_i \times \mu_{iH}(x_i), \sum_{i=1}^N w_i \times \mu_{iVH}(x_i) \right\}$$

This results in the aggregated vector $Z_k^*(x)$ with five values of the corresponding membership functions:

$$Z_k^*(x) = \{\mu_{VE}(x), \mu_E(x), \mu_A(x), \mu_D(x), \mu_{VD}(x)\},$$

where x is the quantitative value of the factor and $\mu_i(x)$ is the membership function in the fuzzy set.

This aggregated vector (averaging vector) can be interpreted as follows. It is a conclusion or aggregation of all combined meanings expressed by the trapezoidal numbers Z_1, \dots, Z_n considered either of equal importance or different importance, depending on the weights w_i . The process of averaging is a cross section of classical statistics and fuzzy set theory, and belongs to a new branch of science- fuzzy statistics (Bojadziev and Bojadziev, 1997).

Step 6: The aggregation, defined by its trapezoidal numbers, has to be expressed by crisp values which are best for the corresponding aggregation. This operation is called defuzzification, an operation that produces a nonfuzzy output, a single value \hat{z} , that adequately represents the aggregated vector $Z_k^*(x)$.

This output must then be ranked for country linguistic classification and comparison. As noted in Bojadziev and Bojadziev (1997), there is no unique way to perform the defuzzification operation. Three methods for defuzzification are widely used: the Center-of-Maximum Method (COM), the Center-of-Gravity method (COG) or Center-of-Area method (COA), and the Mean-of-Maxima method (MOM).

Because more than one output linguistic term could be regarded as valid, the defuzzification method must compromise between different results. (Bojadziev and Bojadziev, 1997). The Center-of-Maximum Method (COM) does this by computing a crisp output as a weighted average of the membership maxima, weighted by the results. The Mean-of-Maximum Method (MOM), computes a system output only for the term with the highest membership between all linguistic terms. Most COA implementations are only approximations since they neglect overlap and can be represented by the COM defuzzification method (Bojadziev and Bojadziev, 1997).

While the COM and COA defuzzification methods result in the “best compromise solution,” MOM results in the “most plausible solution”. The COM defuzzification method was chosen for our work. When we have trapezoidal fuzzy membership functions we can use the midpoint (center) of range of the trapezoidal fuzzy number for each linguistic term at the maximum level, when $\mu_i = 1$. Since we use a fuzzy set with a standard (uniform) five linguistic terms for aggregation, the centers of maximum are $z_{i\max} = \{0.1, 0.3, 0.5, 0.7, 0.9\}$, and the crisp output \hat{z} can be calculated in our case as follows:

$$\hat{z} = \frac{\sum_{i=1}^N \mu_i \times z_{i\max}}{\sum_{i=1}^N \mu_i}.$$

Step 7: All countries are ranked by each of their aggregated indicators, so each indicator for each country is recognized in the resulting linguistic description. In this step we derive knowledge rules for each level in the hierarchy G. For example, the knowledge rule for F_1 can be presented as:

IF $F_{1,1} = (VL, L, M, H, VH)$ and $F_{1,2} = (VL, L, M, H, VH)$ and $F_{1,3} = (VL, L, M, H, VH)$,
THEN $F_1 = (VE, E, A, D, VD)$.

These rules can be presented for all hierarchy levels in matrix or tabular form.

4. ILLUSTRATIVE EXAMPLE

Data

Doing Business reports from the World Bank are a series of annual reports investigating the regulations that enhance business activity and those that constrain it. Doing Business presents quantitative indicators on business regulations and the protection of property rights that can be compared across 178 economies—from Afghanistan to Zimbabwe—and over time (World Bank, 2007). Regulations affecting 10 stages of a business's life are measured: starting a business, dealing with licenses, employing workers, registering property, getting credit, protecting investors, paying taxes, trading across borders, enforcing contracts, and closing a business. The indicators are used to analyze economic outcomes and identify what reforms have worked, where, and why (World Bank, 2007).

The indicators presented and analyzed in the Doing Business Survey measure business regulation and the protection of property rights—and their effect on businesses, especially small and medium-size domestic firms (World Bank, 2007). First, the indicators document the degree of regulation, such as the number of procedures to start a business or register commercial property. Second, they determine regulatory outcomes, such as the time and cost to enforce a contract, to go through bankruptcy or trade across borders. Third, they measure the degree of legal protection of property - for example, the protection of investors against looting by company directors or the range of assets that can be used as collateral according to security transaction laws. Fourth, they measure the flexibility of employment regulation. Finally, a set of indicators documents the tax burden on businesses (World Bank, 2005, 2006, 2007). The Ease of Doing Business index ranks economies from 1 to 178. The index is calculated as the ranking on the simple average of country percentile rankings on each of the 10 topics (sub- indicators) covered in Doing Business 2008. The ranking on each topic is the simple average of the percentile rankings on its component indicators (World Bank, 2003, 2004, 2005, 2006, 2007). This research is based on a Doing Business 2004-2008 data set from World Bank, which is available online. We do not describe here each indicator, since their definitions for each year can be found in Doing Business reports (World Bank 2003, 2004, 2005, 2006, 2007). The availability of data for each year is presented in Table 1. We will illustrate calculations only for one year - the Doing Business report (World Bank, 2007), named Doing Business 2008 for Canada.

Table 1. World Bank Data Availability

No	Aggregated Indicator	No	Indicator*	Doing Business Reports					
				2004	2005	2006	2007	2008	
				Number of countries					
				133	145	155	175	178	
1	Starting a Business	1.1	s	Procedures (number)	***	+	+	+	+
		1.2	s	Time (days)	+	+	+	+	+
		1.3	s	Cost (% of income per capita)	+	+	+	+	+
		1.4	s	Min. capital (% of income per capita)	+	+	+	+	+
2	Dealing with Licenses	2.1	s	Procedures (number)	***	-	+	+	+
		2.3	s	Time (days)	-	-	+	+	+
		2.4	s	Cost (% of income per capita)	-	-	+	+	+
3	Employing Workers	3.1.1	s	Difficulty of Hiring Index	+	+	+	+	+
		3.1.2	s	Rigidity of Hours Index	+	+	+	+	+
		3.1.3	s	Difficulty of Firing Index	+	+	+	+	+
		3.1	a	Rigidity of Employment Index	+	+	+	+	+
		3.2	s	Nonwage labor cost (% of salary)	-	-	+	+	+
		3.3	s	Firing Costs (weeks)	+	+	+	+	+
4	Registering Property	4.1	s	Procedures (number)	-	+	+	+	+
		4.2	s	Time (days)	-	+	+	+	+
		4.3	s	Cost (% of property value)	-	+	+	+	+
5	Getting Credit	5.1	s	Legal Rights Index	-	+	+	+	+
		5.2	s	Credit Information Index	+	+	+	+	+
6	Protecting Investors	6.1	s	Disclosure Index	-	-	+	+	+
		6.2	s	Director Liability Index	-	-	+	+	+
		6.3	s	Shareholder Suits Index	-	-	+	+	+
7	Paying Taxes	7.1	s	Payments (number)	-	-	+	+	+
		7.2	s	Time (hours)	-	-	+	+	+
		7.3.1	s	Profit tax (%)	-	-	-	-	+
		7.3.2	s	Labor tax and contributions (%)	-	-	-	-	+

		7.3.3	s	Other taxes (%)	-	-	-	-	+
		7.3	a	Total tax rate (% profit)	-	-	+	+	+
8	Trading	8.1.1	s	Documents for export (number)	-	-	+	+	+
	Across								
	Borders	8.1.2	s	Time for export (days)	-	-	+	+	+
		8.1.3	s	Cost to export (US\$ per container)	-	-	+	+	+
		8.1	a	Easy to Export	-	-	+	+	+
		8.2.1	s	Documents for import (number)	-	-	+	+	+
		8.2.2	s	Time for import (days)	-	-	+	+	+
		8.2.3	s	Cost to import (US\$ per container)	-	-	+	+	+
		8.2	a	Easy to Import	-	-	+	+	+
9	Enforcing	9.1	s	Procedures (number)	+	+	+	+	+
	Contracts	9.2	s	Time (days)	+	+	+	+	+
		9.3	s	Cost (% of debt)	+	+	+	+	+
10	Closing	10.1.1	s	Time (years)	+	+	+	+	+
	Business	10.1.2	s	Cost (% of estate)	+	+	+	+	+
		10.1	a	Recovery rate (cents on the dollar)	+	+	+	+	+
Number of composite indicators 1-10					5	6	10	10	10
Number of simple indicators					14	17	33	33	36

* s- simple indicator, a- aggregated (composite) indicator;

** "+ " - data available, "- " - data not available.

It should be mentioned that for aggregated indicators "Starting a Business (SB)" (1), "Dealing with Licenses (DL)" (2), "Employing Workers (EW)" (3), "Registering Property (RP)" (4), "Paying Taxes (PT)" (7), "Trading Across Borders (TAB)" (8), "Enforcing Contracts (EC)" (9) low values of indicators are more desirable, but for aggregated indicators "Getting Credit (GC)" (5), "Protecting Investors (PI)" (6) and "Closing Business (CB)" (10) high values are better.

Step 1. Clustering

For example, doing the clustering procedures for indicator $x_{1,1}$ - "Procedures for Starting Business" resulted in the following prototypes (class centers) $V_{1,1} = \{10.49, 8.40, 13.15, 3.14, 5.9\}$.

Step 2. Ranking

A fuzzy set with five linguistic terms was chosen. Their centers are termed C_4, C_3, C_5, C_1 and C_2 and their definitions in each case are L_4, L_3, L_5, L_1 and L_2 , respectively. In this step we also determine each linguistic term for each linguistic variable. We define for all individual indicators the following linguistic terms:

$L_i = \{VL \text{ (Very Low)}, L \text{ (Low)}, M \text{ (Medium)}, H \text{ (High)}, VH \text{ (Very High)}\}.$

After ranking indicator $x_{1,1}$ - "Procedures for Starting Business"
 $V_{1,1} = \{v_{1,1,1}, v_{2,1,1}, v_{3,1,1}, v_{4,1,1}, v_{5,1,1}\} = \{v_{VL,1,1}, v_{L,1,1}, v_{M,1,1}, v_{H,1,1}, v_{VH,1,1}\} = \{3.14, 5.9, 8.40, 10.49, 13.15\}$

Clustering results for all indicators and their ranking of Doing Business 2008 are presented in Table 2.

Table 2. Prototypes (class centers) for All Indicators (2008)

a) For simple indicators

Linguistic scale	1. Starting Business				2. Dealing with Licenses				3. Employing Workers				
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1.1	3.1.2	3.1.3	3.1	3.2	3.3
VL	3.14	10.21	5.46	0.43	10.17	74.14	18.64	10	10	10	10	2.52	4.49
L	5.90	24.05	21.29	17.06	14.10	142.36	62.40	30	30	30	30	10.77	21.81
M	8.40	38.17	38.97	34.05	18.78	205.18	121.84	50	50	50	50	18.41	36.86
H	10.49	54.60	57.19	55.73	24.01	254.37	188.51	70	70	70	70	27.08	58.38
VH	13.15	76.87	85.78	97.85	31.95	336.17	253.52	90	90	90	90	37.97	95.47

Linguistic scale	4. Registering Property			5. Getting Credit		6. Protecting Investors			7. Paying Taxes					
	4.1	4.2	4.3	5.1	5.2	6.1	6.2	6.3	7.1	7.2	7.3.1	7.3.2	7.3.3	7.3
VL	2.72	13.47	0.96	1.5	0.00	1.5	1.5	1.5	9.25	74.37	1.08	2.72	2.02	19.64
L	4.80	44.37	4.07	3.5	1.17	3.5	3.5	3.5	21.61	139.61	11.00	11.11	7.57	35.67
M	6.21	77.97	6.94	5.5	2.83	5.5	5.5	5.5	35.70	211.83	18.39	19.70	20.10	48.64
H	8.23	127.86	10.84	7.5	4.04	7.5	7.5	7.5	53.97	285.98	26.28	29.02	36.99	63.24
VH	12.83	189.97	14.72	9.5	5.45	9.5	9.5	9.5	84.98	407.77	32.34	42.22	75.82	79.89

Linguistic scale	8. Trading Across Borders					9. Enforcing Contracts			10. Closing Business			
	8.1.1	8.1.2	8.1.3	8.1	8.2.1	8.2.2	8.2.3	8.2	9.1	9.2	9.3	10.10
VL	4.04	9.29	542.80	0.10	4.65	10.58	620.90	0.10	27.34	263.46	14.56	1.34
L	5.87	19.89	793.30	0.30	6.75	22.29	993.20	0.30	33.49	420.54	23.92	19.32
M	7.01	30.06	1045.60	0.50	8.47	37.93	1331.20	0.50	38.68	556.93	33.19	32.91
H	8.35	50.84	1309.00	0.70	10.50	65.18	1913.70	0.70	44.08	701.91	46.88	46.86
VH	11.10	83.65	1735.80	0.90	13.42	100.70	2643.00	0.90	50.72	874.06	78.13	82.18

b) For aggregated indicators

Linguistic scale *	Aggregated Indicators
C	d
Range	[0-1]
VE	VD
	0.10

E	D	0.30
A	A	0.50
D	E	0.70
VD	VE	0.90

- * c) For aggregated indicators: DB overall, 1, 2, 3, 4, 7, 8, 9;
d) For aggregated indicators: 5, 6, 10.

Step 3. Indicator Fuzzification

The points $a_{1.1.1}, a_{2.1.1}, a_{3.1.1}, a_{4.1.1}, a_{5.1.1}, a_{6.1.1}, a_{7.1.1}, a_{8.1.1}$ are calculated according to formula (2.1) from the previous section. Thus for indicator $x_{1.1}$ - "Procedures for Starting Business" we have:

$$a_{1.1.1} = v_{1.1.1} + \frac{v_{2.1.1} - v_{1.1.1}}{3} = 3.14 + \frac{5.9 - 3.14}{3} = 4.06$$

$$a_{2.1.1} = v_{2.1.1} - \frac{v_{2.1.1} - v_{1.1.1}}{3} = 5.9 - \frac{5.9 - 3.14}{3} = 4.98;$$

$$a_{3.1.1} = v_{2.1.1} + \frac{v_{3.1.1} - v_{2.1.1}}{3} = 5.9 + \frac{8.4 - 5.9}{3} = 6.73;$$

$$a_{4.1.1} = v_{3.1.1} - \frac{v_{3.1.1} - v_{2.1.1}}{3} = 8.4 - \frac{8.4 - 5.9}{3} = 7.56;$$

$$a_{5.1.1} = v_{3.1.1} + \frac{v_{4.1.1} - v_{3.1.1}}{3} = 8.4 + \frac{10.49 - 8.4}{3} = 9.09;$$

$$a_{6.1.1} = v_{4.1.1} - \frac{v_{4.1.1} - v_{3.1.1}}{3} = 10.49 - \frac{10.49 - 8.4}{3} = 9.79;$$

$$a_{7.1.1} = v_{4.1.1} + \frac{v_{5.1.1} - v_{4.1.1}}{3} = 10.49 + \frac{10.49 - 8.4}{3} = 11.37;$$

$$a_{8.1.1} = v_{5.1.1} - \frac{v_{5.1.1} - v_{4.1.1}}{3} = 13.15 - \frac{13.15 - 10.49}{3} = 12.26.$$

Fuzzy numbers for the linguistic terms for all (four) indicators (1.1,1.2,1.2,1.4) of the Starting Business composite indicator (1) of Doing Business 2008 are presented in Table 3.

Table 3. Trapezoidal Fuzzy Numbers for Starting Business Indicators (2008)

	Linguistic variable: 1.1. Number of procedures	1.2. Time (days)	1.3. Cost (% of income per capita)
Linguistic term			
VL <i>Very Low</i>	(0, 0, 4.06, 4.98)	(0, 0, 14.8, 19.4)	(0, 0, 10.7, 16.0)
L <i>Low</i>	(4.06, 4.98, 6.73, 7.56)	(14.8, 19.4, 28.7, 33.4)	(10.7, 16.0, 27.1, 33.0)
M <i>Medium</i>	(6.73, 7.56, 9.09, 9.79)	(28.7, 33.4, 43.6, 49.1)	(27.1, 33.0, 45.0, 51.1)
H <i>High</i>	(9.09, 9.79, 11.37, 12.26)	(43.6, 49.1, 62.0, 69.4)	(45.0, 51.1, 66.7, 76.2)
VH <i>Very High</i>	(11.37, 12.26, 20, 20)	(62.0, 69.4, 69.4, 69.4)	(66.7, 76.2, 107.5.2, 107.5.2)

Linguistic variable: 1.4. Min. capital (% of income per capita)

1. Starting Business

Linguistic term

VL <i>Very Low</i>	(0, 0, 5.97, 11.5)	(0, 0, 0.15, 0.25)
L <i>Low</i>	(5.97, 11.5, 22.7, 28.3)	(0.15, 0.25, 0.35, 0.45)
M <i>Medium</i>	(22.7, 28.3, 41.2, 48.5)	(0.35, 0.45, 0.55, 0.65)
H <i>High</i>	(41.2, 48.5, 69.7, 83.8)	(0.55, 0.65, 0.75, 0.85)
VH <i>Very High</i>	(69.7, 83.8, 3673.3, 3673.3)	(0.75, 0.85, 1, 1)

Graphically the membership function for indicator $x_{1,1}$ - “Procedures for Starting Business” can be represented as in Fig.4. All other graphical membership functions for all indicators for Doing Business 2008 are presented in Appendix 1.

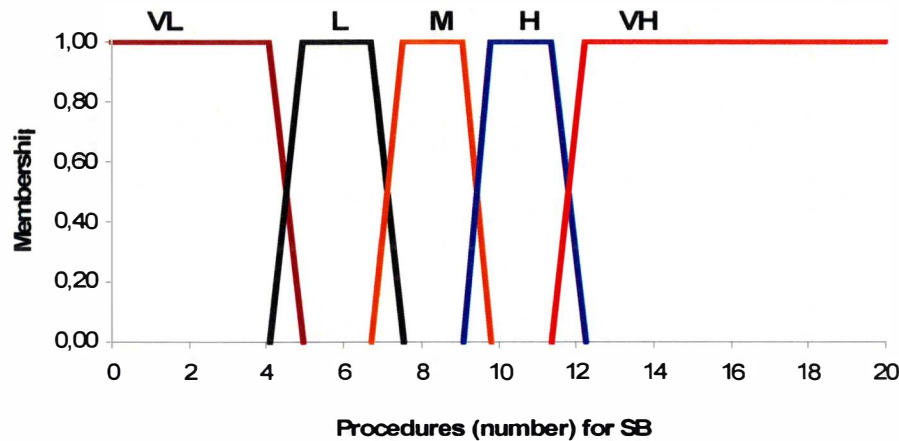


Fig.4. Membership Function for Linguistic Variable $x_{1,1}$ - “Procedures for Starting Business”.

At this step we have to identify linguistically (classify) and fuzzify the indicator $x_{1,1}$ - “Procedures for Starting Business”. For example, for Canada $x_{1,1}=2$. Looking at fig. 4 we can determine that it should be “Very Low (VL)”. This can be done by applying the following simple algorithm:

```

IF  $X_{ik} \geq a_n$ , THEN  $X_{ik}$  is VH;
IF  $X_{ik} \geq a_{n-1}$ , THEN  $X_{ik}$  is VH&H;
IF  $X_{ik} \geq a_{n-2}$ , THEN  $X_{ik}$  is H;
IF  $X_{ik} \geq a_{n-3}$ , THEN  $X_{ik}$  is H&M;
IF  $X_{ik} \geq a_{n-4}$ , THEN  $X_{ik}$  is M;
IF  $X_{ik} \geq a_{n-5}$ , THEN  $X_{ik}$  is M&L;
IF  $X_{ik} \geq a_{n-6}$ , THEN  $X_{ik}$  is L;
IF  $X_{ik} \geq a_{n-7}$ , THEN  $X_{ik}$  is VL&L;
ELSE  $X_{ik}$  is VL.

```

The following step is fuzzification, based on formula 2.2a, for the linguistic term “Very Low (VL)” with membership $\mu_{VL1.1} = 1$, and $\mu_{L1.1} = \mu_{M1.1} = \mu_{H1.1} = \mu_{VH1.1} = 0$.

$$\mu_{VL1.1}(x_{1.1}) = \begin{cases} 1 & \text{for } 0 \leq x \leq 4.06 \\ \frac{a_2 - x}{a_2 - a_1} & \text{for } 4.06 \leq x \leq 4.98. \\ 0 & \text{otherwise} \end{cases}$$

Thus we derive the vector for indicator $x_{1.1}$ - “Procedures for Starting Business” with five values of corresponding membership functions for Canada:

$$Z_{1.1}^*(x_{1.1}) = \{\mu_{VL_{1.1}}(x_{1.1}), \mu_{L_{1.1}}(x_{1.1}), \mu_{M_{1.1}}(x_{1.1}), \mu_{H_{1.1}}(x_{1.1}), \mu_{VH_{1.1}}(x_{1.1})\} = \{1, 0, 0, 0, 0\}.$$

At this step all indicators for all countries are identified linguistically and fuzzified.

Step 4. The Indicators Hierarchy

The hierarchy of indicators is presented in Fig.5.

For calculating the x_1 sub-indicator “Starting Business”, for example in Canada, the other vectors Z_i^* for $x_{1.2} = 3, x_{1.3} = 0.9, x_{1.4} = 0$, previously calculated, have to be aggregated. The weight of all indicators

are equal, so $w_{1.1} = w_{1.2} = w_{1.3} = w_{1.4} = \frac{1}{4} = 0.25$.

$$Z_{1.1}^*(x_{1.1}) = \{\mu_{VL_{1.1}}(x_{1.1}), \mu_{L_{1.1}}(x_{1.1}), \mu_{M_{1.1}}(x_{1.1}), \mu_{H_{1.1}}(x_{1.1}), \mu_{VH_{1.1}}(x_{1.1})\} = \{1, 0, 0, 0, 0\}$$

$$Z_{2.1}^*(x_{2.1}) = \{\mu_{VL_{2.1}}(x_{2.1}), \mu_{L_{2.1}}(x_{2.1}), \mu_{M_{2.1}}(x_{2.1}), \mu_{H_{2.1}}(x_{2.1}), \mu_{VH_{2.1}}(x_{2.1})\} = \{1, 0, 0, 0, 0\}$$

$$Z_{3.1}^*(x_{3.1}) = \{\mu_{VL_{3.1}}(x_{3.1}), \mu_{L_{3.1}}(x_{3.1}), \mu_{M_{3.1}}(x_{3.1}), \mu_{H_{3.1}}(x_{3.1}), \mu_{VH_{3.1}}(x_{3.1})\} = \{1, 0, 0, 0, 0\}$$

$$Z_{4.1}^*(x_{4.1}) = \{\mu_{VL_{4.1}}(x_{4.1}), \mu_{L_{4.1}}(x_{4.1}), \mu_{M_{4.1}}(x_{4.1}), \mu_{H_{4.1}}(x_{4.1}), \mu_{VH_{4.1}}(x_{4.1})\} = \{1, 0, 0, 0, 0\}.$$

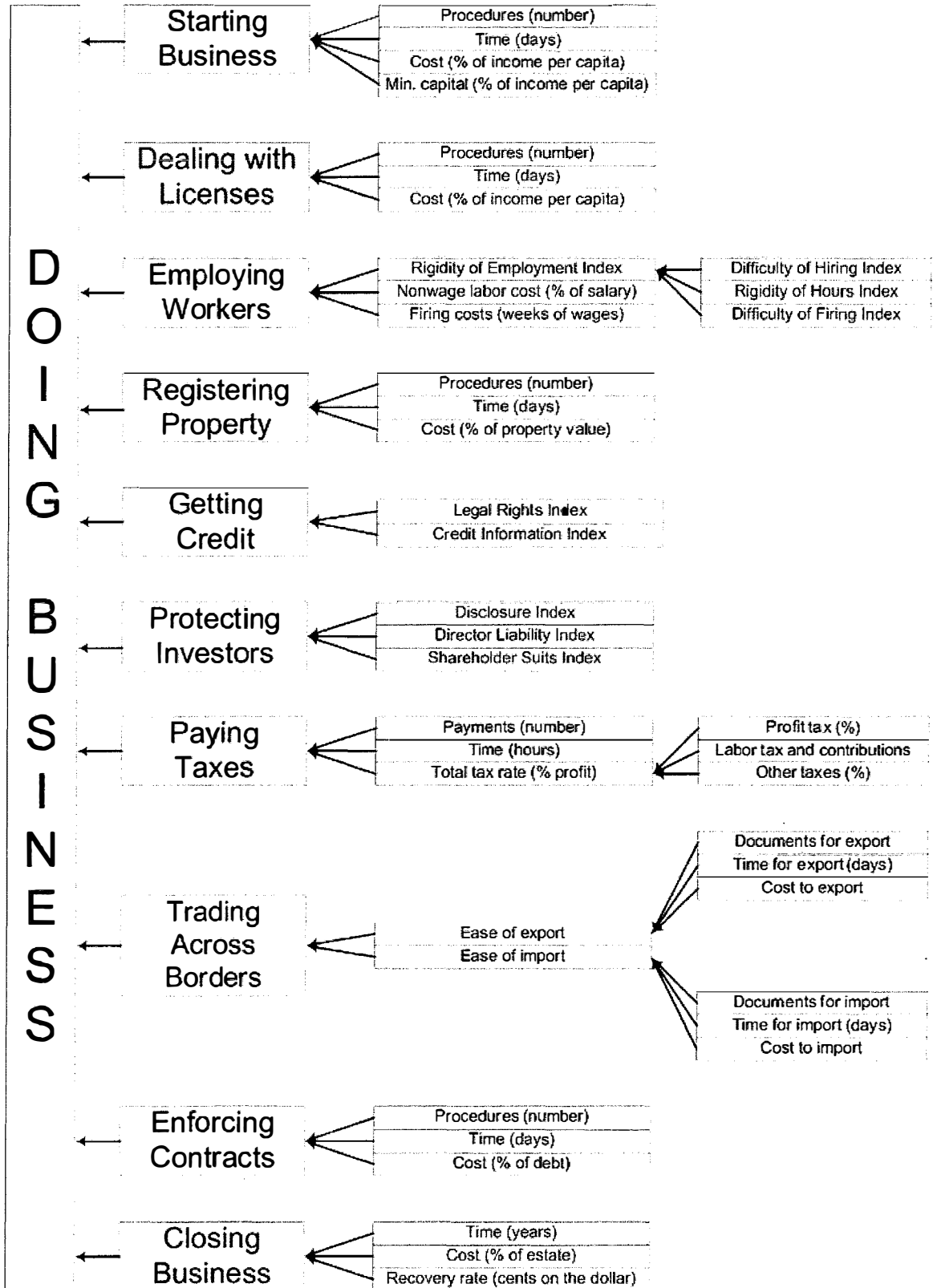


Fig.5. The Hierarchy of "Ease of Doing Business" Indicators

$$\begin{aligned}
Z_1^*(x_1) &= \sum_{i=1}^N w_i \times \{\mu_{iVL}(x_i), \mu_{iL}(x_i), \mu_{iM}(x_i), \mu_{iH}(x_i), \mu_{iVH}(x_i)\} = \\
&= \left\{ \sum_{i=1}^N w_i \times \mu_{iVL}(x_i), \sum_{i=1}^N w_i \times \mu_{iL}(x_i), \sum_{i=1}^N w_i \times \mu_{iM}(x_i), \sum_{i=1}^N w_i \times \mu_{iH}(x_i), \sum_{i=1}^N w_i \times \mu_{iVH}(x_i) \right\} = \\
&= \{0.25 \times 1 + 0.25 \times 1 + 0.25 \times 1 + 0.25 \times 1, 0.25 \times 0 + 0.25 \times 0 + 0.25 \times 0 + 0.25 \times 0, \dots \\
&0.25 \times 0 + 0.25 \times 0 + 0.25 \times 0 + 0.25 \times 0\} = \{1, 0, 0, 0, 0\}
\end{aligned}$$

The result is:

$$Z_1^*(x_1) = \{\mu_{VE_1}(x_1), \mu_{L_1}(x_1), \mu_{M_1}(x_1), \mu_{H_1}(x_1), \mu_{VH_1}(x_1)\} = \{1, 0, 0, 0, 0\}.$$

Step 6. Defuzzification

The membership function for the standard (uniform) classifier for five linguistic terms is presented in Fig.6..

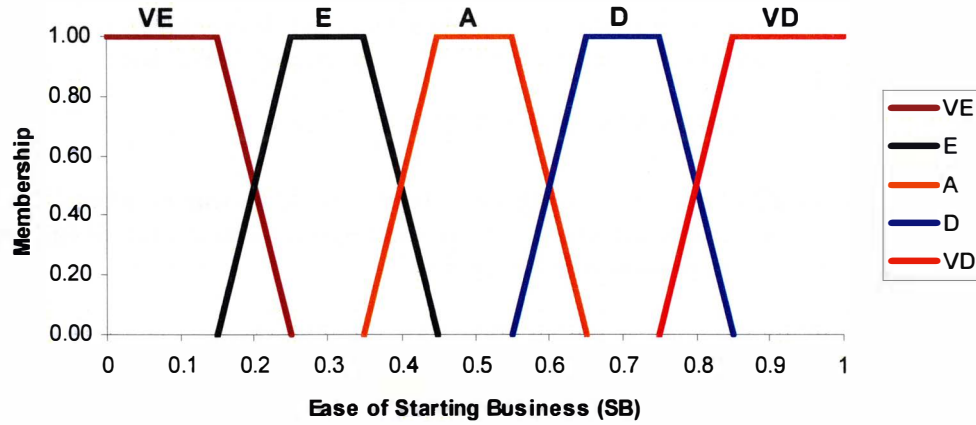


Fig.6. Membership Function for Five Level Classifier

We use for aggregation the fuzzy set with the standard (uniform) five linguistic terms, and the centers of maxima are $z_{i\max} = \{0.1, 0.3, 0.5, 0.7, 0.9\}$. The crisp output \hat{z}_1 can be calculated in our case as follows:

$$\hat{z}_1 = \frac{\sum_{i=1}^N \mu_i \times z_{i\max}}{\sum_{i=1}^N \mu_i} = \frac{1 \times 0.1 + 0 \times 0.3 + 0 \times 0.5 + 0 \times 0.7 + 0 \times 0.9}{1 + 0 + 0 + 0 + 0} = 0.1$$

Step 7: Ranking

All the sub-indicators are then aggregated in “Ease of Doing Business” in the same way as above. All countries are then ranked by their aggregated indicators and each indicator for each country is recognized in its linguistic description.

The crisp number for the “Starting Business” aggregated indicator is 0.1, and it can be identified from Fig.6 and Table 3, as Very Easy (VE). Thus we develop the knowledge rule for the first sub-indicator x_1 “Starting Business”, for Canada as:

IF Procedures for Starting Business is *Very Low*, and
Time for Starting Business is *Very Low*, and
Cost for Starting Business is *Very Low*, and
Minimal capital for Starting Business is *Very Low*,
THEN Starting Business in this Country is *Very Easy*.

All other indicators and the EDB composite indicators are calculated similarly.

5. RESULTS

In previous studies on Doing Business 2008 the index “Ease of Doing Business” was calculated as the ranking on the simple average of country percentile rankings on each of the 10 topics covered in Doing Business 2008. The ranking on each topic is the simple average of the percentile rankings on its component indicators (World Bank 2006, 2007). In this study another approach for composite EDB indicators is proposed. This approach employed fuzzy set theory which is very effective for integrating various indicators which are too complicated and multifaceted to evaluate.

5.1. EASE OF DOING BUSINESS IN WORLD COUNTRIES

Number and percent of countries in linguistic classes for all indicators for each research year is presented in Appendix 2. Number and percent of countries in linguistic classes for all aggregated (1-10) indicators for each research year is presented in Appendix 3.

The main result for all countries during 2004-2008 years is presented in Table 4.

Table 4. Number of Countries in Linguistic Classes for Composite “Ease of Doing Business” Indicator (2008-2004)

Linguistic Term	Ease of Doing Business									
	Year					Year				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
	Countries (number)					Countries (%)				
VE	3	0	2	2	2	2.26	0.00	1.29	1.14	1.12
VE & E	12	9	8	9	8	9.02	6.21	5.16	5.14	4.49
E	15	9	11	9	14	11.28	6.21	7.10	5.14	7.87
E & A	17	22	27	37	34	12.78	15.17	17.42	21.14	19.10
A	33	38	48	59	64	24.81	26.21	30.97	33.71	35.96
A & D	25	41	45	45	44	18.80	28.28	29.03	25.71	24.72
D	26	26	14	14	12	19.55	17.93	9.03	8.00	6.74
D & VD	2	0	0	0	0	1.50	0.00	0.00	0.00	0.00
VD	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00

As we can see in 2008 only 2 countries or 1.12% of 178 countries can be classified as Very Easy by the composite “Ease of Doing Business” indicator. In 2004 it was 3 countries, and then their quality for “Ease

of Doing Business” became worse. It was difficult for Doing Business in 12 countries in 2008, or 6.74 %. Nearly 31.5 % or 56 countries in 2008 had difficulties in doing business, with this number growing over the time period from 2004 to 2008.

5.2. EASE OF DOING BUSINESS IN CANADA

Tables 5a and 5b present the main results on crisp numbers and our linguistic classification of all aggregated indicators for all the years for which Doing Business is available for Canada. Although data for Canada did not change (to our knowledge there were no major reforms) during these years, some of the linguistic interpretation (classification) results did change. These changes occurred due to changes in the overall data. For every year, the membership functions according to cluster centers were built individually, and other countries were added to the study. For example from the report on Doing Business 2004 to Doing Business 2008, 45 countries were added (World Bank 2003,2007).

Table 5. Main Results for Canada

a) Crisp numbers for aggregated indicators

Aggregated Indicator	Doing Business Reports				
	2004	2005	2006	2007	2008
Ease of Doing Business	0.1678	0.2340	0.2278	0.2453	0.2312
1. Starting a Business	0.100	0.100	0.100	0.100	0.100
2. Dealing with Licenses	-	-	0.300	0.300	0.300
3. Employing Workers	0.200	0.433	0.258	0.258	0.249
4. Registering Property	-	0.233	0.233	0.167	0.233
5. Getting Credit	6*	0.80	0.80	0.80	0.80
6. Protecting Investors	-	-	0.767	0.767	0.767
7. Paying Taxes	-	-	0.276	0.473	0.300
8. Trading Across Borders	-	-	0.233	0.267	0.267
9. Enforcing Contracts	0.339	0.337	0.344	0.355	0.330
10. Closing Business	0.890	0.900	0.900	0.890	0.888

b) Linguistic interpretation (class) of aggregated indicators

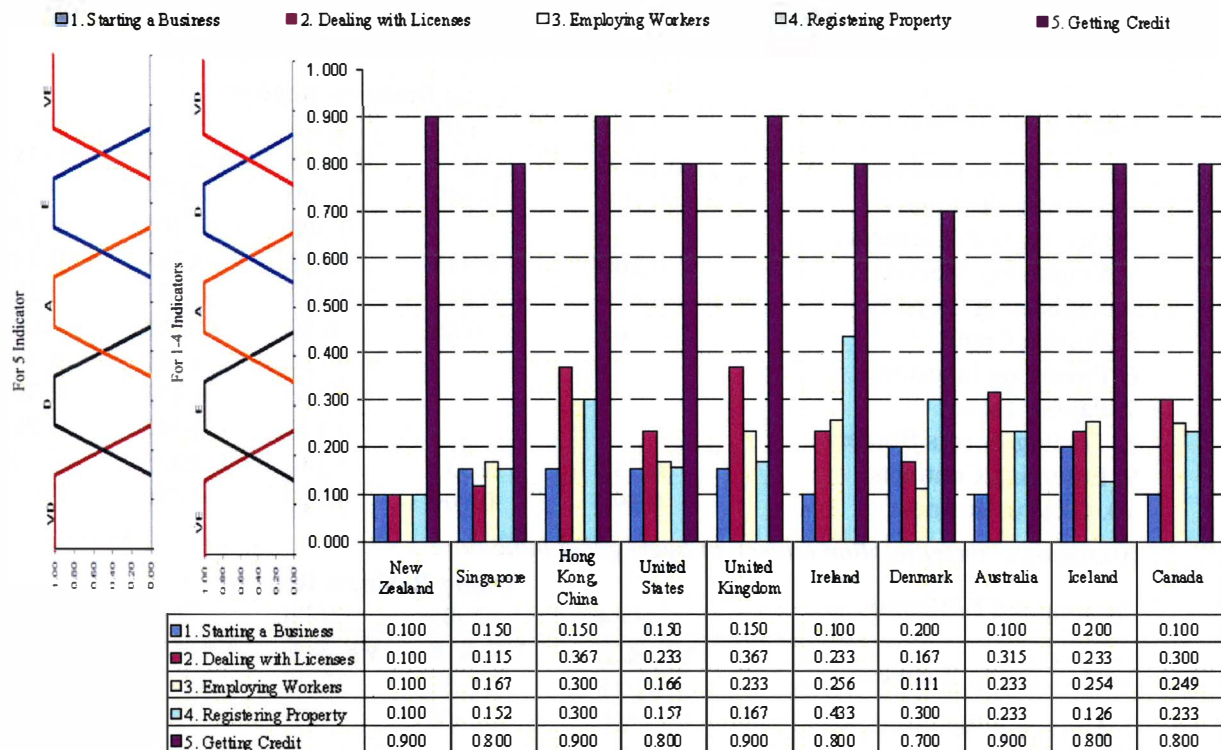
Aggregated Indicator		Doing Business Reports				
		2004	2005	2006	2007	2008
Ease of Doing Business	L	VE & E	VE & E	VE & E	VE & E	VE & E
	%	82:18	16:84	22:78	05:95	19:81
1. Starting a Business		VE	VE	VE	VE	VE
2. Dealing with Licenses		-	-	E	E	E
3. Employing Workers		VE & E	E & A	E	E	VE & E
4. Registering Property			VE & E	VE & E	VE & E	VE & E
5. Getting Credit		VE*	E & VE	E & VE	E & VE	E & VE
6. Protecting Investors		-	-	E & VE	E & VE	E & VE
7. Paying Taxes		-	-	E	A	E
8. Trading Across Borders		-	-	VE & E	E	E
9. Enforcing Contracts		E	E	E	E & A	E
10. Closing Business		VE	VE	VE	VE	VE

* in Doing Business 2004, “Getting Credit” is not an aggregating indicator.

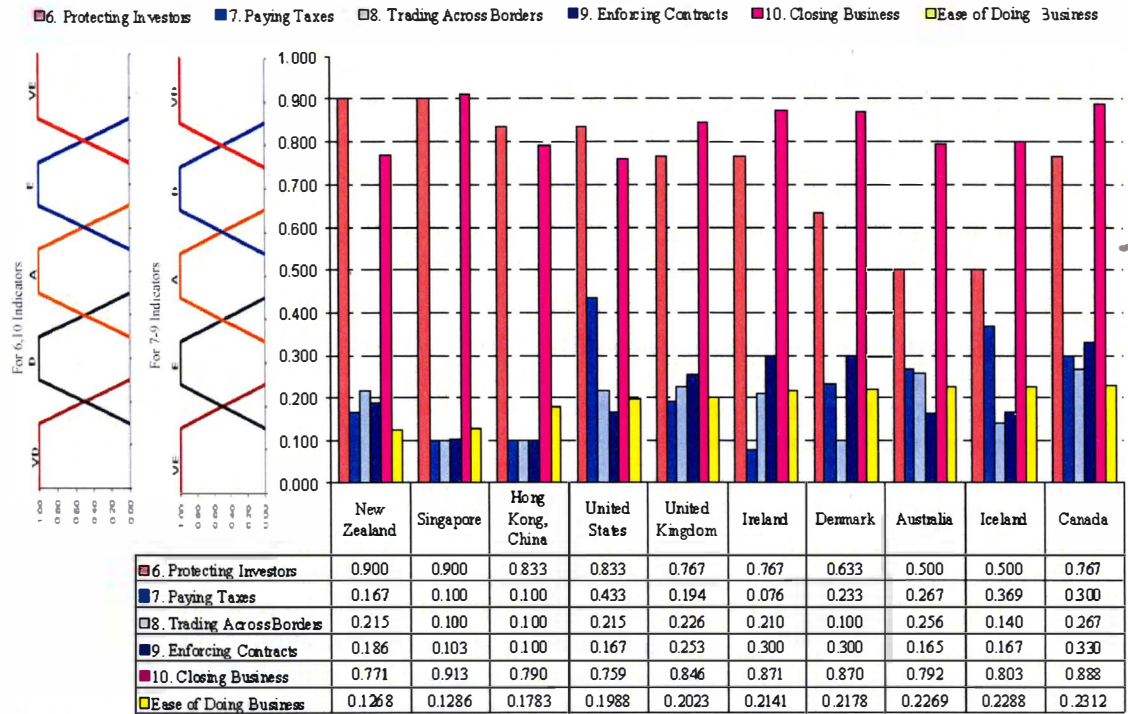
Low values for aggregated indicators (1-4, 7-9) are more desirable, but for the aggregated indicators “Getting Credit (GC)” (5), “Protecting Investors (PI)” (6) and “Closing Business (CB)” (10) higher values are better.

Table 5b can be used as a knowledge base for Canada during the 2004-2008 years. Although the “Ease of Doing Business” indicator for Canada did not change linguistically – it was between Very Easy and Easy, when identifying doing business in Canada it is more easy than very easy. For example, for Doing Business 2008 this indicator was only 19% Very Easy and 81% Easy. It was very easy to start and close business, more easy than very easy to employ workers, registering property, getting credit and protecting investors. It was easy to deal with licenses, to enforce contracts, to pay taxes and to trade across borders.

Figure 7 a,b presents the top ten countries in the world for Doing Business 2008, including Canada, where doing business is more easy.



a)



b)
Fig 7. Comparing Top 10 countries for Doing Business 2008 :
 a) 1-5 Indicators; b) 6-10 Indicators and EDB

Table 6 presents a linguistic interpretation of the results from Fig.7. It can be used as a knowledge base for these ten countries during the 2008 year. The “Ease of Doing Business” composite indicator for these ten countries is “Very Easy” and “Very Easy and Easy”. The only indicator that changed Canada’s performance among the top ten countries is “Ease of Total Tax “ indicator (7.3), which was “Medium” among the other country indicators.

Table 6. Linguistic Interpretation (class) of an Aggregated Indicators for Top Ten Countries *

Rank	Country	EDB	SB	DL	EW	RP	GC	PI
	Aggregated Indicator		1	2	3	4	5	6
1	New Zealand	VE	VE	VE	VE	VE	VE	VE
2	Singapore	VE	VE	VE	VE & E	VE & E	E & VE	VE
3	Hong Kong, China	VE & E	VE	E & A	E	E	VE	E & VE
4	United States	VE & E	VE	VE & E	VE & E	VE & E	E & VE	E & VE
5	United Kingdom	VE & E	VE	E & A	VE & E	VE & E	VE	E & VE
6	Ireland	VE & E	VE	VE & E	E	E & A	E & VE	E & VE
7	Denmark	VE & E	VE & E	VE & E	VE	E	E	A & E
8	Australia	VE & E	VE	E	VE & E	VE & E	VE	A
9	Iceland	VE & E	VE & E	VE & E	E	VE	E & VE	A
10	Canada	VE & E	VE	E	VE & E	VE & E	E & VE	E & VE
	Aggregated Indicator	TT	PT	EE	EI	TAB	EC	CB
		7.3	7	8.1	8.2	8	9	10
1	New Zealand	L	VE & E	E	VE	VE & E	VE & E	VE

2	Singapore	VL	VE	VE	VE	VE	VE	VE
3	Hong Kong, China	VL	VE	VE	VE	VE	VE	VE
4	United States	M	E & A	VE & E	VE & E	VE & E	VE & E	VE
5	United Kingdom	L	VE & E	VE & E	VE & E	VE & E	E	VE
6	Ireland	VL & L	VE	VE & E	VE & E	VE & E	E	VE
7	Denmark	L	VE & E	VE	VE	VE	E	VE
8	Australia	M	E	E	VE & E	E	VE & E	VE
9	Iceland	VL & L	E & A	VE & E	VE	VE	VE & E	VE
10	Canada	M	E	E	VE & E	E	E	VE

***Note:** **EDB** = Ease of Doing Business; **SB** = Starting a Business; **DL** = Dealing With Licenses; **EW** = Employing Workers; **RP** = Registering Property; **GC** = Getting Credit; **PI** = Protecting Investors; **TT** = Total Tax; **PT** = Paying Taxes; **EE** = Ease of Exporting; **EI** = Ease of Importing; **TAB** = Trading Across Borders; **EC** = Enforcing Contracts; **CB** = Closing a Business.

Ranking Comparison with World Bank Ranking

Table 7 presents a comparison for each sub-indicator for Canada between World Bank results and results from proposed approach for the last two study years. In the proposed fuzzy linguistic modeling approach some countries have the same crisp number after defuzzification. Thus, several countries have the same rating for their aggregated indicators in both systems. For example, Canada has the same crisp number 0.1 for “Starting Business” indicator with three other countries: Australia, New Zealand, and Ireland. (see Fig. 7.). These four are OECD countries with high incomes. Thus Canada shares first to fourth places with these countries for the “Starting Business” aggregated indicator.

Table 7. Comparison Between World Bank and Proposed Approach(Canadian Data Only)

Aggregated Indicator	Doing Business Reports							
	2004	2005	2006		2007		2008	
			WB	PA	WB	PA	WB	PA
Easy of Doing Business	6	7	6	7	11	7	10	
1. Starting a Business	1-3	1-3	1-3	1	1-7	2	1-4	
2. Dealing with Licenses	-	-	21-26	25	27-30	26	26-29	
3. Employing Workers	18	20-23	27	17	35	19	32	
4. Registering Property		20-23	20-25	26	15-20	28	29	
5. Getting Credit	1-14	5-11	5-13	7	5-14	7	5-17	
6. Protecting Investors	-	-	6-9	5	7-9	5	7-9	
7. Paying Taxes	-	-	22	28	48	25	29-34	
8. Trading Across Borders	-	-	23	36	39-40	39	43-44	
9. Enforcing Contracts	35-37	36-38	38-40	43	41-43	43	43-44	
10. Closing Business	4	3	4	4	3-4	4	4	

WB- World Bank Results, **PA-** Proposed Approach

As we can see from Table 7, the proposed fuzzy linguistic modeling approach is similar to the World Bank approach. The largest differences in rating indicators between the two are for employing workers and paying taxes. These differences are due the fact that the proposed fuzzy linguistic approach takes into account not only the crisp data, but also the membership for linguistic labels in fuzzy sets. The membership function changed over the years 2004 - 2008, as new countries were added. For example, Canada was in 98th place (Medium and High) for the Paying Tax indicator among the 175 countries (Data from Doing Business 2007), with low payments and low hours (respectively 15th and 26th) for

paying taxes. After aggregating all these indicators into the “Paying Taxes” composite indicator, the linguistic classification for Canada was average among all 175 countries, being in 48th place. A similar explanation applies for the “Employing Workers” aggregated indicator.

6. SYSTEM IMPLEMENTATION

Microsoft Excel spreadsheets were used for the demonstration of the Fuzzy System of Ease of Doing Business Indicators described here. The Excel-based system has several benefits which have to be taken into consideration when systems are implemented for business and management purposes. Microsoft Excel spreadsheets are universally available on a PC, and most business professionals are already familiar with the Microsoft Excel application. This allows users easy access to ‘knowledge’ about Ease of Doing Indicators, and inter-country differences. The other advantages are its scalability and interoperability. New indicators may also be added, and indicator weights can be changed easily. Excel spreadsheets can be converted for Web display in HTML and XML formats. They can also be e-mailed, allowing experts to update and contribute to Excel-based solutions collaboratively.

Screenshots of the implemented fuzzy system are presented in Figs.8 and 9. Fig 8. presents membership calculations, and Fig 9. presents linguistic interpretation of aggregated indicators and their ranks in the overall system. The system automatically calculates the membership functions for indicators, linguistically interprets them, aggregates simple indicators into aggregated indicators 1-10 and the EDB indicator, and then ranks all countries for each indicator

N	Country	Region	Income Category	Year	1. Starting a Business				2. Dealing with Licenses				3. Employing Workers				4. Registering						
N	Country			Year	E	A	D	VC	E	A	D	VC	E	A	D	VC	E	A	D	VC			
30	27	Canada	OECD	High income: OECD	2008	1.000	0.000	0.000	0.000	0.000	0.333	0.333	0.333	0.000	0.000	0.33	0.59	0.08	0.00	0.00	0.667	0.000	0.333
31	28	Cape Verde	Sub-Saharan Africa	Lower middle income	2008	0.000	0.000	0.250	0.574	0.176	0.000	0.333	0.333	0.000	0.333	0.00	0.17	0.44	0.06	0.33	0.000	0.000	1.000
32	29	Central African Republic	Sub-Saharan Africa	Low income	2008	0.250	0.000	0.000	0.250	0.500	0.000	0.000	0.241	0.426	0.333	0.00	0.33	0.50	0.17	0.00	0.333	0.000	0.333
33	30	Chad	Sub-Saharan Africa	Low income	2008	0.000	0.000	0.000	0.000	1.000	0.333	0.052	0.292	0.000	0.333	0.00	0.12	0.82	0.05	0.00	0.000	0.533	0.333
34	31	Chile	Latin America & Caribbean	Upper middle income	2008	0.500	0.250	0.250	0.000	0.000	0.000	0.333	0.867	0.000	0.000	0.44	0.22	0.00	0.33	0.00	0.433	0.234	0.333
35	32	China	East Asia & Pacific	Lower middle income	2008	0.250	0.000	0.250	0.500	0.000	0.000	0.000	0.000	0.000	1.000	0.17	0.11	0.06	0.00	0.67	0.216	0.785	0.000
36	33	Colombia	Latin America & Caribbean	Lower middle income	2008	0.250	0.250	0.250	0.250	0.000	0.000	0.667	0.000	0.000	0.333	0.09	0.19	0.06	0.67	0.00	0.504	0.189	0.000
37	34	Comoros	Sub-Saharan Africa	Low income	2008	0.000	0.250	0.000	0.250	0.500	0.000	0.665	0.346	0.000	0.000	0.33	0.12	0.18	0.06	0.33	0.325	0.341	0.000
38	35	Congo, Dem Rep	Sub-Saharan Africa	Low income	2008	0.250	0.000	0.000	0.000	0.750	0.000	0.333	0.000	0.000	0.667	0.12	0.27	0.28	0.28	0.06	0.000	0.291	0.079
39	36	Congo, Rep	Sub-Saharan Africa	Lower middle income	2008	0.000	0.080	0.250	0.250	0.500	0.000	0.576	0.091	0.000	0.333	0.00	0.00	0.39	0.58	0.03	0.000	0.000	0.275
40	37	Costa Rica	Latin America & Caribbean	Upper middle income	2008	0.250	0.250	0.000	0.074	0.426	0.000	0.099	0.234	0.333	0.333	0.11	0.05	0.49	0.34	0.00	0.333	0.333	0.333
41	38	Côte d'Ivoire	Sub-Saharan Africa	Low income	2008	0.000	0.000	0.250	0.250	0.500	0.000	0.000	0.241	0.092	0.667	0.06	0.17	0.49	0.29	0.00	0.000	0.142	0.467
42	39	Croatia	Europe & Central Asia	Upper middle income	2008	0.204	0.296	0.600	0.000	0.000	0.000	0.000	0.060	0.616	0.333	0.00	0.05	0.88	0.07	0.00	0.000	0.667	0.000
43	40	Czech Republic	Europe & Central Asia	Upper middle income	2008	0.382	0.118	0.250	0.250	0.000	0.333	0.067	0.266	0.000	0.333	0.06	0.56	0.06	0.00	0.33	0.061	0.605	0.000
44	41	Denmark	Europe & Central Asia	High income: OECD	2008	0.750	0.000	0.250	0.000	0.000	0.867	0.333	0.000	0.000	0.000	0.94	0.05	0.00	0.00	0.00	0.333	0.333	0.333
45	42	Djibouti	Middle East & North Africa	Lower middle income	2008	0.000	0.000	0.250	0.250	0.500	0.000	0.333	0.333	0.000	0.333	0.00	0.17	0.39	0.44	0.00	0.000	0.333	0.275
46	43	Dominica	Latin America & Caribbean	Upper middle income	2008	0.274	0.726	0.000	0.000	0.000	0.200	0.456	0.333	0.000	0.000	0.35	0.32	0.00	0.33	0.00	0.051	0.616	0.000
47	44	Dominican Republic	Latin America & Caribbean	Lower middle income	2008	0.250	0.334	0.415	0.000	0.000	0.000	0.046	0.954	0.000	0.000	0.11	0.30	0.26	0.01	0.33	0.000	0.509	0.433
48	45	Ecuador	Latin America & Caribbean	Lower middle income	2008	0.204	0.211	0.086	0.150	0.350	0.000	0.667	0.333	0.000	0.000	0.00	0.34	0.27	0.05	0.33	0.343	0.323	0.000
49	46	Egypt	Middle East & North Africa	Lower middle income	2008	0.250	0.610	0.140	0.000	0.000	0.000	0.000	0.000	0.487	0.503	0.17	0.06	0.06	0.39	0.33	0.333	0.000	0.275

Fig 8. Fuzzy System for Doing Business Indicators (Membership)

Year	Country	Region	Income Category	1. Starting a Business			2. Dealing with Licenses			3. Employing Workers			4. Registering Property					
				Ease of Starting a Business	Classification of SB_1	Rank 1	Ease of Dealing with License	Classification of DL_2	Rank 2	Ease of Employing Workers	Classification of EW_3	Rank 3	Ease of Registering Property	Classification of RP_4	Rank 4			
2008	Afghanistan	South Asia	Low income	0.300	E	55	0.100	D	150	26.67	E	62	0.156	VE & E	10	0.700	D	167
2008	Albania	Europe & Central Asia	Lower middle income	0.300	A	114	0.833	D & VD	173	36.00	E & A	92	0.536	A	135	0.378	E & A	73
2008	Algeria	Middle East & North Africa	Lower middle income	0.500	A	115	0.557	A & D	88	49.33	A	142	0.498	A	109	0.567	A & D	143
2008	Angola	Sub-Saharan Africa	Lower middle income	0.833	D & VD	173	0.700	D	150	68.67	D	175	0.562	A & D	149	0.712	D	189
2008	Antigua and Barbuda	Sub-Saharan Africa	High income, non-OECD	0.286	VE & E	26	0.233	VE & E	18	13.33	VE	23	0.378	E & A	69	0.426	E & A	83
2008	Argentina	Latin America & Caribbean	Upper middle income	0.374	VE & A	77	0.867	VD	134	42.67	E & A	120	0.676	D	172	0.423	E & A	83
2008	Australia	Europe & Central Asia	Lower middle income	0.209	VE	4	0.515	E	31	10.00	VE	12	0.233	VE & E	28	0.233	VE & E	24
2008	Austria	East Asia & Pacific	High income, OECD	0.400	E & A	83	0.567	E & A	51	36.67	E & A	106	0.294	E & A	72	0.220	VE & E	21
2008	Azerbaijan	Europe & Central Asia	High income, OECD	0.510	E & A	73	0.767	D & VD	164	36.67	E & A	106	0.405	E & A	74	0.244	E	56
2008	Bahrain	South Asia	Low income	0.510	A	118	0.633	A & D	127	36.00	E & A	92	0.453	A	86	0.767	D & VD	171
2008	Balios	Europe & Central Asia	Low income	0.490	A	104	0.577	A & D	92	30.00	E	68	0.500	A	132	0.512	A	122
2008	Belgium	OECD	Lower middle income	0.150	VE	15	0.318	E	33	20.00	VE & E	39	0.466	A	92	0.674	D	158
2008	Belize	Latin America & Caribbean	High income, OECD	0.453	A	96	0.100	VE	3	18.00	VE & E	33	0.193	VE & E	16	0.460	A	97
2008	Benin	Sub-Saharan Africa	Upper middle income	0.640	A & D	142	0.700	D	150	59.33	E & A	111	0.531	A	131	0.500	A	108
2008	Bhutan	South Asia	Low income	0.240	E	66	0.629	A & D	114	13.33	VE	23	0.111	VE	6	0.284	E	54
2008	Bolivia	South Asia	Low income	0.350	D	148	0.624	A & D	112	75.33	D & VD	178	0.669	D	171	0.445	E & A	93
2008	Bosnia and Herzegovina	Latin America & Caribbean	Lower middle income	0.622	A & D	140	0.715	D	151	46.67	A	138	0.455	A	87	0.578	A & D	147
2008	Botswana	Sub-Saharan Africa	Lower middle income	0.450	A	88	0.645	A & D	129	23.33	VE & E	48	0.411	E & A	76	0.264	E	31
2008	Brazil	Latin America & Caribbean	Upper middle income	0.500	A	114	0.567	A & D	103	48.67	A	140	0.629	A & D	164	0.485	A	103
2008	Brunai	East Asia & Pacific	High income, non-OECD	0.200	A	114	0.445	E & A	63	13.33	VE	23	0.111	VE	6	0.908	VD	178
2008	Bulgaria	Europe & Central Asia	Upper middle income	0.434	E & A	86	0.623	A & D	110	28.00	E	65	0.353	E	57	0.320	E	52
2008	Burkina Faso	Sub-Saharan Africa	Low income	0.584	A & D	132	0.785	D & VD	166	62.80	A & D	164	0.540	A	139	0.770	D & VD	172
2008	Burundi	Sub-Saharan Africa	Low income	0.530	A	126	0.767	D & VD	164	40.00	E & A	114	0.309	E	45	0.500	A	116
2008	Cameroon	Sub-Saharan Africa	Lower middle income	0.800	D & VD	173	0.700	D	150	46.67	A	138	0.489	A	105	0.567	A & D	143
2008	Canada	OECD	High income, OECD	0.100	VE	4	0.300	E	29	10.00	VE	12	0.249	VE & E	32	0.233	VE & E	29
2008	Cape Verde	Sub-Saharan Africa	Lower middle income	0.685	D	150	0.567	A & D	103	43.33	E & A	124	0.611	A & D	161	0.200	A	116
2008	Central African Republic	Sub-Saharan Africa	Low income	0.650	D	148	0.718	D	150	40.00	A & D	163	0.463	A	94	0.473	E & A	80

Fig 9. Fuzzy System for Doing Business Indicators (Classification and Rank)

7. DISCUSSION

Doing Business annual reports published by the World Bank (World Bank, 2003, 2004, 2005, 2006, 2007) are useful for “investigating the regulations that enhance business activity and those that constrain it”. Quantitative indicators on business regulations and their enforcement can be compared across 178 countries—from Afghanistan to Zimbabwe—over time, and over 10 topics. *Doing Business in 2004: Understanding Regulation* (World Bank, 2003) presented indicators in 5 topics across 133 nations: starting a business, hiring and firing workers, enforcing contracts, getting credit and closing a business. *Doing Business in 2005: Removing Obstacles to Growth* (World Bank, 2004) updated these measures and added another two sets: registering property and protecting investors across 145 countries. *Doing Business in 2006: Creating Jobs* (World Bank, 2005) updated all previous measures and added three more topics: dealing with licenses, paying taxes and trading across borders, to create a total of 10 areas measured across 155 countries. *Doing Business 2007: How to Reform* (World Bank, 2006) and *Doing Business in 2008* (World Bank, 2007) also updated all previous measures with the inclusion of results from 175 and 178 countries respectively. The quantitative indicators can be used to analyze economic outcomes and identify what reforms have worked, where, and why. These indicators can also be used to summarize multiple Ease of Doing Business indicators into one composite indicator “Ease of Doing Business (EDB)” (World Bank, 2003, 2004, 2005, 2006, 2007). After indicator aggregation, all countries were ranked in these reports. Higher rankings on the Ease of Doing Business are associated with more growth, more jobs and a smaller share of the economy in the informal sector (Djankov et al., 2006).

Although EDB can help in decision making and in reforming the business environment, both the indicator and methodology have been subject to criticism from economists and legal experts, as recently reported in du Marais (2006). The main problems cited are the weak explanatory power of the composite EDB indicator and the quality of the underlying information (Blanchet, 2006). In such situations, when we have uncertain data gathered from various experts on different data types, classical or traditional mathematical modeling are not very useful. Traditional or classical modeling techniques often do not capture the nature of complex systems, especially when humans are involved. This is also especially true for business,

financial and managerial systems which involve a great number of interacting factors (Bojadziev and Bojadziev, 1997).

In contrast, fuzzy sets and fuzzy logic are effective tools for modeling, in absence of complete and precise information, complex business and management systems. Lotfi Zadeh (Zadeh, 2008) noted that fuzzy logic may be viewed as “an attempt at formalization/mechanization of two remarkable human capabilities. First, the capability to converse, reason, and make rational decisions in an environment of imprecision, uncertainty, incompleteness of information, conflicting information, partiality of truth and partiality of possibility – in short, in an environment of imperfect information. And second, the capability to perform a wide variety of physical and mental tasks without any measurements and computations”.

It is accepted that the need for fuzzy set theory arises because our natural language contains words that cannot be given precise definitions. Reality needs to be classified, to be divided into parts, and the set of values that a variable can take into broad categories needs to be partitioned (Baldwin et al, 1998). This necessarily introduces fuzzy boundaries and fuzzy sets that can be used for classification and ranking. Fuzzy logic is a component of intelligent methodology that can play a unique role in handling natural word input in addition to numerical data, improved human computer interfaces, and the ability to handle multiple conflicting expert opinions. This study suggests an alternative fuzzy linguistic approach for calculating composite EDB indicators, which are too complicated, incomplete, gathered from different experts and multifaceted to evaluate. Fuzzy linguistic modeling is conceptually easy to understand and implement, flexible, very fast, and computationally inexpensive, and based on natural language. The main contribution from this research is that it proposes not only modeling for ranking but also for country classification. The proposed approach can be applied in a broader sense for modeling various complex systems (social, economic, medical, ecological, etc.) in conditions of uncertainty, for identification, estimation, classification, monitoring and diagnostics.

Although this approach can become very useful to business owners and government decision makers, there are several additional issues that should be addressed through ongoing research. First, in this study the indicators were aggregated with equal weight, while in reality they are not equal. Additional data could be gathered from economic experts that would help determine appropriate weights. With several experts from each country providing such data, the aggregated weights of a variety of expert opinions could be calculated using fuzzy multi-objective group decision making methods. Expert opinions could also be used to determine fuzzy terms (labels), membership functions (trapezoidal or otherwise), and linguistic variables.

Note: Detailed results are available on request from the authors for classification and ranking and a complete comparison of our results with World Bank results, for the years 2004 through 2008. The World Bank data upon which this research is based are available online at <http://www.doingbusiness.org/CustomQuery/>.

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APPENDIX

1. MEMBERSHIP FUNCTIONS FOR EASE OF DOING BUSINESS INDICATORS

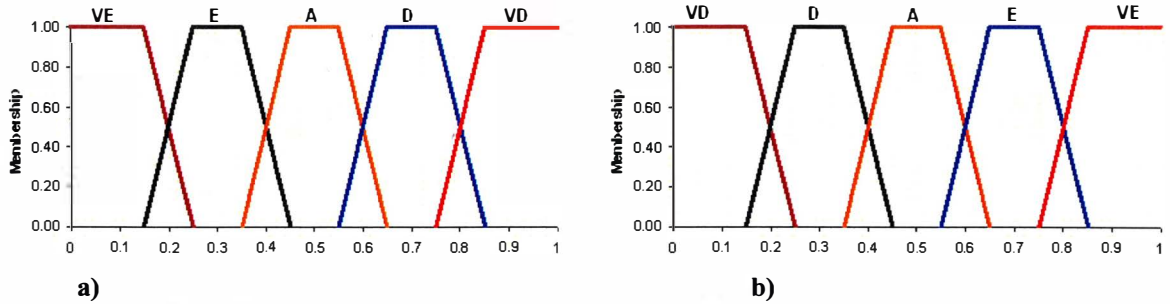


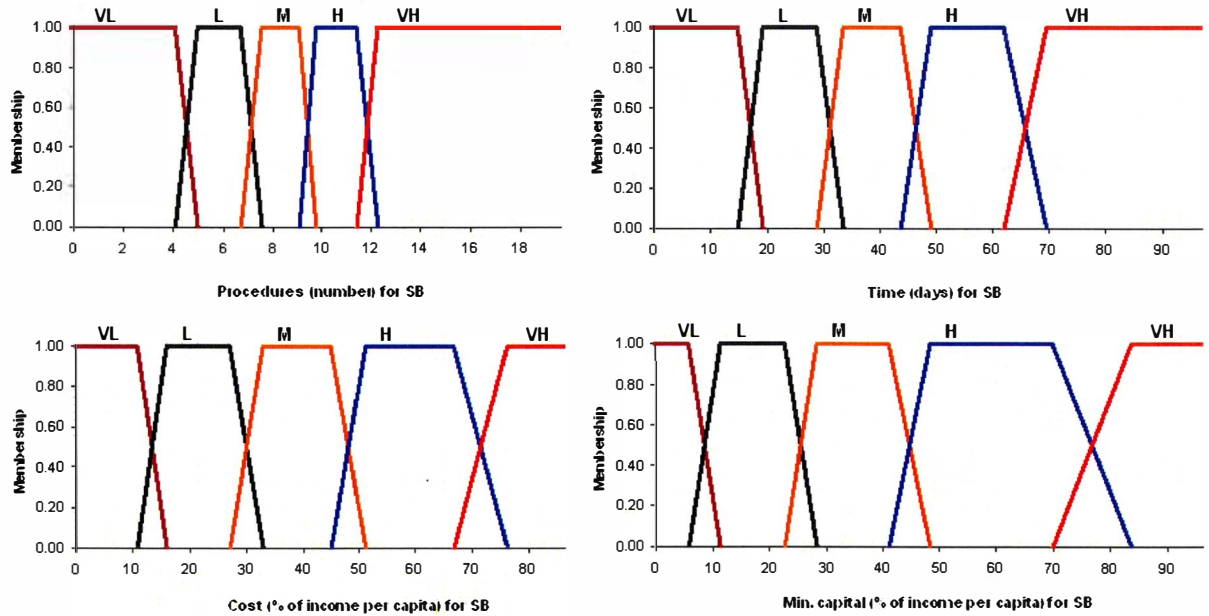
Fig. 1. Membership Function for Ease of Doing Business aggregated indicators:
a) 1-4, 7-9, EDB;
b) 5, 6, 10

Description:

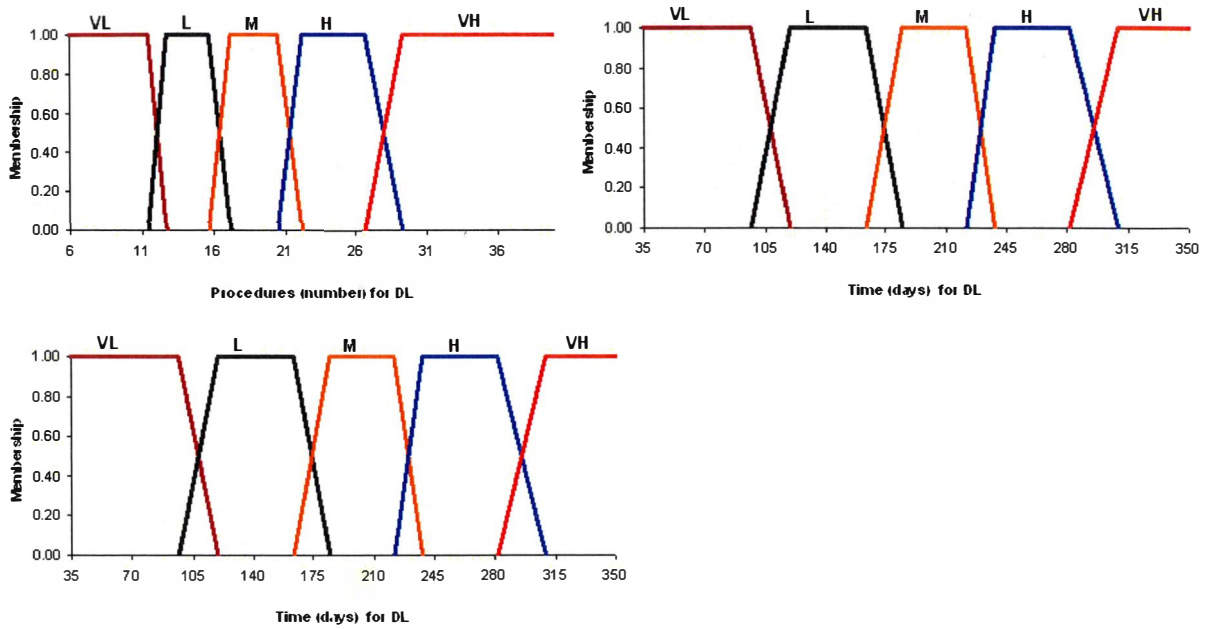
VE - Very Ease; E - Ease; A - Average; D - Difficult; VD - Very Difficult.

VL - Very Low; L - Low; M - Medium; H - High; VH - Very High.

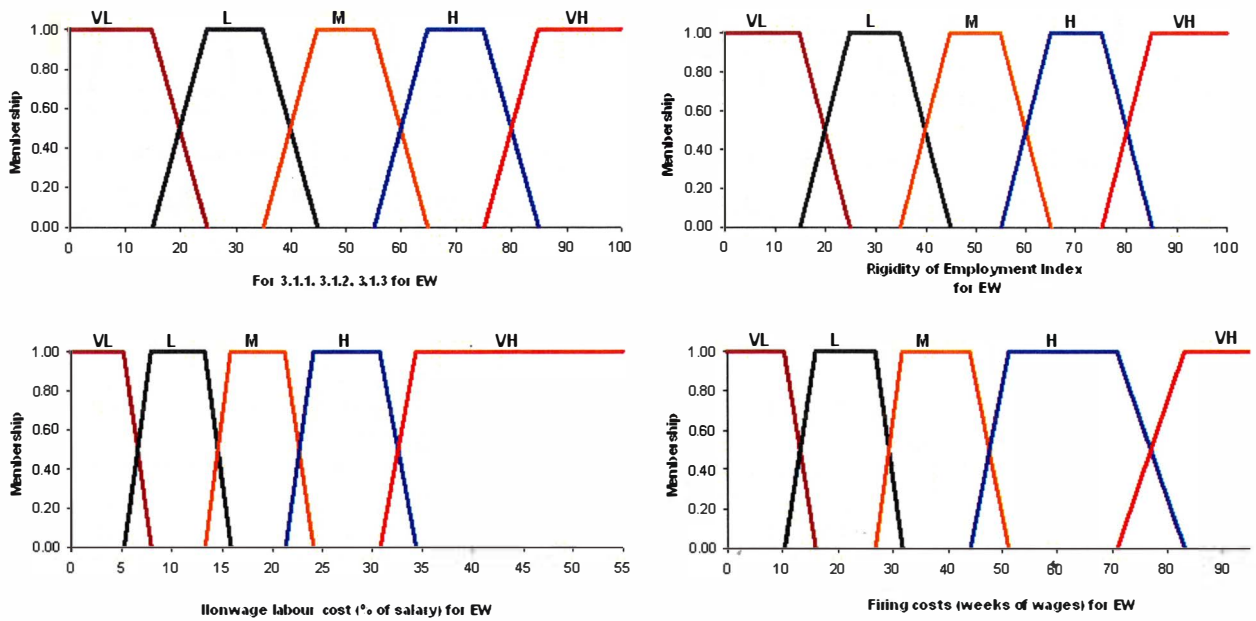
1.1. Membership Functions for Ease of Starting Business Indicators.



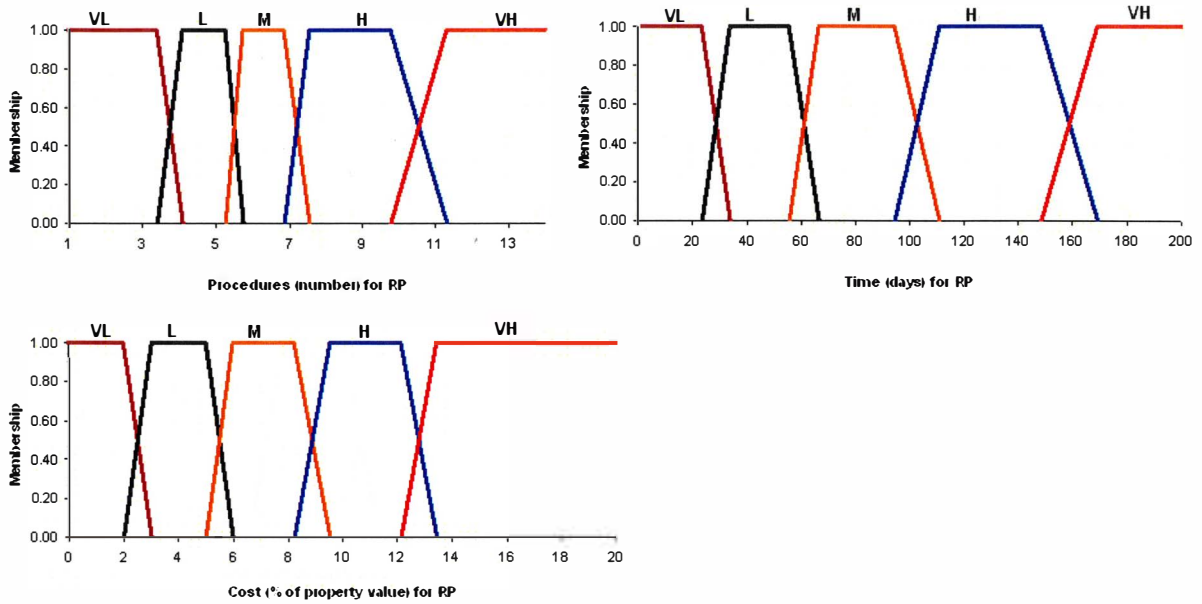
1.2. Membership Functions for Ease of Dealing with Licenses Indicators.



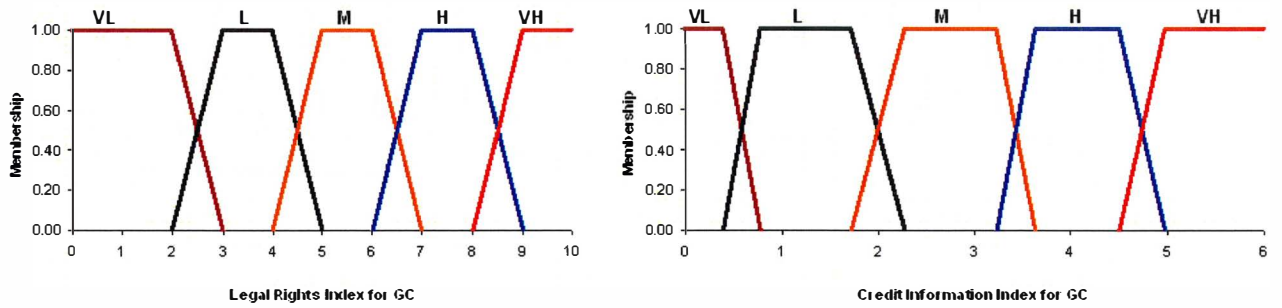
1.3. Membership Functions for Ease of Employing Workers Indicators.



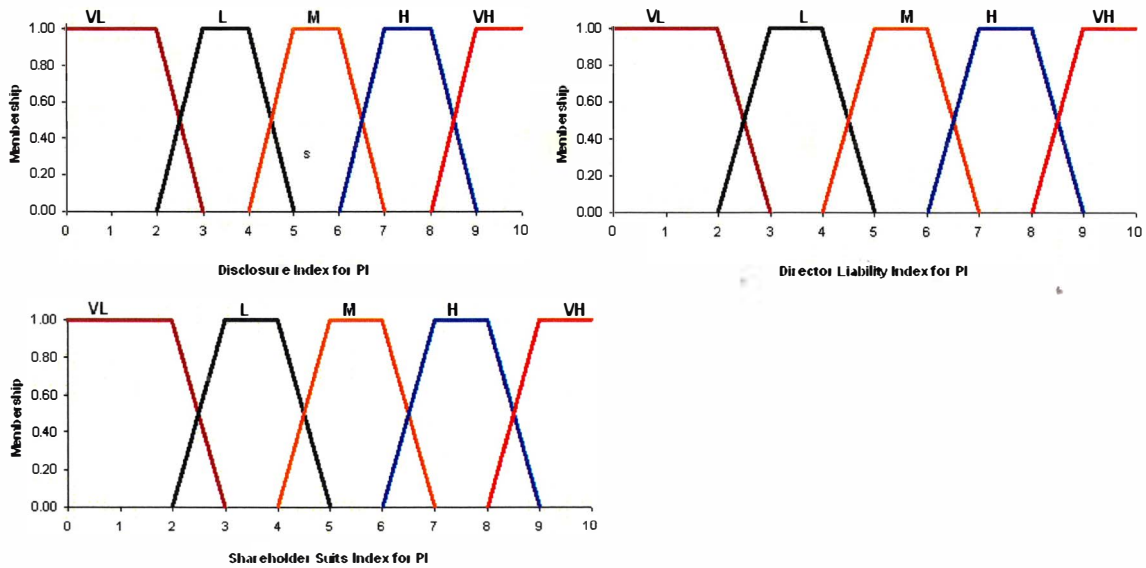
1.4. Membership Functions for Ease of Registering Property Indicators.



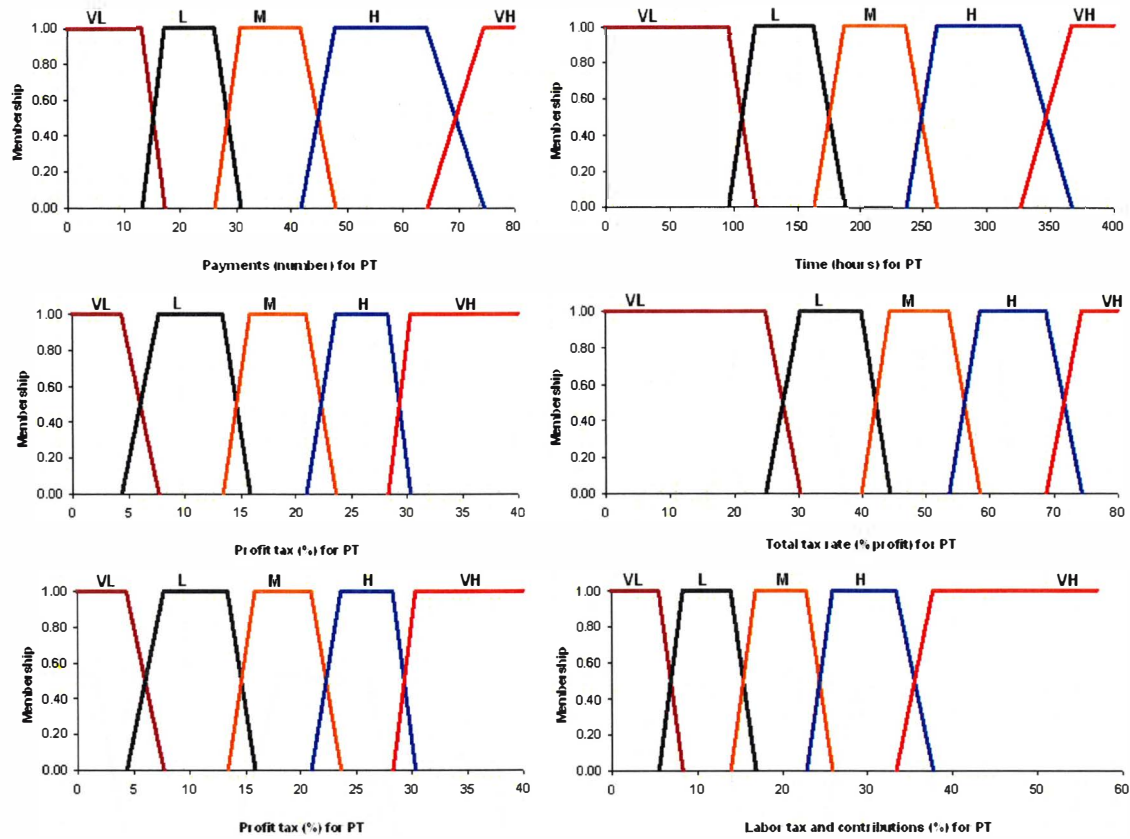
1.5. Membership Functions for Ease of Getting Credit Indicators.



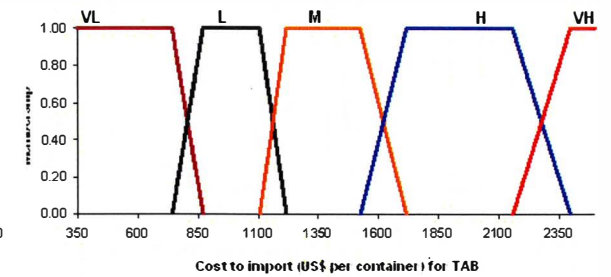
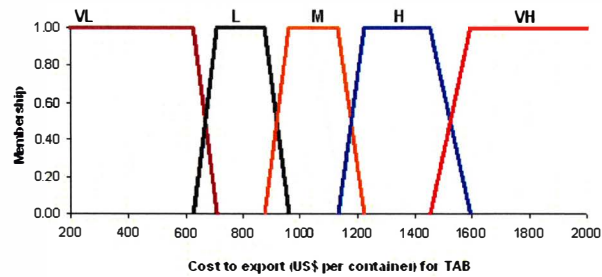
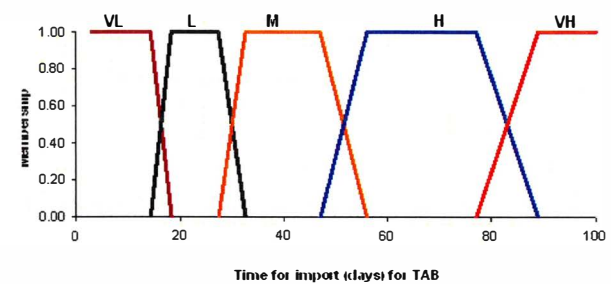
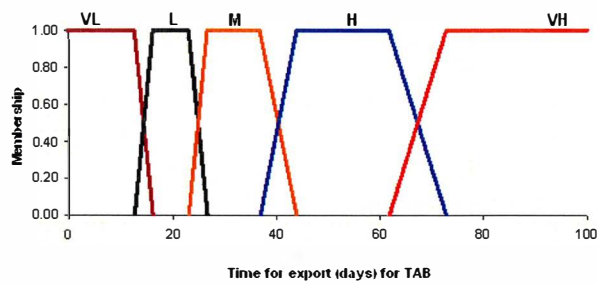
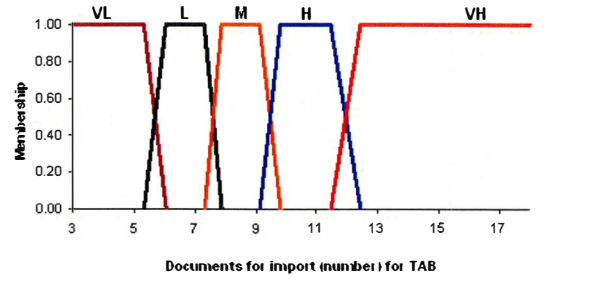
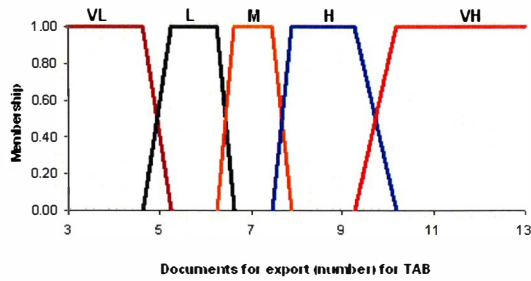
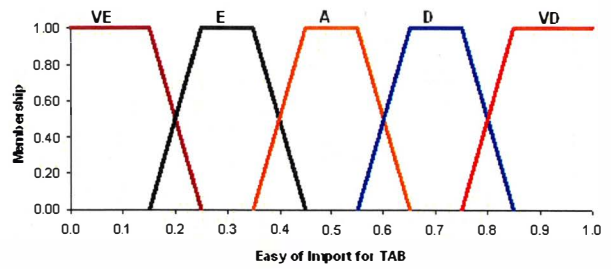
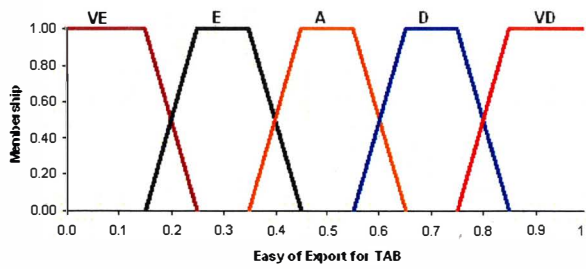
1.6. Membership Functions for Ease of Protecting Investors Indicators.



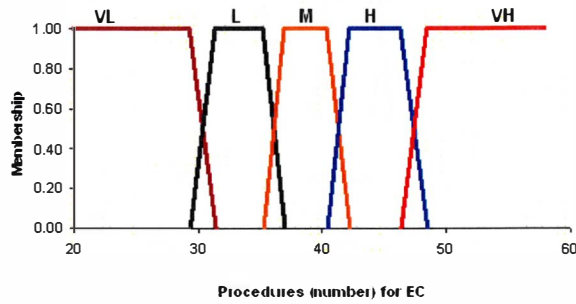
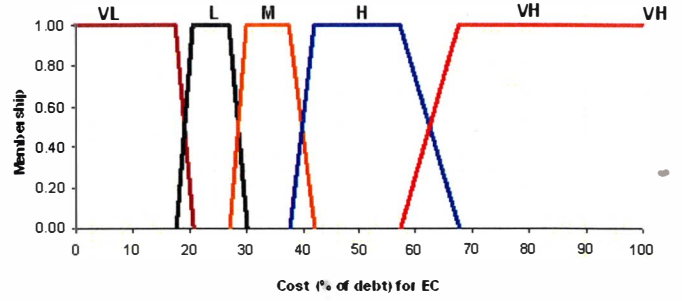
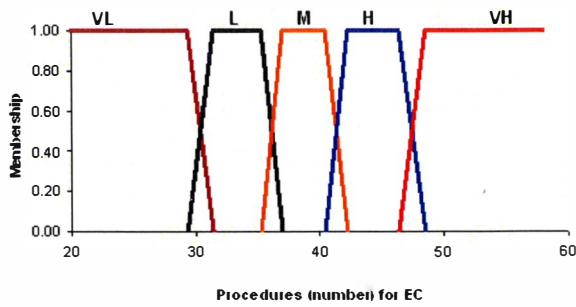
1.7. Membership Functions for Ease of Paying Taxes Indicators.



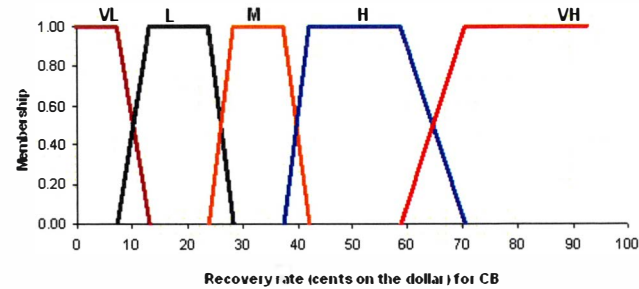
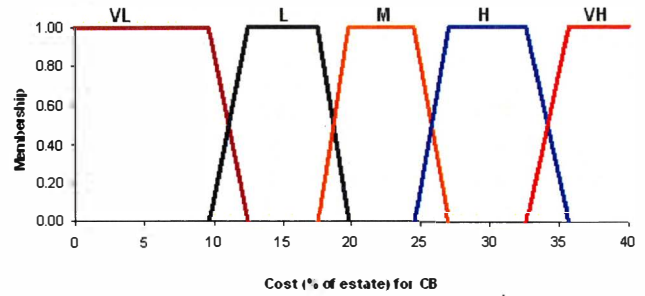
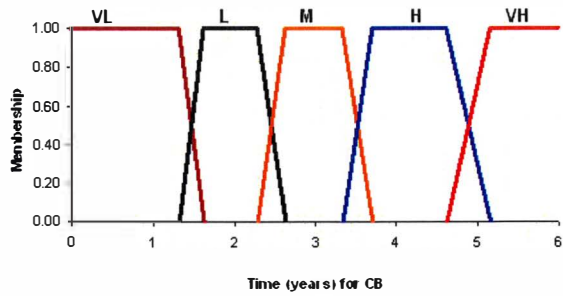
1.8. Membership Functions for Ease of Trading Across Borders Indicators.



1.9. Membership Functions for Ease of Enforcing Contracts Indicators.



1.10. Membership Functions for Ease of Closing Business Indicators.



2. NUMBER AND PERCENT OF COUNTRIES IN LINGUISTIC CLASSES FOR INDICATORS (2008-2004)

Table 2.1.1. Number of countries in linguistic classes (2008)

Linguistic scale	1. Starting Business				2. Dealing with Licenses			3. Employing Workers					
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1.1	3.1.2	3.1.3	3.1	3.2	3.3
VL	10	33	64	86	20	18	31	61	24	46	29	35	30
VL & L	0	17	12	5	8	13	6	16	36	26	32	17	9
L	32	31	24	14	42	30	20	37	0	25	32	37	32
L & M	14	15	10	8	19	15	3	19	58	36	33	9	10
M	46	27	8	11	35	35	17	2	0	18	28	35	27
M & H	0	13	5	4	17	13	5	13	49	12	14	11	3
H	37	13	10	13	17	18	11	13	0	11	8	16	22
H & VH	11	3	3	0	3	8	1	12	11	2	2	9	5
VH	28	26	42	37	17	28	84	5	0	2	0	9	40

Linguistic scale	4. Registering Property			5. Getting Credit		6. Protecting Investors			7. Paying Taxes					
	4.1	4.2	4.3	5.1	5.2	6.1	6.2	6.3	7.1	7.2	7.3.1	7.3.2	7.3.3	7.3
VL	22	42	31	18	56	30	56	15	30	17	20	28	87	16
VL & L	19	21	20	0	0	0	0	0	14	8	5	19	19	9
L	32	34	35	74	14	39	35	36	29	27	33	37	35	50
L & M	0	14	12	0	15	0	0	0	13	11	16	10	3	18
M	31	18	28	55	13	63	54	57	41	21	34	33	13	46
M & H	19	6	4	0	0	0	0	0	13	8	16	15	0	6
H	35	13	20	24	26	33	25	55	24	30	32	20	7	12
H & VH	6	2	6	0	0	0	0	0	7	12	7	5	3	6
VH	14	28	22	7	54	13	8	15	7	44	15	11	11	15

Linguistic scale	8. Trading Across Borders						9. Enforcing Contracts			10. Closing Business	
	8.1.1	8.1.2	8.1.3	8.2.1	8.2.2	8.2.3	9.1	9.2	9.3	10.1.1	10.1.2
VL	22	29	23	33	37	25	16	25	40	22	67
VL & L	23	16	10	22	18	23	15	8	15	3	3
L	35	53	29	33	51	33	29	31	41	30	26
L & M	0	19	10	0	13	19	10	14	12	9	14
M	31	29	31	47	31	26	49	36	29	38	20
M & H	0	5	13	0	8	8	16	8	9	4	0
H	44	19	18	34	16	16	22	18	13	25	8
H & VH	10	3	4	1	1	5	9	5	4	9	0
VH	13	5	40	8	3	23	12	33	15	38	40

Table 2.1.2. Percent of countries in linguistic classes (2008)

Linguistic scale	1. Starting Business				2. Dealing with Licenses			3. Employing Workers					
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1.1	3.1.2	3.1.3	3.1	3.2	3.3
VL, %	5.62	18.54	35.96	48.31	11.24	10.11	17.42	34.27	13.48	25.84	16.29	19.66	16.85
VL & L, %	0.00	9.55	6.74	2.81	4.49	7.30	3.37	8.99	20.22	14.61	17.98	9.55	5.06
L, %	17.98	17.42	13.48	7.87	23.60	16.85	11.24	20.79	0.00	14.04	17.98	20.79	17.98
L & M, %	7.87	8.43	5.62	4.49	10.67	8.43	1.69	10.67	32.58	20.22	18.54	5.06	5.62
M, %	25.84	15.17	4.49	6.18	19.66	19.66	9.55	1.12	0.00	10.11	15.73	19.66	15.17
M & H, %	0.00	7.30	2.81	2.25	9.55	7.30	2.81	7.30	27.53	6.74	7.87	6.18	1.69
H, %	20.79	7.30	5.62	7.30	9.55	10.11	6.18	7.30	0.00	6.18	4.49	8.99	12.36
H & VH, %	6.18	1.69	1.69	0.00	1.69	4.49	0.56	6.74	6.18	1.12	1.12	5.06	2.81
VH, %	15.73	14.61	23.60	20.79	9.55	15.73	47.19	2.81	0.00	1.12	0.00	5.06	22.47

Linguistic scale	4. Registering Property			5. Getting Credit		6. Protecting Investors			7. Paying Taxes					
	4.1	4.2	4.3	5.1	5.2	6.1	6.2	6.3	7.1	7.2	7.3.1	7.3.2	7.3.3	7.3
VL, %	12.36	23.60	17.42	10.11	31.46	16.85	31.46	8.43	16.85	9.55	11.24	15.73	48.88	8.99
VL & L, %	10.67	11.80	11.24	0.00	0.00	0.00	0.00	0.00	7.87	4.49	2.81	10.67	10.67	5.06
L, %	17.98	19.10	19.66	41.57	7.87	21.91	19.66	20.22	16.29	15.17	18.54	20.79	19.66	28.09
L & M, %	0.00	7.87	6.74	0.00	8.43	0.00	0.00	0.00	7.30	6.18	8.99	5.62	1.69	10.11
M, %	17.42	10.11	15.73	30.90	7.30	35.39	30.34	32.02	23.03	11.80	19.10	18.54	7.30	25.84
M & H, %	10.67	3.37	2.25	0.00	0.00	0.00	0.00	0.00	7.30	4.49	8.99	8.43	0.00	3.37
H, %	19.66	7.30	11.24	13.48	14.61	18.54	14.04	30.90	13.48	16.85	17.98	11.24	3.93	6.74
H & VH, %	3.37	1.12	3.37	0.00	0.00	0.00	0.00	0.00	3.93	6.74	3.93	2.81	1.69	3.37
VH, %	7.87	15.73	12.36	3.93	30.34	7.30	4.49	8.43	3.93	24.72	8.43	6.18	6.18	8.43

Linguistic scale	8. Trading Across Borders						9. Enforcing Contracts			10. Closing Business	
	8.1.1	8.1.2	8.1.3	8.2.1	8.2.2	8.2.3	9.1	9.2	9.3	10.1.1	10.1.2
VL, %	12.36	16.29	12.92	18.54	20.79	14.04	8.99	14.04	22.47	12.36	37.64
VL & L, %	12.92	8.99	5.62	12.36	10.11	12.92	8.43	4.49	8.43	1.69	1.69
L, %	19.66	29.78	16.29	18.54	28.65	18.54	16.29	17.42	23.03	16.85	14.61
L & M, %	0.00	10.67	5.62	0.00	7.30	10.67	5.62	7.87	6.74	5.06	7.87
M, %	17.42	16.29	17.42	26.40	17.42	14.61	27.53	20.22	16.29	21.35	11.24
M & H, %	0.00	2.81	7.30	0.00	4.49	4.49	8.99	4.49	5.06	2.25	0.00
H, %	24.72	10.67	10.11	19.10	8.99	8.99	12.36	10.11	7.30	14.04	4.49
H & VH, %	5.62	1.69	2.25	0.56	0.56	2.81	5.06	2.81	2.25	5.06	0.00
VH, %	7.30	2.81	22.47	4.49	1.69	12.92	6.74	18.54	8.43	21.35	22.47

Table 2.2.1. Number of countries in linguistic classes (2007)

Linguistic scale	1. Starting Business				2. Dealing with Licenses			3. Employing Workers					
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1.1	3.1.2	3.1.3	3.1	3.2	3.3
VL	20	27	59	83	20	18	30	65	22	46	27	34	29
VL & L	17	16	10	5	7	8	6	11	37	24	32	17	8
L	34	31	25	13	42	36	18	36	0	27	34	34	33
L & M	0	18	6	7	19	13	6	19	56	33	29	16	11
M	45	25	13	10	35	32	17	1	0	18	30	37	22
M & H	0	12	4	4	15	12	3	14	50	12	13	10	6
H	15	14	8	8	16	19	11	16	0	11	7	21	22
H & VH	10	4	5	3	4	7	1	9	10	2	3	4	5
VH	34	28	45	42	17	30	83	5	0	2	0	3	39

Linguistic scale	4. Registering Property			5. Getting Credit		6. Protecting Investors			7. Paying Taxes					
	4.1	4.2	4.3	5.1	5.2	6.1	6.2	6.3	7.1	7.2	7.3.1	7.3.2	7.3.3	7.3
VL	22	43	37	19	56	31	55	15	5	16	-	-	-	10
VL & L	19	15	14	0	14	0	0	0	1	8	-	-	-	6
L	64	38	32	74	17	40	35	35	36	25	-	-	-	25
L & M	0	10	11	0	0	0	0	0	31	9	-	-	-	14
M	44	20	30	54	18	60	53	56	52	21	-	-	-	30
M & H	0	7	5	0	0	0	0	0	15	8	-	-	-	16
H	12	11	18	21	18	31	25	55	21	30	-	-	-	42
H & VH	2	2	8	0	0	0	0	0	8	11	-	-	-	10
VH	12	29	20	7	53	13	8	14	6	47	-	-	-	22

Linguistic scale	8. Trading Across Borders						9. Enforcing Contracts			10. Closing Business	
	8.1.1	8.1.2	8.1.3	8.2.1	8.2.2	8.2.3	9.1	9.2	9.3	10.1.1	10.1.2
VL	20	34	21	33	34	27	13	25	40	32	68
VL & L	21	15	7	15	15	17	13	6	14	20	3
L	32	56	28	28	43	37	25	31	40	38	23
L & M	0	17	12	22	19	20	15	14	9	9	0
M	34	23	32	18	34	23	52	37	31	24	0
M & H	25	9	12	18	6	7	9	7	9	5	14
H	26	14	17	25	17	18	29	18	13	17	20
H & VH	8	2	5	9	3	5	8	7	4	2	7
VH	9	5	41	7	4	21	11	30	15	28	40

Table 2.2.2. Percent of countries in linguistic classes (2007)

Linguistic scale	1. Starting Business				2. Dealing with Licenses			3. Employing Workers					
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1.1	3.1.2	3.1.3	3.1	3.2	3.3
VL, %	11.43	15.43	33.71	47.43	11.43	10.29	17.14	36.93	12.57	26.29	15.43	19.32	16.57
VL & L, %	9.71	9.14	5.71	2.86	4.00	4.57	3.43	6.25	21.14	13.71	18.29	9.66	4.57
L, %	19.43	17.71	14.29	7.43	24.00	20.57	10.29	20.45	0.00	15.43	19.43	19.32	18.86
L & M, %	0.00	10.29	3.43	4.00	10.86	7.43	3.43	10.80	32.00	18.86	16.57	9.09	6.29
M, %	25.71	14.29	7.43	5.71	20.00	18.29	9.71	0.57	0.00	10.29	17.14	21.02	12.57
M & H, %	0.00	6.86	2.29	2.29	8.57	6.86	1.71	7.95	28.57	6.86	7.43	5.68	3.43
H, %	8.57	8.00	4.57	4.57	9.14	10.86	6.29	9.09	0.00	6.29	4.00	11.93	12.57
H & VH, %	5.71	2.29	2.86	1.71	2.29	4.00	0.57	5.11	5.71	1.14	1.71	2.27	2.86
VH, %	19.43	16.00	25.71	24.00	9.71	17.14	47.43	2.84	0.00	1.14	0.00	1.70	22.29

Linguistic scale	4. Registering Property			5. Getting Credit		6. Protecting Investors			7. Paying Taxes					
	4.1	4.2	4.3	5.1	5.2	6.1	6.2	6.3	7.1	7.2	7.3.1	7.3.2	7.3.3	7.3
VL, %	12.57	24.57	21.14	10.86	31.82	17.71	31.25	8.57	2.86	9.14	-	-	-	5.71
VL & L, %	10.86	8.57	8.00	0.00	7.95	0.00	0.00	0.00	0.57	4.57	-	-	-	3.43
L, %	36.57	21.71	18.29	42.29	9.66	22.86	19.89	20.00	20.57	14.29	-	-	-	14.29
L & M, %	0.00	5.71	6.29	0.00	0.00	0.00	0.00	0.00	17.71	5.14	-	-	-	8.00
M, %	25.14	11.43	17.14	30.86	10.23	34.29	30.11	32.00	29.71	12.00	-	-	-	17.14
M & H, %	0.00	4.00	2.86	0.00	0.00	0.00	0.00	0.00	8.57	4.57	-	-	-	9.14
H, %	6.86	6.29	10.29	12.00	10.23	17.71	14.20	31.43	12.00	17.14	-	-	-	24.00
H & VH, %	1.14	1.14	4.57	0.00	0.00	0.00	0.00	0.00	4.57	6.29	-	-	-	5.71
VH, %	6.86	16.57	11.43	4.00	30.11	7.43	4.55	8.00	3.43	26.86	-	-	-	12.57

Linguistic scale	8. Trading Across Borders						9. Enforcing Contracts			10. Closing Business	
	8.1.1	8.1.2	8.1.3	8.2.1	8.2.2	8.2.3	9.1	9.2	9.3	10.1.1	10.1.2
VL, %	11.43	19.43	12.00	18.86	19.43	15.43	7.43	14.29	22.86	18.29	38.86
VL & L, %	12.00	8.57	4.00	8.57	8.57	9.71	7.43	3.43	8.00	11.43	1.71
L, %	18.29	32.00	16.00	16.00	24.57	21.14	14.29	17.71	22.86	21.71	13.14
L & M, %	0.00	9.71	6.86	12.57	10.86	11.43	8.57	8.00	5.14	5.14	0.00
M, %	19.43	13.14	18.29	10.29	19.43	13.14	29.71	21.14	17.71	13.71	0.00
M & H, %	14.29	5.14	6.86	10.29	3.43	4.00	5.14	4.00	5.14	2.86	8.00
H, %	14.86	8.00	9.71	14.29	9.71	10.29	16.57	10.29	7.43	9.71	11.43
H & VH, %	4.57	1.14	2.86	5.14	1.71	2.86	4.57	4.00	2.29	1.14	4.00
VH, %	5.14	2.86	23.43	4.00	2.29	12.00	6.29	17.14	8.57	16.00	22.86

Table 2.3.1. Number of countries in linguistic classes (2006)

Linguistic scale	1. Starting Business				2. Dealing with Licenses			3. Employing Workers					
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1.1	3.1.2	3.1.3	3.1	3.2	3.3
VL	10	23	31	68	16	14	21	54	19	43	20	25	27
VL & L	9	10	6	3	14	6	6	7	28	18	29	17	7
L	14	17	31	12	33	30	16	34	0	24	30	30	30
L & M	9	13	8	6	18	10	6	18	52	31	31	15	10
M	33	32	15	11	30	29	14	2	0	16	27	29	20
M & H	0	16	4	3	7	13	5	17	48	11	11	9	6
H	37	15	8	7	19	19	10	11	0	10	5	22	15
H & VH	13	4	4	2	3	6	2	7	8	1	2	4	5
VH	30	25	48	43	15	28	75	5	0	1	0	4	35

Linguistic scale	4. Registering Property			5. Getting Credit		6. Protecting Investors			7. Paying Taxes					
	4.1	4.2	4.3	5.1	5.2	6.1	6.2	6.3	7.1	7.2	7.3.1	7.3.2	7.3.3	7.3
VL	21	38	33	18	44	27	46	15	29	14	-	-	-	16
VL & L	17	13	13	0	0	0	0	0	10	11	-	-	-	8
L	27	33	25	71	14	31	34	32	27	20	-	-	-	43
L & M	0	5	12	0	15	0	0	0	5	13	-	-	-	15
M	27	19	26	42	14	54	51	47	38	28	-	-	-	38
M & H	19	5	4	0	0	0	0	0	8	8	-	-	-	6
H	26	12	17	17	22	31	17	49	23	16	-	-	-	11
H & VH	7	1	5	0	0	0	0	0	5	3	-	-	-	2
VH	11	29	20	7	46	12	7	12	10	42	-	-	-	16

Linguistic scale	8. Trading Across Borders						9. Enforcing Contracts			10. Closing Business	
	8.1.1	8.1.2	8.1.3	8.2.1	8.2.2	8.2.3	9.1	9.2	9.3	10.1.1	10.1.2
VL	16	27	23	25	26	25	15	20	39	-	-
VL & L	17	18	9	6	14	9	14	7	10	-	-
L	27	38	27	39	40	34	20	26	31	-	-
L & M	0	13	8	15	9	11	13	14	11	-	-
M	30	24	22	34	29	28	48	36	22	-	-
M & H	0	12	11	9	10	7	7	8	8	-	-
H	41	14	14	16	18	14	21	15	15	-	-
H & VH	8	5	4	6	4	4	8	6	4	-	-
VH	16	4	37	5	5	23	9	23	15	-	-

Table 2.3.2. Percent of countries in linguistic classes (2006)

Linguistic scale	1. Starting Business				2. Dealing with Licenses			3. Employing Workers					
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1.1	3.1.2	3.1.3	3.1	3.2	3.3
VL, %	6.45	14.84	20.00	43.87	10.32	9.03	13.55	34.84	12.26	27.74	12.90	16.13	17.42
VL & L, %	5.81	6.45	3.87	1.94	9.03	3.87	3.87	4.52	18.06	11.61	18.71	10.97	4.52
L, %	9.03	10.97	20.00	7.74	21.29	19.35	10.32	21.94	0.00	15.48	19.35	19.35	19.35
L & M, %	5.81	8.39	5.16	3.87	11.61	6.45	3.87	11.61	33.55	20.00	20.00	9.68	6.45
M, %	21.29	20.65	9.68	7.10	19.35	18.71	9.03	1.29	0.00	10.32	17.42	18.71	12.90
M & H, %	0.00	10.32	2.58	1.94	4.52	8.39	3.23	10.97	30.97	7.10	7.10	5.81	3.87
H, %	23.87	9.68	5.16	4.52	12.26	12.26	6.45	7.10	0.00	6.45	3.23	14.19	9.68
H & VH, %	8.39	2.58	2.58	1.29	1.94	3.87	1.29	4.52	5.16	0.65	1.29	2.58	3.23
VH, %	19.35	16.13	30.97	27.74	9.68	18.06	48.39	3.23	0.00	0.65	0.00	2.58	22.58

Linguistic scale	4. Registering Property			5. Getting Credit		6. Protecting Investors			7. Paying Taxes					
	4.1	4.2	4.3	5.1	5.2	6.1	6.2	6.3	7.1	7.2	7.3.1	7.3.2	7.3.3	7.3
VL, %	13.55	24.52	21.29	11.61	28.39	17.42	29.68	9.68	18.71	9.03	-	-	-	10.32
VL & L, %	10.97	8.39	8.39	0.00	0.00	0.00	0.00	0.00	6.45	7.10	-	-	-	5.16
L, %	17.42	21.29	16.13	45.81	9.03	20.00	21.94	20.65	17.42	12.90	-	-	-	27.74
L & M, %	0.00	3.23	7.74	0.00	9.68	0.00	0.00	0.00	3.23	8.39	-	-	-	9.68
M, %	17.42	12.26	16.77	27.10	9.03	34.84	32.90	30.32	24.52	18.06	-	-	-	24.52
M & H, %	12.26	3.23	2.58	0.00	0.00	0.00	0.00	0.00	5.16	5.16	-	-	-	3.87
H, %	16.77	7.74	10.97	10.97	14.19	20.00	10.97	31.61	14.84	10.32	-	-	-	7.10
H & VH, %	4.52	0.65	3.23	0.00	0.00	0.00	0.00	0.00	3.23	1.94	-	-	-	1.29
VH, %	7.10	18.71	12.90	4.52	29.68	7.74	4.52	7.74	6.45	27.10	-	-	-	10.32

Linguistic scale	8. Trading Across Borders						9. Enforcing Contracts			10. Closing Business	
	8.1.1	8.1.2	8.1.3	8.2.1	8.2.2	8.2.3	9.1	9.2	9.3	10.1.1	10.1.2
VL, %	10.32	17.42	14.84	16.13	16.77	16.13	9.68	12.90	25.16	-	-
VL & L, %	10.97	11.61	5.81	3.87	9.03	5.81	9.03	4.52	6.45	-	-
L, %	17.42	24.52	17.42	25.16	25.81	21.94	12.90	16.77	20.00	-	-
L & M, %	0.00	8.39	5.16	9.68	5.81	7.10	8.39	9.03	7.10	-	-
M, %	19.35	15.48	14.19	21.94	18.71	18.06	30.97	23.23	14.19	-	-
M & H, %	0.00	7.74	7.10	5.81	6.45	4.52	4.52	5.16	5.16	-	-
H, %	26.45	9.03	9.03	10.32	11.61	9.03	13.55	9.68	9.68	-	-
H & VH, %	5.16	3.23	2.58	3.87	2.58	2.58	5.16	3.87	2.58	-	-
VH, %	10.32	2.58	23.87	3.23	3.23	14.84	5.81	14.84	9.68	-	-

Table 2.4.1. Number of countries in linguistic classes (2005)

Linguistic scale	1. Starting Business				2. Dealing with Licenses			3. Employing Workers					
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1.1	3.1.2	3.1.3	3.1	3.2	3.3
VL	8	26	26	59	-	-	-	51	19	42	21	-	30
VL & L	9	9	13	3	-	-	-	11	24	14	23	-	12
L	24	27	29	9	-	-	-	28	0	23	29	-	40
L & M	10	12	6	5	-	-	-	17	47	30	34	-	10
M	17	21	16	9	-	-	-	2	0	13	20	-	16
M & H	18	6	6	3	-	-	-	13	48	11	9	-	3
H	29	15	9	10	-	-	-	8	0	10	8	-	22
H & VH	0	4	3	4	-	-	-	8	7	1	1	-	3
VH	30	25	37	43	-	-	-	7	0	1	0	-	9

Linguistic scale	4. Registering Property			5. Getting Credit		6. Protecting Investors			7. Paying Taxes					
	4.1	4.2	4.3	5.1	5.2	6.1	6.2	6.3	7.1	7.2	7.3.1	7.3.2	7.3.3	7.3
VL	18	34	30	15	42	-	-	-	-	-	-	-	-	-
VL & L	18	12	14	0	0	-	-	-	-	-	-	-	-	-
L	27	35	24	69	14	-	-	-	-	-	-	-	-	-
L & M	0	7	9	0	15	-	-	-	-	-	-	-	-	-
M	42	14	24	39	15	-	-	-	-	-	-	-	-	-
M & H	0	4	3	0	0	-	-	-	-	-	-	-	-	-
H	26	12	18	15	20	-	-	-	-	-	-	-	-	-
H & VH	4	0	5	0	0	-	-	-	-	-	-	-	-	-
VH	10	27	18	7	39	-	-	-	-	-	-	-	-	-

Linguistic scale	8. Trading Across Borders						9. Enforcing Contracts			10. Closing Business	
	8.1.1	8.1.2	8.1.3	8.2.1	8.2.2	8.2.3	9.1	9.2	9.3	10.1.1	10.1.2
VL	-	-	-	-	-	-	25	19	38	19	63
VL & L	-	-	-	-	-	-	3	7	9	3	1
L	-	-	-	-	-	-	26	23	27	23	19
L & M	-	-	-	-	-	-	6	11	9	9	16
M	-	-	-	-	-	-	37	36	21	33	17
M & H	-	-	-	-	-	-	15	6	8	4	0
H	-	-	-	-	-	-	17	16	15	23	5
H & VH	-	-	-	-	-	-	4	5	4	8	0
VH	-	-	-	-	-	-	12	22	14	23	24

Table 2.4.2. Percent of countries in linguistic classes (2005)

Linguistic scale	1. Starting Business				2. Dealing with Licenses			3. Employing Workers					
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1.1	3.1.2	3.1.3	3.1	3.2	3.3
VL, %	5.52	17.93	17.93	40.69	-	-	-	35.17	13.10	28.97	14.48	-	20.69
VL & L, %	6.21	6.21	8.97	2.07	-	-	-	7.59	16.55	9.66	15.86	-	8.28
L, %	16.55	18.62	20.00	6.21	-	-	-	19.31	0.00	15.86	20.00	-	27.59
L & M, %	6.90	8.28	4.14	3.45	-	-	-	11.72	32.41	20.69	23.45	-	6.90
M, %	11.72	14.48	11.03	6.21	-	-	-	1.38	0.00	8.97	13.79	-	11.03
M & H, %	12.41	4.14	4.14	2.07	-	-	-	8.97	33.10	7.59	6.21	-	2.07
H, %	20.00	10.34	6.21	6.90	-	-	-	5.52	0.00	6.90	5.52	-	15.17
H & VH, %	0.00	2.76	2.07	2.76	-	-	-	5.52	4.83	0.69	0.69	-	2.07
VH, %	20.69	17.24	25.52	29.66	-	-	-	4.83	0.00	0.69	0.00	-	6.21

Linguistic scale	4. Registering Property			5. Getting Credit		6. Protecting Investors			7. Paying Taxes					
	4.1	4.2	4.3	5.1	5.2	6.1	6.2	6.3	7.1	7.2	7.3.1	7.3.2	7.3.3	7.3
VL, %	12.41	23.45	20.69	10.34	28.97	-	-	-	-	-	-	-	-	-
VL & L, %	12.41	8.28	9.66	0.00	0.00	-	-	-	-	-	-	-	-	-
L, %	18.62	24.14	16.55	47.59	9.66	-	-	-	-	-	-	-	-	-
L & M, %	0.00	4.83	6.21	0.00	10.34	-	-	-	-	-	-	-	-	-
M, %	28.97	9.66	16.55	26.90	10.34	-	-	-	-	-	-	-	-	-
M & H, %	0.00	2.76	2.07	0.00	0.00	-	-	-	-	-	-	-	-	-
H, %	17.93	8.28	12.41	10.34	13.79	-	-	-	-	-	-	-	-	-
H & VH, %	2.76	0.00	3.45	0.00	0.00	-	-	-	-	-	-	-	-	-
VH, %	6.90	18.62	12.41	4.83	26.90	-	-	-	-	-	-	-	-	-

Linguistic scale	8. Trading Across Borders						9. Enforcing Contracts			10. Closing Business	
	8.1.1	8.1.2	8.1.3	8.2.1	8.2.2	8.2.3	9.1	9.2	9.3	10.1.1	10.1.2
VL, %	-	-	-	-	-	-	17.24	13.10	26.21	13.10	43.45
VL & L, %	-	-	-	-	-	-	2.07	4.83	6.21	2.07	0.69
L, %	-	-	-	-	-	-	17.93	15.86	18.62	15.86	13.10
L & M, %	-	-	-	-	-	-	4.14	7.59	6.21	6.21	11.03
M, %	-	-	-	-	-	-	25.52	24.83	14.48	22.76	11.72
M & H, %	-	-	-	-	-	-	10.34	4.14	5.52	2.76	0.00
H, %	-	-	-	-	-	-	11.72	11.03	10.34	15.86	3.45
H & VH, %	-	-	-	-	-	-	2.76	3.45	2.76	5.52	0.00
VH, %	-	-	-	-	-	-	8.28	15.17	9.66	15.86	16.55

Table 2.5.1. Number of countries in linguistic classes (2004)

Linguistic scale	1. Starting Business				2. Dealing with Licenses			3. Employing Workers					
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1.1	3.1.2	3.1.3	3.1	3.2	3.3
VL	5	18	21	50	-	-	-	45	14	34	14	-	23
VL & L	6	7	7	3	-	-	-	7	19	12	20	-	20
L	15	22	31	8	-	-	-	28	0	23	27	-	29
L & M	11	9	7	2	-	-	-	14	46	29	33	-	7
M	16	25	12	9	-	-	-	2	0	13	22	-	16
M & H	17	3	4	4	-	-	-	13	48	10	8	-	4
H	29	18	8	7	-	-	-	9	0	10	8	-	21
H & VH	0	6	5	3	-	-	-	8	6	1	1	-	3
VH	34	25	38	47	-	-	-	7	0	1	0	-	10

Linguistic scale	4. Registering Property			5. Getting Credit		6. Protecting Investors			7. Paying Taxes					
	4.1	4.2	4.3	5.1	5.2	6.1	6.2	6.3	7.1	7.2	7.3.1	7.3.2	7.3.3	7.3
VL	-	-	-	-	33	-	-	-	-	-	-	-	-	-
VL & L	-	-	-	-	14	-	-	-	-	-	-	-	-	-
L	-	-	-	-	15	-	-	-	-	-	-	-	-	-
L & M	-	-	-	-	0	-	-	-	-	-	-	-	-	-
M	-	-	-	-	18	-	-	-	-	-	-	-	-	-
M & H	-	-	-	-	0	-	-	-	-	-	-	-	-	-
H	-	-	-	-	18	-	-	-	-	-	-	-	-	-
H & VH	-	-	-	-	20	-	-	-	-	-	-	-	-	-
VH	-	-	-	-	15	-	-	-	-	-	-	-	-	-

Linguistic scale	8. Trading Across Borders						9. Enforcing Contracts			10. Closing Business	
	8.1.1	8.1.2	8.1.3	8.2.1	8.2.2	8.2.3	9.1	9.2	9.3	10.1.1	10.1.2
VL	-	-	-	-	-	-	24	17	35	-	-
VL & L	-	-	-	-	-	-	3	6	7	-	-
L	-	-	-	-	-	-	22	18	25	-	-
L & M	-	-	-	-	-	-	5	8	10	-	-
M	-	-	-	-	-	-	32	38	20	-	-
M & H	-	-	-	-	-	-	15	7	6	-	-
H	-	-	-	-	-	-	17	14	16	-	-
H & VH	-	-	-	-	-	-	4	4	3	-	-
VH	-	-	-	-	-	-	11	21	11	-	-

Table 2.5.2. Percent of countries in linguistic classes (2004)

Linguistic scale	1. Starting Business				2. Dealing with Licenses			3. Employing Workers					
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1.1	3.1.2	3.1.3	3.1	3.2	3.3
VL, %	3.76	13.53	15.79	37.59	-	-	-	33.83	10.53	25.56	10.53	-	17.29
VL & L, %	4.51	5.26	5.26	2.26	-	-	-	5.26	14.29	9.02	15.04	-	15.04
L, %	11.28	16.54	23.31	6.02	-	-	-	21.05	0.00	17.29	20.30	-	21.80
L & M, %	8.27	6.77	5.26	1.50	-	-	-	10.53	34.59	21.80	24.81	-	5.26
M, %	12.03	18.80	9.02	6.77	-	-	-	1.50	0.00	9.77	16.54	-	12.03
M & H, %	12.78	2.26	3.01	3.01	-	-	-	9.77	36.09	7.52	6.02	-	3.01
H, %	21.80	13.53	6.02	5.26	-	-	-	6.77	0.00	7.52	6.02	-	15.79
H & VH, %	0.00	4.51	3.76	2.26	-	-	-	6.02	4.51	0.75	0.75	-	2.26
VH, %	25.56	18.80	28.57	35.34	-	-	-	5.26	0.00	0.75	0.00	-	7.52

Linguistic scale	4. Registering Property			5. Getting Credit		6. Protecting Investors			7. Paying Taxes					
	4.1	4.2	4.3	5.1	5.2	6.1	6.2	6.3	7.1	7.2	7.3.1	7.3.2	7.3.3	7.3
VL, %	-	-	-	-	24.81	-	-	-	-	-	-	-	-	-
VL & L, %	-	-	-	-	10.53	-	-	-	-	-	-	-	-	-
L, %	-	-	-	-	11.28	-	-	-	-	-	-	-	-	-
L & M, %	-	-	-	-	0.00	-	-	-	-	-	-	-	-	-
M, %	-	-	-	-	13.53	-	-	-	-	-	-	-	-	-
M & H, %	-	-	-	-	0.00	-	-	-	-	-	-	-	-	-
H, %	-	-	-	-	13.53	-	-	-	-	-	-	-	-	-
H & VH, %	-	-	-	-	15.04	-	-	-	-	-	-	-	-	-
VH, %	-	-	-	-	11.28	-	-	-	-	-	-	-	-	-

Linguistic scale	8. Trading Across Borders						9. Enforcing Contracts			10. Closing Business	
	8.1.1	8.1.2	8.1.3	8.2.1	8.2.2	8.2.3	9.1	9.2	9.3	10.1.1	10.1.2
VL, %	-	-	-	-	-	-	18.05	12.78	26.32	-	-
VL & L, %	-	-	-	-	-	-	2.26	4.51	5.26	-	-
L, %	-	-	-	-	-	-	16.54	13.53	18.80	-	-
L & M, %	-	-	-	-	-	-	3.76	6.02	7.52	-	-
M, %	-	-	-	-	-	-	24.06	28.57	15.04	-	-
M & H, %	-	-	-	-	-	-	11.28	5.26	4.51	-	-
H, %	-	-	-	-	-	-	12.78	10.53	12.03	-	-
H & VH, %	-	-	-	-	-	-	3.01	3.01	2.26	-	-
VH, %	-	-	-	-	-	-	8.27	15.79	8.27	-	-

3. NUMBER OF COUNTRIES IN LINGUISTIC CLASSES FOR AGGREGATED INDICATORS (2008-2004)

Table 3.1. Number and percent of countries in linguistic classes for aggregated indicators (2008-2004)- SB and DL

Linguistic scale	1. Ease of Starting a Business					2. Ease of Dealing with Licenses				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
	Countries (number)									
VE	8	10	10	14	15	-	-	3	5	5
VE & E	7	12	10	21	14	-	-	13	18	16
E	14	17	22	31	40	-	-	14	19	18
E & A	11	18	17	21	17	-	-	19	19	24
A	37	36	37	35	42	-	-	23	25	21
A & D	13	14	16	17	14	-	-	36	41	47
D	23	21	23	20	20	-	-	25	25	23
D & VD	13	12	11	8	12	-	-	17	17	19
VD	7	5	9	8	4	-	-	5	6	5
	Countries (%)									
VE	6.02	6.90	6.45	8.00	8.43	-	-	1.94	2.86	2.81
VE & E	5.26	8.28	6.45	12.00	7.87	-	-	8.39	10.29	8.99
E	10.53	11.72	14.19	17.71	22.47	-	-	9.03	10.86	10.11
E & A	8.27	12.41	10.97	12.00	9.55	-	-	12.26	10.86	13.48
A	27.82	24.83	23.87	20.00	23.60	-	-	14.84	14.29	11.80
A & D	9.77	9.66	10.32	9.71	7.87	-	-	23.23	23.43	26.40
D	17.29	14.48	14.84	11.43	11.24	-	-	16.13	14.29	12.92
D & VD	9.77	8.28	7.10	4.57	6.74	-	-	10.97	9.71	10.67
VD	5.26	3.45	5.81	4.57	2.25	-	-	3.23	3.43	2.81

Table 3.2. Number and percent of countries in linguistic classes for aggregated indicators (2008-2004)- EW and RP

Linguistic scale	3. Ease of Employing Workers					4. Ease of Registering Property				
	Year					Year				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
	Countries (number)									
VE	8	0	7	7	9	-	5	7	12	7
VE & E	20	0	16	22	23	-	18	19	32	22
E	29	0	27	30	29	-	25	27	22	28
E & A	24	27	27	31	24	-	32	30	43	37
A	33	49	49	53	59	-	23	27	26	32
A & D	13	42	23	23	23	-	25	25	23	29
D	5	22	6	9	11	-	9	9	9	14
D & VD	1	4	0	0	0	-	4	6	4	4
VD	0	1	0	0	0	-	4	5	4	5
	Countries (%)									
VE	6.02	0.00	4.52	4.00	5.06	-	3.45	4.52	6.86	3.93
VE & E	15.04	0.00	10.32	12.57	12.92	-	12.41	12.26	18.29	12.36
E	21.80	0.00	17.42	17.14	16.29	-	17.24	17.42	12.57	15.73
E & A	18.05	18.62	17.42	17.71	13.48	-	22.07	19.35	24.57	20.79
A	24.81	33.79	31.61	30.29	33.15	-	15.86	17.42	14.86	17.98
A & D	9.77	28.97	14.84	13.14	12.92	-	17.24	16.13	13.14	16.29
D	3.76	15.17	3.87	5.14	6.18	-	6.21	5.81	5.14	7.87
D & VD	0.75	2.76	0.00	0.00	0.00	-	2.76	3.87	2.29	2.25
VD	0.00	0.69	0.00	0.00	0.00	-	2.76	3.23	2.29	2.81

Table 3.3. Number and percent of countries in linguistic classes for aggregated indicators (2008-2004)- GC and PI

Linguistic scale	5. Ease of Getting Credit					6. Strength of Protecting Investors				
						Year				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
	Countries (number)									
VE	14	4	4	4	4	-	-	2	2	2
VE & E	20	7	9	10	13	-	-	7	7	7
E	18	14	19	24	23	-	-	2	2	2
E & A	0	23	26	23	27	-	-	28	39	40
A	18	19	19	24	24	-	-	28	28	31
A & D	0	16	19	14	23	-	-	56	58	57
D	15	33	32	39	31	-	-	22	24	24
D & VD	14	25	20	29	25	-	-	9	14	14
VD	33	4	7	8	8	-	-	1	1	1
	Countries (%)									
VE	10.61	2.76	2.58	2.29	2.25	-	-	1.29	1.14	1.12
VE & E	15.15	4.83	5.81	5.71	7.30	-	-	4.52	4.00	3.93
E	13.64	9.66	12.26	13.71	12.92	-	-	1.29	1.14	1.12
E & A	0.00	15.86	16.77	13.14	15.17	-	-	18.06	22.29	22.47
A	13.64	13.10	12.26	13.71	13.48	-	-	18.06	16.00	17.42
A & D	0.00	11.03	12.26	8.00	12.92	-	-	36.13	33.14	32.02
D	11.36	22.76	20.65	22.29	17.42	-	-	14.19	13.71	13.48
D & VD	10.61	17.24	12.90	16.57	14.04	-	-	5.81	8.00	7.87
VD	25.00	2.76	4.52	4.57	4.49	-	-	0.65	0.57	0.56

Table 3.4. Number and percent of countries in linguistic classes for aggregated indicators (2008-2004)- PT and TAB

Linguistic scale	7. Ease of Paying Taxes					8. Ease of Trading Across Borders				
						Year				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
	Countries (number)									
VE	-	-	6	1	8	-	-	8	11	11
VE & E	-	-	15	9	13	-	-	21	20	22
E	-	-	11	10	17	-	-	24	34	34
E & A	-	-	34	26	43	-	-	31	37	37
A	-	-	22	29	23	-	-	27	31	34
A & D	-	-	35	38	41	-	-	14	13	11
D	-	-	18	35	18	-	-	14	12	11
D & VD	-	-	11	21	13	-	-	15	15	16
VD	-	-	3	6	2	-	-	1	2	2
	Countries (%)									
VE	-	-	3.87	0.57	4.49	-	-	5.16	6.29	6.18
VE & E	-	-	9.68	5.14	7.30	-	-	13.55	11.43	12.36
E	-	-	7.10	5.71	9.55	-	-	15.48	19.43	19.10
E & A	-	-	21.94	14.86	24.16	-	-	20.00	21.14	20.79
A	-	-	14.19	16.57	12.92	-	-	17.42	17.71	19.10
A & D	-	-	22.58	21.71	23.03	-	-	9.03	7.43	6.18
D	-	-	11.61	20.00	10.11	-	-	9.03	6.86	6.18
D & VD	-	-	7.10	12.00	7.30	-	-	9.68	8.57	8.99
VD	-	-	1.94	3.43	1.12	-	-	0.65	1.14	1.12

Table 3.4.1. Number and percent of countries in linguistic classes for aggregated indicators (2008-2004)-Ease of Export and Ease of Import for TAB

Linguistic scale	8.1. Ease of Export					8.2. Ease of Import				
	Year									
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
	Countries (number)									
VE	-	-	7	8	9	-	-	10	13	11
VE & E	-	-	20	18	19	-	-	24	26	33
E	-	-	20	31	34	-	-	22	31	31
E & A	-	-	32	40	33	-	-	38	43	48
A	-	-	23	29	29	-	-	17	22	15
A & D	-	-	20	19	21	-	-	18	14	15
D	-	-	11	13	8	-	-	13	11	9
D & VD	-	-	20	16	21	-	-	12	14	16
VD	-	-	2	1	4	-	-	1	1	0
	Countries (%)									
VE	-	-	4.52	4.57	5.06	-	-	6.45	7.43	6.18
VE & E	-	-	12.90	10.29	10.67	-	-	15.48	14.86	18.54
E	-	-	12.90	17.71	19.10	-	-	14.19	17.71	17.42
E & A	-	-	20.65	22.86	18.54	-	-	24.52	24.57	26.97
A	-	-	14.84	16.57	16.29	-	-	10.97	12.57	8.43
A & D	-	-	12.90	10.86	11.80	-	-	11.61	8.00	8.43
D	-	-	7.10	7.43	4.49	-	-	8.39	6.29	5.06
D & VD	-	-	12.90	9.14	11.80	-	-	7.74	8.00	8.99
VD	-	-	1.29	0.57	2.25	-	-	0.65	0.57	0.00

Table 3.5. Number and percent of countries in linguistic classes for aggregated indicators (2008-2004)- EC and CB

Linguistic scale	9. Ease of Enforcing Contracts					10. Ease of Closing Business				
						Year				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
	Countries (number)									
VE	5	5	4	3	5	17	15	17	20	21
VE & E	17	18	20	20	19	2	4	4	1	5
E	16	17	17	17	22	11	7	8	11	15
E & A	28	33	38	49	46	7	4	5	8	14
A	23	28	27	27	26	21	22	27	34	30
A & D	25	26	30	36	35	11	10	12	15	12
D	11	10	13	17	20	22	32	33	42	37
D & VD	8	8	5	5	4	15	13	16	8	11
VD	0	0	1	1	1	27	38	33	36	33
	Countries (%)									
VE	3.76	3.45	2.58	1.71	2.81	12.78	10.34	10.97	11.43	11.80
VE & E	12.78	12.41	12.90	11.43	10.67	1.50	2.76	2.58	0.57	2.81
E	12.03	11.72	10.97	9.71	12.36	8.27	4.83	5.16	6.29	8.43
E & A	21.05	22.76	24.52	28.00	25.84	5.26	2.76	3.23	4.57	7.87
A	17.29	19.31	17.42	15.43	14.61	15.79	15.17	17.42	19.43	16.85
A & D	18.80	17.93	19.35	20.57	19.66	8.27	6.90	7.74	8.57	6.74
D	8.27	6.90	8.39	9.71	11.24	16.54	22.07	21.29	24.00	20.79
D & VD	6.02	5.52	3.23	2.86	2.25	11.28	8.97	10.32	4.57	6.18
VD	0.00	0.00	0.65	0.57	0.56	20.30	26.21	21.29	20.57	18.54



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