Application of Logistic Regression Model in Rasch Measurement to establish a Performance Index: 
A case study in Audits on Malaysian Institutions of Higher Learning

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Abstract: Performance measurement has traditionally been determined using historical data to establish the ‘best fit line’. Measuring performance in an appropriate way is vital to ensure valid quality information can be generated for meaningful use. A matter of prime concern in organisational excellence is internal audit, a control mechanism against systems failures. This paper promulgate the attempt of a new approach in establishing a performance measurement based on the Plan-Execute-Report-Monitor (PERM) Model, in this case the Audit Performance index; AP_i. A perception survey was conducted on auditors from selected Malaysian Institution of Higher Learning (IHL). Data obtained is used to calculate the performance indicators; D_i and index which are closely connected with various emotional, cognitive and intentional components. Instead of the common use of simple means over several ordinal variables, Rasch Measurement ‘logit unit’ enable the construction of a linear scale, based on a set of survey items where the mean, $\bar{x}_i$ is the probability of a successful audit hence; the AP_i index. Using Logistic Regression Model, it was found that the probabilistic model can help establish a theoretical basis for measuring such service performance and help IHL top management in improving their judgemental decision making. Rather than deterministic linear regression, the performance index established based on probabilistic model is more appropriate since the process outcome is a dependant variable; $\theta$ which is predictable within the limit of 0.0 to 1.0. Since the index is modelled using dimensions and attributes related to the audit process, the AP_i enables a more holistic and reliable evaluation of an audit process effectiveness, A_e; hence, the level of service effectiveness rendered.

Keywords: Rasch Model, performance measurement, continuous improvement, quality, engineering education.

1 Introduction
Performance measurement looks at the performance criteria, performance measures and performance standards. The performance criteria are used to evaluate performance and the values derived act as the measures. Accepted levels of performance for each criterion ultimately become the standard. Performance measurement has traditionally been determined using historical data to establish the ‘best fit line’. This is reactive in nature and has limitations for repeatability of measurement. There is a need for a departure from the repeatability of results when the instrument for measurement is the source of error. Measurement with the correct tool and method is of prime importance. The measure of reliability now shifts to the reproducibility of
measures rather than expressing the reproducibility of raw scores [1]. By focusing on the reproducibility of the latent trait instead of forcing the expected generation of the same raw score, the concept of reliability takes its rightful place in supporting validity rather than being in contensions. Hence; measuring performance in an appropriate way is vital to ensure valid quality information can be generated for meaningful use. This paper describes an alternative approach using bio-based Rasch Unidimensional Measurement probabilistic model as a more accurate performance measurement tool to establish a performance index.

2. Literature Review

The achievement of an performance level is dependent upon the way an organization is directed and controlled, i.e., corporate governance [2]. There exist increasing calls for good governance from both the public and private sector in the wake of corporate failures as demonstrated by the collapsed of the National Safety Council of Australia in the 1980s and the Pyramid Building Society in Victoria, Australia in 1990 [3]. This was followed by the fall of HIH group with a deficiency of AUD5.3 billion in 2001. In America, Enron Corporation filed for bankruptcy in 2001 after incurring US$62 billion through manipulations of financial statements by the company executives. In 2002, American telecommunications company WorldCom collapsed with losses of about US$11 billion. More reliance on the effectiveness of an audit function and the Audit Committee becomes a significant aspect of good corporate governance. Among other controls, internal audit is employed as part of a control mechanism against systems failures within the corporate governance framework. It is a self assessment mechanism that calls for the highest order of honesty and integrity for disclosure of facts.

Tunku Abdul Aziz [4] believes that unethical public behaviour within the government administration in the long run jeopardizes the perceived integrity and economic well-being of the country. Any move for better governance goes hand in hand with fairness, accountability, transparency and responsibility of use of public funding [5]. Malaysia formulated its Vision 2020 in 1991 with the aim to be a fully developed and industrialised country by year 2020. The strategies and development programs laid out for Sixth Malaysia Plan (6MP) focused on human resource development with an allocation of RM8.5 billion for development of education and training [6]. The expenditure for education and training in 8MP stood at RM43.73 billion and escalated to RM50.6 billion in Ninth Malaysia Plan or 9MP [7]. Good governance which translates to good performance in quality education paves the way in ensuring the disclosure to the Malaysian public that the way moneys are spent is without waste and extravagance, utilised in projects efficiently and effectively.

Effective audit has been shown to aid organizational excellence. In the engineering education, audit and continued efforts by the top management of a Malaysian public IHL in taking corrective actions as part of its continuous improvement process to reduce students failure rates is highly applaud. The combined effect since 2002/03 is a significant reduction by 65.71% in year 2004/05 in institutional recurrent costs [8].

Despite it’s importance; audit performance measurement has never been put in the proper perspective. Audit is central to an organisation’s sustainability and it’s very survival. Performance measures generally assess the efficiency and effectiveness of processes vis-à-vis an organisation strategic objectives. Measurements are made because they can indicate the degree of performance of a certain satisfactory level; measure whether the organization as a whole is functioning as intended. Psychologically, measurement acts as a motivator for the individual and the organization [9].

Wright and Mok, 2004 [1] suggested that experience is continuous but at the moment or time we notice the experience, it becomes discrete. Now it has the stochastic function of time, t, and space; hence dimensions. There are situations where indications of more or less of a dimension can be introduced as categories within each observation. This is the assumption used of scales in Rasch Measurement Model.

3. Measurement Methodology

Following from the dimensions in an audit process, audit performance is measurable; by criterion referencing on a dichotomous scale, in terms of the extent of use of best practices by counting responses to the attributes in the respective dimensions. Reporting of audit findings and the subsequent monitoring of corrective actions by management are important as avenues for continuous improvement in organizational excellence. The sample population of this study are
the internal auditors who assess the effectiveness of an engineering teaching and learning system and the management of an institution of higher learning, who undertake the operations and disclosure of their activities to their stakeholders.

Questionnaires are constructed based on a modified dichotomous ‘YES’ or ‘NO’ model [10] and the degree of achievement [8], reflecting the relative impact of a ‘YES’ answer to an attribute. The rating scale for the level of agreement on the 35 items in the survey are 0 – Disagree, 1 – Agree Slightly, 2 – Agree and 3 - Agree Strongly. This ordered category is also termed as ‘polytomous’ [11]. Subjects are asked to rank their agreement on the items representing the audit impact.

Literature reviews revealed aplenty best audit practices using the infamous PDCA Model. This model is adapted from Shewhart’s P-D-S-A Cycle which has been adopted and benefited many organisations worldwide, the performance criteria used to assess an audit effectiveness in this study is based on the same premise; their dimensions relevant to an audit process known as Plan – Execute –Report -Monitor (P-E-R-M) Model [12].

Each of these four dimensions is further analysed from literature reviews to derive at relevant proxies or attributes which are vital in the implementation of an effective audit. These attributes comprised of auditing best practices and as emphasized by the Institute of Internal Auditors in its performance standards [13] and ISO Guide to Auditing [14]. Table 1 shows one of the dimensions; i.e. PLAN and it’s relevant attributes under study.

<table>
<thead>
<tr>
<th>Dimension ‘PLAN’</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Audit scope</td>
</tr>
<tr>
<td>2 Evaluate policy</td>
</tr>
<tr>
<td>3 Auditors’ knowledge of area audited</td>
</tr>
<tr>
<td>4 Monitoring of auditor competency</td>
</tr>
<tr>
<td>5 Frequency of audits</td>
</tr>
</tbody>
</table>

The conceptual framework for transforming the survey results is as follows: Suppose that for one of the dimensions, there are five attributes relating to the dimension and the survey resulted in ten responses. First, the average or mean is calculated for the responses received on an attribute. The first method of calculating the mean, \( \bar{x}_i \) is simply to add the scores and divide by the number of scores added, \( N \) events; expressed as;

\[
\bar{x}_i = \frac{0 + 1 + 3 + 2 + 2 + 2 + 1 + 0 + 2 + 1}{10} = \frac{14}{10} = 1.4
\]

This can be written as;

\[
\bar{x}_i = \frac{\sum_{v=0}^{N} x_{vi}}{N} \quad \text{Equ.(1)}
\]

where, \( i \) = item in the event,
\( v \) = respondent or person, and
\( vi \) = response to item (0, 1, 2, 3)
\( N \) = total number of event

Hence; the probability of success; \( Pr(x=1) \) can be construed as the mean; \( \bar{x}_i \) arising from the turn of event [11]. This fundamental is now taken to the next step. The other way is to notice that there are only 4 different values; 2 0’s, 3 1’s, 4 2’s and 1 3’s and the expression is shortened by frequency, \( f_{xi} \) instead;

\[
\bar{x}_i = \frac{2(0) + 3(1) + 4(2) + 1(3)}{10} = \frac{0 + 3 + 8 + 3}{10} = \frac{14}{10} = 1.4
\]

This can be expressed in a frequency function;

\[
\bar{x}_i = \frac{\sum_{x=0}^{3} x_{vi} f_{xi}}{N} \quad \text{Equ.(2)}
\]

where, \( x_i \) = possible score for item,
\( f_{xi} \) = frequency of possible score

The expression for the mean, \( \bar{x}_i \) can be made as a product of a proportion. Since we know that there are 10 persons, we can divide the frequencies immediately by 10. This gives the proportion of times that a particular score appears;

\[
\bar{x}_i = \frac{2(0) + 3(1) + 4(2) + 1(3)}{10} = \frac{0.2)(0) + (0.3)(1) + (0.4)(2) + (0.1)(3)}{10} = 0.0 + 0.3 + 0.8 + 0.3; \quad \bar{x}_i = 1.4
\]

Thus, by dividing each frequency first by the number of cases to get the proportion of cases with...
each score, and then multiplying by the score and adding, we immediately get the mean, $\bar{x}_i$. This calculation is summarised below:

\[ \bar{x}_i = \sum_{x=0}^{3} p_{xi} x_i \quad \text{Equ.(3)} \]

where $p_{xi} =$ proportion of cases in each score

$x_i = f_{xi} =$ frequency of possible score

Hence, the frequency of cases for each score is converted into a proportion. The theoretical proportion of times that each score would occur is the probability that each score would occur. The theoretical mean can be calculated by using the same equation as that of Equation (3). Thus for an estimate $p_{xi}$ of the proportion of times each score $x$ would appear for item $i$, then, it can be estimated that the average score that item would get is from using the above equation. This theoretical mean is often called the "Expected Value"; $E[X_i]$ in statistics. The theoretical Expected Value is compared with the relevant Observed Mean in tests of fit in the Rasch measurement analysis. The equation is written as:

\[ E[X_i] = \bar{x}_i = \sum_{x=0}^{n} p_{xi} x_i \quad \text{Equ.(4)} \]

This is the rational in using the mean, $\bar{x}_i$ as the audit performance index.

Hence, for the establishment of the internal audit dimensions and indicators, Equation (2) and (4) are used to compute the attributes mean; $\overline{A}_j$ and by substitution, mathematically it can be shown as follows:

\[ \overline{A}_j = \frac{\sum_{x=0}^{3} s_i \omega_i}{N} \quad \text{Equ.(5)} \]

where $s_i =$ item score ($i = 0, 1, 2, 3$),

$\omega_i =$ frequency or number of respondents giving score $i$

$n =$ total number of responses, and

$j =$ item (1, 2, …, $n$).

This yield a series of performance indicators and which is fundamentally the input to Dimension indicators of $n$-numbers; $D_{kn}$. Cumulatively the attribute mean, $\overline{A}_j$ is further analysed by summing it up and divided by the number of items assessed;

\[ D_k = \frac{\sum_{j=1}^{n} A_j}{r} \quad \text{Equ.(6)} \]

where $A_j =$ item indicator, from Equation (5)

$n_k =$ total items in a dimension, and

$r =$ total number of items assessed

As previously shown, in Rasch Measurement the mean of events, $\bar{x}_i$ is the probability of success. Hence, the internal audit performance index, $AP_i$, can be established by summing up all the audit dimension indicators; $D_k$ based on the overall responses of the auditors.

\[ AP_i = \frac{\sum_{j=1}^{d_k} D_k}{N} \quad \text{Equ.(7)} \]

where $D_k =$ Dimension indicator, from Equ. (6)

$d_k =$ dimensions; area of study.

$N =$ total number of dimensions ($1, 2, \ldots, d_k$)

The $AP_i$ is next converted as a proportion of the full score of 3 (the maximum item rating score, $s_i$ in the questionnaire) which serves as the measurement of the audit effectiveness. Supposed the calculated $AP_i = 2.09$, then, the level of Audit Effectiveness; $A_e$ is obtained as follows:

\[ A_e = \frac{2.09}{3} \times 100 = 69.55\% \quad \text{Equ.(8)} \]

Both index and audit effectiveness, over time will then provide indications on the trend of the audit performances.

The rating is in line with the recently introduced scale by the Malaysian Government and is used in interpreting the index, $A_e$. The rating scale is also deemed to be the performance standard. The Auditor-General uses star ratings in evaluating the financial management skills of the ministries in Malaysia [15]. The star ratings are as follows:

- 4 stars - **Excellent** (90% - 100%)
- 3 stars - **Good** (70% - 89%)
- 2 stars - **Satisfactory** (50% - 69%)
- 1 stars - **Not Satisfactory** (49% and below)

Based on this rating scale, in this example, an audit
performance at the particular point in time when the audit function was first assessed, the audit was found to be ‘satisfactory’.

Apart from the above, as the index is computed based on the four dimensions, individual dimension’s weaknesses can be assessed and evaluated further. Low ratings achieved in the attributes can be analysed by the Head of Audit Department or the Audit Committee for corrective actions to be undertaken in ensuring a better performance level in the internal audit process.

4. Findings and Discussion

A pilot study was conducted at University of Teknologi Malaysia (UTM) and subsequently followed by another surveys at three (3) IHL’s. Table 2 shows the total number of responses; N=36 from UTM internal showing their level of perceptions on each attribute surveyed for the Dimension PLAN. From Equation (2), summing up the multiplication of the rating with the frequency of each score perceived;

\[ \bar{x}_i = \frac{\sum_{s=0}^{3} x_{si} f_{si}}{N} \]

where, \( \bar{x}_i \) is obtained; e.g. Attribute 1 - Audit Scope:

\[ \bar{x}_i = \frac{0(0) + 4(1) + 14(2) + 18(3)}{36} = \frac{0 + 4 + 28 + 54}{36} = \frac{86}{36} = 2.39 \]

Table 2 also indicate other attributes that warrants further investigation assuming the acceptable threshold value is above 2.00 (the ‘Agree’ level); in this case, the attributes are D EXECUTE \( A_j = 1.98 \), \( A_2 = 1.83 \), \( A_3 = 1.70 \) and \( A_4 = 1.95 \) respectively.

The results of all these dimension indicators are summarized to form the audit performance index, AP\(_i\), as shown in Table 4.

The computation is duly completed for the rest of the other PLAN attributes; \( \bar{x}_{1-5} \) and all the other dimensions respectively. This yield the ‘PLAN’ mean sum of raw score = 81.40 and indicator D PLAN = 2.26. The process is repeated for the other dimensions and summarised in Table 3.

It is noted that the lowest Attribute score for the auditors in Dimension PLAN is Attribute 4 (Competency); D PLAN, \( A_4 = 1.92 \) while the highest score is for Attribute 2 (Policy); D PLAN, \( A_2 = 2.44 \). The analysis can delve further for each dimension; and this IS the uniqueness of Rasch Measurement; it’s ability to scrutinise each moment or item individually on a unidimensional scale.

Table 3. UTM: Dimension Indicators, D\(_k\)

<table>
<thead>
<tr>
<th>Attribute; ( A_j )</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>D(_{kn})</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLAN</td>
<td>2.39</td>
<td>2.44</td>
<td>2.22</td>
<td>1.92</td>
<td>2.28</td>
<td>2.26</td>
</tr>
<tr>
<td>EXECUTE</td>
<td>2.18</td>
<td>1.98</td>
<td>1.83</td>
<td>1.76</td>
<td>1.95</td>
<td>1.96</td>
</tr>
<tr>
<td>REPORT</td>
<td>2.31</td>
<td>2.41</td>
<td>2.17</td>
<td>2.36</td>
<td>2.31</td>
<td>2.32</td>
</tr>
<tr>
<td>MONITOR</td>
<td>2.13</td>
<td>2.21</td>
<td>2.25</td>
<td>2.19</td>
<td>2.16</td>
<td>2.19</td>
</tr>
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Table 4. UTM: Audit Performance Index; AP\(_i\) and A\(_e\)

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The audit performance index for UTM based on the perceptions of auditors showed that the rating for audit carried out has a total value of AP\(_i\) = 2.18 or a grading A\(_e\) = 72.67%. Based on the star rating used by the Auditor-General, the audit performance is rated as ‘Good’. Note that D\(_{EXECUTE}\) = 1.96, or 65.33% is below the agreement level of 2.00 and star rating of 70% respectively.

This audit performance index is then compared across the other three public IHLs as shown in Table 5. This index gives an insight on the perception of the level of adequacy of each audit dimension being implemented. The overall achievement for the four IHL in this study are AP\(_i\).

Table 5. UTM: Audit Performance Index for the other three public IHLs

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<tr>
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This audit performance index is then compared across the other three public IHLs as shown in Table 5. This index gives an insight on the perception of the level of adequacy of each audit dimension being implemented. The overall achievement for the four IHL in this study are AP\(_i\).
The model for the audit probability is stated as;

\[ \text{Pr}(\theta) \]

of a successful audit is stated as; \( \text{Pr}(\theta_1) = 1 \)

whilst a failure, \( \text{Pr}(\theta_0) = 1 \) - 0.

This can be readily shown as a Logistic Regression Model where all the other probable values are along the Sigmoidal Curve [11, 16] hence; Rasch Model.

### 5. Conclusion

Management relies on the audit function as a management tool to gauge the performance of the organization. Achieving good corporate governance is becoming the focus for both the private and public sector. A suitable method in measuring the effectiveness of auditors, \( A_e \), within the corporate governance framework is vital as audits assure the performance level of an organization is achieved as targeted. This is relevant in the wake of the Malaysian Government calls for quality education and strengthening of the public IHLs through initiatives in the National Higher Education Action Plan 2007-2010. The Board of Directors of public IHLs will be subjected to the same principles of good governance that regulate the private sector.

In this paper, the method in computing the \( A_e \) is put forward based on the PERM Model. The index makes use of the mean computation applied in the Rasch Measurement Model which is found to be accurate and reliable. It gives in-depth measurement and detailed insight of the audit’s performance. It is an excellent tool with high potential for the public IHL top management to explore and effectively improve the quality of higher education.

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### Table 5. P-E-R-M Model – Public IHL’s in Malaysia

<table>
<thead>
<tr>
<th>IHL</th>
<th>( D_{De} )</th>
<th>( D_{Di} )</th>
<th>( D_{Dr} )</th>
<th>( D_{Dr} )</th>
<th>AP</th>
<th>( A_e ) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.27</td>
<td>1.96</td>
<td>2.32</td>
<td>2.19</td>
<td>2.18</td>
<td>72.67</td>
</tr>
<tr>
<td>B</td>
<td>2.03</td>
<td>2.03</td>
<td>2.18</td>
<td>1.99</td>
<td>2.06</td>
<td>68.67</td>
</tr>
<tr>
<td>C</td>
<td>2.00</td>
<td>1.86</td>
<td>1.90</td>
<td>1.91</td>
<td>1.92</td>
<td>64.00</td>
</tr>
<tr>
<td>D</td>
<td>2.22</td>
<td>2.09</td>
<td>2.28</td>
<td>2.21</td>
<td>2.20</td>
<td>73.33</td>
</tr>
<tr>
<td>Dp</td>
<td>2.13</td>
<td>1.99</td>
<td>2.17</td>
<td>2.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OVERALL IHL-AP</td>
<td>2.09</td>
<td>69.66</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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### 6. References


