Assessing Organizational Diversity with the McIntosh Index

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By

Salomón Alcocer Guajardo

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Assessing Organizational Diversity with the McIntosh Index

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By Salomón Alcocer Guajardo

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This book is dedicated posthumously to Dr. Robert P. McIntosh (1920–2017) for creating the diversity indices of evenness presented in this book and for contributing to the quantitative measurement of diversity.

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NYC DEPARTMENTS

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Borough President-Brooklyn	BP-BK
Borough President-Manhattan	BP-MAN
Borough President-Queens	BP-QNS
Borough President-Staten Island	BP-SI
Business Integrity Commission	BIC
Campaign Finance Board	CFB
City Commission on Human Rights	CCHR
Civilian Complaint Review Board	CCRB
Conflicts of Interest Board	COIB
Department for the Aging	DFTA
Department of Buildings	DOB
Department of City Planning	DCP
Department of Citywide Administrative Services	DCAS
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Department of Education	DOE
Department of Environment Protection	DEP
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PREFACE

As stated in *Assessing Organizational Diversity with the Simpson Index* (Guajardo, 2023a), the Simpson (1949), Shannon (1948), and McIntosh (1967) evenness indices have been used to assess and measure demographic (or social) diversity in nonprofit, private, and public organizations (Guajardo, 2013 and 2015). In *Assessing Organizational Diversity with the Simpson Index* (Guajardo, 2023a), the Simpson index was used to assess demographic and organizational diversity of NYC departments. The application of the Shannon diversity index to NYC departments was discussed and presented in *Assessing Organizational Diversity with the Shannon Index* (Guajardo, 2023b). This book focuses exclusively on the application of McIntosh diversity indices to employment data reported by NYC departments for fiscal year 2019. In so doing, this book discusses the advantages and disadvantages of applying the McIntosh indices to employment data to obtain measures of demographic (or social) and organizational diversity.

Unlike the Simpson (1949) and Shannon (1948) evenness (or standardized) indices, the McIntosh (1967) diversity indices incorporate simultaneously a measure of similarity ($\sqrt{p^2}$), organizational size, and the number of groups (or categories) to obtain a diversity score. This is accomplished by using the following formulas:

- $M = \frac{1 - \sqrt{\sum p^2}}{1 - \frac{1}{n}}$
- $M_E = \frac{1 - \sqrt{\sum p^2}}{1 - \frac{1}{\sqrt{n}}}$

In the formulas above, *p* represents the percent of individuals in each group (or category), and *n* represents the number of groups (or categories).

Unlike Shannon (1948) and Simpson (1949), McIntosh (1967) provided formulas for obtaining the empirical minimum and maximum values of diversity for a community. The formula for obtaining the empirical minimum value is as follows:

- $M_{Min} = \frac{1}{n}\sqrt{n}$

The empirical maximum value (EMV) is obtained with the following formula:

- $M_{Max} = 1 - \frac{1}{\sqrt{n}}$

Briefly, M_{Max} is used as the denominator when M_E is applied to obtain an evenness (or standardized) measure of diversity.

This book focuses on the adaptation and assessment of McIntosh indices of diversity when they are applied to demographic employment data to obtain measures of evenness. Consistent with previous companion books in the series (Guajardo, 2023a, 2023b, 2023c, and 2023d), this book addresses fundamental analytical and measurement issues and questions that arise when McIntosh indices of diversity are applied to demographic and employment data to obtain measures of heterogeneity. The issues and questions addressed in this book include the following:

- How is measurement bias addressed by a particular diversity index?
- How is the number of categories used for a demographic (or social) characteristic addressed by a particular diversity index?
- What are the statistical properties of a distribution of scores of a particular diversity index when it is applied to demographic and employment data?
- What is the appropriate statistical method to use based on the distribution of scores obtained by a particular diversity index?
- What is the maximum value of diversity that is obtainable by a particular diversity index?

These issues are addressed throughout this book because little empirical research has been devoted to examining the adaptation and use of diversity indices to measure and analyze demographic (or social) diversity in organizations. Although the issues and questions addressed in this and its companion books are fundamental to carrying out empirical research, practitioners and researchers alike often ignore or take the analytical or measurement issues and questions for granted.

As stated in previous companion books (Guajardo, 2023a, 2023b, 2023c, and 2023d), the book series consists of 9 books. They are the following:

- *Assessing Organizational Diversity with the Simpson Index* applies the Simpson diversity index to demographic and employment data reported by New York City (NYC) departments for fiscal year 2019. This book focuses on the application and analysis of Simpson diversity formulas for calculating biased and unbiased measures of demographic heterogeneity.
- *Assessing Organizational Diversity with the Shannon Index* applies the Shannon diversity index to the same demographic and employment data used in the first book. This book focuses exclusively on the application and analysis of Shannon diversity formulas for calculating biased and unbiased measures of demographic heterogeneity.
- *Assessing Organizational Diversity with the Heip Index* applies the Heip, Sheldon, and other Shannon-based diversity indices to the data used in the first and second books. The Heip, the Sheldon, and the other Shannon-based diversity indices presented in the book are modifications of the Shannon index of diversity. From a statistical standpoint, the Heip and Sheldon indices possess statistical properties that are superior to the original Shannon index. Like the first and second books, this book focuses on the application and analysis of the indices in terms of measuring demographic heterogeneity in organizations.
- *Assessing Organizational Diversity with the Smith and Wilson Indices* applies the Smith and Wilson (SW) indices to the same data used in the previous companion books. In addition to applying the SW indices, other Simpson-based indices such as the Ray and Singer (RS) index of concentration are presented in the book. The SW and RS indices are modifications of the Simpson ($D = 1- \sum p^2$) diversity index and assess demographic heterogeneity as well. This book applies the Simpson-based indices to the same data used in previous books to measure demographic heterogeneity in organizations.
- *Assessing Organizational Diversity with the McIntosh Index* applies the McIntosh evenness index to the same demographic and employment data used in the preceding companion books. This book focuses on the analysis of diversity scores obtained by the McIntosh index. Because the index incorporates the number of groups used to categorize a demographic (or social) characteristic of interest and the size of the workforce simultaneously, the diversity scores contain less measurement bias and have a greater degree of compatibility in comparison to the other diversity indices covered in the previous companion books.

- *Assessing Organizational Diversity with the Index of Qualitative Variation* (IQV) applies the Mueller and Schuessler IQV to the same demographic and employment data used in the previous companion books. Because the IQV may not be invariant to *ordering sequences*, this book focuses on the application and analysis of heterogeneity scores obtained from the different ordering sequences of the data. Like the McIntosh evenness index presented in the 5th book, the IQV incorporates jointly the number of groups used in the categorization of the demographic (or social) characteristic of interest and the size of the workforce.
- *Assessing the Validity of Diversity Indices* compares the indices used in each book jointly and uses factor analysis to determine whether they assess the same (or different) aspects of demographic (or social) diversity. Pearson pairwise correlation analyses are also performed to assess the statistical associations amongst the diversity indices. Statistical analyses for equality of means are performed as well.
- *Assessing Organizational Diversity with Quantile Regression* applies quantile regression analysis to each of the diversity indices presented in this book series. This book performs quantile regression analyses at the 25th, 50th, 75th, and 90th percentiles for age, ethnic, and gender diversity.
- *Assessing Organizational Diversity with Structural Equation Modeling* (SEM) focuses exclusively on causal modeling. This book focuses on the development and analysis of a SEM for specific diversity indices discussed in the book series. In so doing, the analyses treat age, ethnic, and gender diversity as intervening (or mediating) variables of organizational performance.

For purposes of continuity and compatibility, each diversity index is subjected to the same statistical analyses. The IQV, McIntosh evenness, Shannon, Simpson, and SW indices are of special focus in this book series because they have been used in previous research on demographic (or social) diversity in nonprofit, private, or public organizations.

This book series is written for practitioners and researchers in human resources and other fields that are interested in measuring and analyzing demographic, occupational, or social heterogeneity in organizations. The purpose of the book series is to addresses measurement and analytical issues that practitioners and researchers alike are likely to face when they apply a particular diversity index to demographic and employment data provided by a nonprofit, private, or public organization. As such, this book series should

serve as a reference for selecting the diversity index that is best suited for measuring and analyzing heterogeneity in an organizational setting. This book series also should serve as a reference for selecting the statistical method that is best suited for analyzing the distribution of scores obtained by the diversity index of choice.

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CHAPTER 1

INTRODUCTION

As stated in the preceding companion books (Guajardo, 2023a, 2023b, 2023c, and 2023d), researchers have used diversity (or *integration*) indices to assess the level of demographic (or social) *heterogeneity* in nonprofit, private, or public organizations since the early 1970s (e.g., Akram, Abrar ul Haq, Natarajan, and Chellakan, 2020; Boehm, Kunze, and Bruch, 2014; Choi, 2010; Gazley, Chang, and Bingham, 2010; Grabosky and Rosenbloom, 1975; Guajardo, 2014; Moon and Christensen, 2020; Nachmias and Rosenbloom, 1973). Of the plethora of indices of diversity that have been developed to assess heterogeneity (or variation), researchers use the Simpson (1949) and Shannon (1948) indices the most frequently. For the most part, the Simpson and Shannon indices have been applied to aggregate demographic employment data to measure age, ethnic, or gender heterogeneity. More recently, diversity indices have been used to assess concepts such as educational and occupational diversity. In most of the previous studies, workforce diversity has served as a *dependent variable*. More recent studies, however, have treated workforce diversity as an *independent variable* which influences organizational performance (e.g., Gazley, Chang, and Bingham, 2010; Khan, Khan, and Senturk, 2019; Lee-Kuen, Sok-Gee, and Zainudin, 2017; Pitts, 2005). Consistent with the preceding companion books (Guajardo, 2023a, 2023b, 2023c, and 2023d), this book takes the position that workforce diversity such as age, ethnic, and gender heterogeneity is an *intervening variable* that influences organizational performance (e.g., Guajardo, 2014; Pitts, 2006).

Indices of diversity and variation

As stated in *Assessing Organizational Diversity with the Simpson Index* (Guajardo, 2023a), several indices of diversity (or variation) have been used to measure demographic (or social) diversity (or *heterogeneity*) in organizations. They include the following:

- Index of qualitative variation (IQV) or measure of variation (MV; e.g., Grabosky and Rosenbloom, 1975; Kellough, 1990; Kim, 1993; Nachmias and Rosenbloom, 1973);
- McIntosh evenness index (e.g., Guajardo, 2013 and 2015);
- Shannon (Teachman) index (e.g., Choi, 2010; Choi and Rainey, 2010); and,
- Simpson (Blau or Lieberson) diversity index (e.g., Guajardo, 2014; Pitts, 2005; Smith and Wilson, 1996; Starks, 2009).

Theoretically, each diversity index produces a distribution of scores that ranges from 0 to 1. Except for the Shannon index, a score of 0 indicates the absence of diversity (or heterogeneity), and a score of 1 indicates absolute diversity. As stated in the Preface, this book focuses exclusively on the McIntosh indices of diversity.

Mueller and Schuessler developed the IQV to assess demographic heterogeneity (or variation; Mueller, Schuessler, and Costner, 1970; Wilcox, 1967). The IQV obtains a measurement of heterogeneity by dividing the total observed difference by the maximum possible differences (Mueller, Schuessler, and Costner, 1970; Wilcox, 1967). Symbolically, the IQV index takes the following form (Wilson, 1967):

$$\text{IQV} = \frac{\text{Total observed differences}}{\text{Maximum Possible Differences}} = \frac{\sum f_i f_j}{\frac{n(n-1)}{2} \text{ x } (\frac{F}{n})^2}$$

where

f represents the frequency (or number) of individuals;

n represents the number of social characteristics (i.e., groups); and,

F represents the total number of individuals.

The index has a distribution of score ranging from 0 to 1, where a score of 0 indicates a lack of heterogeneity (i.e., homogeneity) and a score of 1 indicates absolute heterogeneity (Mueller, Schuessler, and Costner, 1970). *Assessing Organizational Diversity with the Index of Qualitative Variation* focuses exclusively on the application of the index to public organizations.

Shannon (1948) created the H index for the communications field to obtain the *probability* of successive messages being independent of each other. Since its creation, the H index has been adapted to assess demographic (or

social) diversity in organizations. The index is presented as follows: $H = -\sum[p_k * \ln(p_k)$, where p is the proportion of individuals in the kth category. Unlike the IQV, McIntosh, and Simpson indices, the Shannon index has a distribution of scores ranging from 0 to ln(n), where ln represents the natural logarithm of a number and n represents the number of demographic (or social) categories (e.g., Harrison and Klein, 2007). For instance, the maximum value of H is 1.609 ($H_M = \ln(5) = 1.609$) when ethnicity is categorized into 5 groups. The following formula is used to standardize H scores and to obtain a distribution of scores with a range from 0 to 1: $H_s = \frac{-\sum[pk*\ln(pk)}{\ln(n)}$. *Assessing Organizational Diversity with the Shannon Index* (Guajardo, 2023b) focuses exclusively on the Shannon index of diversity. Shannon-based diversity indices are discussed in *Assessing Organizational Diversity with the Heip Index* (Guajardo, 2023c).

The Simpson diversity index is used frequently to assess demographic (or social) heterogeneity in organizations. Simpson (1949) created the diversity index to obtain the probability that two individuals chosen at random from the same community would share the same (or different) characteristics. Smith and Wilson (1996) developed several diversity indices based on Simpson's index. Theoretically, Simpson's index has a distribution of scores ranging from 0 to 1, where a score of 0 indicates the absence of diversity and a score of 1 indicates absolute diversity. In actuality, the maximum value for a particular demographic (or social) characteristic is determined by the following formula: $S_M = \frac{k-1}{k}$, where k is the number of categories (or groups) created for the demographic (or social) characteristic of interest. For instance, the maximum diversity score is 0.80 ($S_M = \frac{k-1}{k} = \frac{4-1}{5} = 0.80$) when ethnicity is categorized into 5 groups. Simpson's index is represented frequently by the following formula: $S_A = 1-\sum p^2$, where p represents the percent of individuals in a particular category (or group). The index also is represented as follows: $S_B = \frac{\sum n(n-1)}{N(N-1)}$, where n is the number of individuals in a category (or group) and N is the total number of individuals. Standardized Simpson scores are obtained by applying the following formula: $S_S = \frac{S}{\left(\frac{k-1}{k}\right)}$, where S equals S_A or S_B and k represents the number of categories or groups. *Assessing Organizational Diversity with the Simpson Index* (Guajardo, 2023a) discusses unstandardized and standardized Simpson diversity indices. Simpson-based diversity indices are discussed in *Assessing Organizational Diversity with the Smith and Wilson Indices* (Guajardo, 2023c).

McIntosh indices of diversity

As discussed by McIntosh (1967), diversity (or similarity) in any community (or sample) may be measured by applying the following index: $\sqrt{\Sigma n^2}$, where *n* is the number of individuals in each group (or category) in a community. According to McIntosh (1967), the observed level of diversity is obtained by subtracting $\sqrt{\Sigma n^2}$ from *N* (the total number of individuals in the community) as follows: $D_N = N - \sqrt{\Sigma n^2}$. When the number (or frequency) of individuals in each group in the community is reported, the *empirical maximum value* (EMV) of diversity is obtained with the following formula: $D_{NM} = N - \frac{N}{\sqrt{S}}$, where *N* is the total number of individuals in the community and *S* is the total number groups (or categories).

Alternatively, $\sqrt{\Sigma p^2}$ may be used when the percentage of individuals in each group (or category) in a community is provided (Guajardo, 2015). The observed level of diversity is obtained by subtracting $\sqrt{\Sigma p^2}$ from 1 as follows: $M_P = 1 - \sqrt{\Sigma p^2}$. The EMV is obtained with the following formula: $M_{PM} = 1 - \frac{1}{\sqrt{n}}$, where *n* is the total number groups (or categories).

When the number of individuals is equal in each group (or category), the following McIntosh (1967) formula is used: $D = \frac{N - \sqrt{\Sigma n^2}}{N - \frac{N}{S}}$, where *N* is the total number of individuals in the community, *n* is the number (or frequency) of individuals in each group, and *S* is the number of groups (or categories). Alternatively, when the percentages are equal for each group, the following formula is used: $M = \frac{1 - \sqrt{\Sigma p^2}}{1 - \frac{1}{n}}$, where *p* is the percent of individual in each group and *n* is the number of groups (or categories). As developed by McIntosh (1967), this index produces a distribution of scores with a range from 0 to 1 where 0 indicates the absence of heterogeneity and 1 indicates maximum diversity.

When the number of individuals differs for each group (or category), the McIntosh evenness index may be used. The McIntosh evenness index is represented as follows: $D_E = \frac{N - \sqrt{\Sigma n^2}}{N - \frac{N}{\sqrt{S}}}$, where *N* is the total number of individuals in the community, *n* is the number of individuals in each group, and *S* is the number of groups (or categories). Alternatively, $M_E = \frac{1 - \sqrt{\Sigma p^2}}{1 - \frac{1}{\sqrt{n}}}$ is

used when the percentage of individuals in each group (or category) differ in the community. This index has a distribution of scores ranging from 0 to 1, where a score of 0 indicates an absence of diversity and a score of 1 indicates absolute diversity.

M_E is used throughout this book for the following reasons:

1. The evenness diversity scores obtained by M_E are consistent with those presented in previous companion books (Guajardo, 2023a, 2023b, 2023c, and 2023d);
2. The frequency (or percent) of individuals in each age, ethnic, and gender category (or group) differs; and,
3. The use of M_E requires fewer mathematical calculations (or operations) in comparison to the use of D_E.

Although the adaptation of M_E to work settings is straightforward, the application of M_E may be compromised due to differences in the number of categories (groups) created for a demographic (or social) characteristic of interest.

Because McIntosh (1967) did not discuss how to apply M_E when classifications (or groups) of different members are absent in a community, it is unclear whether the application of M_E should include only groups with members present in a community (or organization) or each group regardless of whether members are present or not. While the inclusion of each group in the calculation of an M_E achieves measurement compatibility amongst different communities (or organizations), measurement compatibility becomes compromised when groups with missing data are excluded. Exhibit 1-1 illustrates how the inclusion and exclusion of groups with missing data impact M_E evenness scores for age diversity amongst 3 NYC departments.

When each age group is used to calculate M_{E1} evenness scores for age diversity for ACS, Council, and TRS, measurement compatibility is achieved and maintained (see Exhibit 1-1). For instance, ACS has an evenness score of 0.950 (M_{E1} = 0.950). Council has an evenness score of 0.937 (M_{E1} = 0.937). Because TRS has fewer age groups with employment data, the department has an evenness score of 0.888 (M_{E1} = 0.888). These M_E scores are compatible because $\sqrt{\sum p^2}$ includes each age group and because $1 - \frac{1}{\sqrt{n}}$ uses an *n* of 11.

Exhibit 1-1. M_{E1} and M_{E2} scores for age for ACS, Council, and TRS for fiscal year 2019

ACS			
Age Group	Frequency	Percent (p)	p^2
Under 20	0	0.00	0.000
20 - 24	147	0.02	0.000
25 - 29	737	0.10	0.010
30 - 34	958	0.13	0.017
35 - 39	958	0.13	0.017
40 - 44	958	0.13	0.017
45 - 49	810	0.11	0.012
50 - 54	884	0.12	0.014
5 5- 59	958	0.13	0.017
60 - 64	589	0.08	0.006
Over 65	368	0.05	0.002
Total	7,367	1.00	0.113
$n_1 = 11$			
$n_2 = 10$			
$M_{E1} = 0.950$			
$M_{E2} = 0.970$			

Council			
Age Group	Frequency	Percent (p)	p^2
Under 20	17	0.02	0.000
20 - 24	104	0.12	0.014
25 - 29	173	0.20	0.040
30 - 34	139	0.16	0.026
35 - 39	104	0.12	0.014
40 - 44	61	0.07	0.005
45 - 49	52	0.06	0.004
50 - 54	52	0.06	0.004
5 5- 59	61	0.07	0.005
60 - 64	43	0.05	0.003
Over 65	61	0.07	0.005
Total	867	1.00	0.119
$n_1 = 11$			
$n_2 = 11$			
$M_{E1} = 0.937$			
$M_{E2} = 0.937$			

TRS			
Age Group	Frequency	Percent (p)	p^2
Under 20	0	0.00	0.000
20 - 24	0	0.00	0.000
25 - 29	0	0.00	0.000
30 - 34	17	0.05	0.003
35 - 39	31	0.09	0.008
40 - 44	35	0.10	0.010
45 - 49	49	0.14	0.020
50 - 54	70	0.20	0.040
5 5- 59	66	0.19	0.036
60 - 64	49	0.14	0.020
Over 65	31	0.09	0.008
Total	349	1.00	0.144
$n_1 = 11$			
$n_2 = 8$			
$M_{E1} = 0.888$			
$M_{E2} = 0.960$			

By contrast, the evenness scores obtained by M_{E2} are incompatible because $\sqrt{n}$ is different for ACS, Council, and TRS (see Exhibit 1-1). For instance, ACS has a M_{E2} score of 0.970 when an *n* of 10 is used. Because Council has employment data in each age group category ($n = 11$), a M_{E2} score of 0.937 is obtained. TRS has a M_{E2} score of 0.960 because $\sqrt{\sum p^2}$ and $1 - \frac{1}{\sqrt{n}}$ are based on an *n* of 8. To ensure measurement compatibility amongst the M_E scores for NYC departments, each category for age, ethnicity, and gender is used when applying the M_E index.

In addition to the issue of measurement compatibility, the exclusion of groups with missing data inflates the M_E scores and impacts the validity of the measurements (see Exhibit 1-1). For instance, when an *n* of 11 is used to calculate the M_{E1} score for TRS, an evenness score of 0.888 is obtained. By contrast, when an *n* of 8 is used, a M_{E2} score of 0.960 is obtained. With respect to the M_E scores for ACS, a M_{E1} score of 0.950 is obtained when an *n* of 11 is used. ACS has a M_{E2} score of 0.970 when an *n* of 10 is used. Because the M_{E2} evenness scores for age diversity are based on *n* of different sizes, the *measurement validity* of the M_{E2} scores is questionable for ACS and TRS. In subsequent chapters, the strengths and weaknesses of M_E are discussed.

Exhibit 1-2 Interpretation of McIntosh diversity scores

A. Interpretation of a standardized M score

M_S	Interpretation
1.00	Attained maximum level of the EMV
0.90 - 0.99	Attained extremely high level of the EMV
0.80 - 0.89	Attained moderately high level of the EMV
0.70 - 0.79	Attained somewhat moderately high level of the EMV
0.60 - 0.69	Attained moderate level of the EMV
0.50 - 0.59	Attained somewhat moderate level of the EMV
0.40 - 0.49	Attained moderately low level of the EMV
0.30 - 0.39	Attained somewhat low level of the EMV
0.20 - 0.29	Attained low level of the EMV
0.10 - 0.19	Attained extremely low level of the EMV
0.00 - 0.09	Absence of proportional attainment of the EMV

B. Interpretation of a M_E score

M_E	Interpretation
1.00	Attained maximum level of employment evenness (equitability)
0.90 - 0.99	Attained extremely high level of employment evenness
0.80 - 0.89	Attained moderately high level of employment evenness
0.70 - 0.79	Attained somewhat moderately high level of employment evenness
0.60 - 0.69	Attained moderate level of employment evenness
0.50 - 0.59	Attained somewhat moderate level of employment evenness
0.40 - 0.49	Attained moderately low level of employment evenness
0.30 - 0.39	Attained somewhat low level of employment evenness
0.20 - 0.29	Attained low level of employment evenness
0.10 - 0.19	Attained extremely low level employment evenness
0.00 - 0.09	Absence of any employment evenness

Exhibit 1-2 provides guidance on how to interpret an M_E score. Based on its M_{E1} score of 0.888, TRS attained a moderately high level (or proportion) of the EMV (EMV = $1 - \frac{1}{\sqrt{n}} = 1 - \frac{1}{\sqrt{11}} = 0.698$). Stated differently, TRS attained 89% of the maximum value of age diversity. Alternatively, TRS achieved a moderately high level of employment evenness in terms of age. When the M_{E2} score of 0.96 is used, TRS attained 96% of the EMV (EMV = $1 - \frac{1}{\sqrt{n}} = 1 - \frac{1}{\sqrt{8}} = 0.646$). The M_{E2} score also suggests that TRS attained an extremely high level of employment evenness in terms of age. Because the M_{E2} score for TRS is based on an *n* of 8, the interpretation and inference made with respect to the achievement of an extremely high level of