Algorithm for Performance Appraisal using Cumulative Average Weighing Method

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Abstract

Performance appraisal is an HR process, which plays an important role to drive employees for achieving organizational goal. Simple Additive Weighing (SAW) method is popularly used as a tool to calculate individual performance score (PS). Reflective factors (opportunity factor and optimum contribution factor) are not accounted in this method. Consequently, the assessed PS found to be less representative and biased. In the proposed Cumulative Average Weighing (CAW) method, those factors have been taken into consideration to make PS more representative and unbiased. A case studied for 5 years on 3 employees of the same status. Overall Performance Index (OPI) and Aptitude Index (API) have been calculated using performance score (PS) obtained in both the methods by Computer Based Performance Appraisal System (CB-PAS) software, developed in Visual Basic (VB). The analysis, using statistical tools (SD, MAD and AD) reflects that the PS as calculated by CAW method is more representative than that of calculated by the SAW method. The rate of change of API as calculated from the aptitude score facilitates the organization to talent management. Besides, Graphical Model for Score Interpretation (GMSI) used as an alternative tool for screening out and selecting the best option using data obtained from the CB-PAS.

Keyword: Performance Score (PS), Overall Performance Index (OPI), Aptitude Index (API), Reflective factors.

Introduction

Performance Appraisal is an HR process, which is critically linked with selection, retention, promotion, layoffs, compensation, utilization of talent,

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and training. As such, it plays a key role in human resource management to drive employees for keeping them aligned with the organizational goal and desired outcome. This performance refers to the behaviors and actions that an employee demonstrates in completing their duties. The 360 degree performance appraisal process is a performance management and career development tool and is being popularly used with focusing on departmental and evaluative perspectives. From a developmental perspective, it aims to enable the individuals to become more aware of their strengths and weakness, and the areas they need to focus on to enhance their performance in the future. From an evaluative perspective, it is used to make key administrative decisions, for example salary increases, promotions etc. whereas cursory look to discover the individual performance is mostly on the quantitative ratings by weighting some set attributes needed for the organization. By the time, a variety of tools has already been developed, and researches are still being continued in the varying context of organizations to device or formulate appropriate tool to extract actual performance of an individual in respective department or organization. Till to date, Simple Additive Weighting (SAW) method is being popularly used as a tool to calculate individual performance score (PS) in many organizations as suggested by 360 degree appraisal system. SAW method, which is also known as weighted linear combination or scoring method based on the weighted average. In this method, an evaluation score is calculated for each alternative by multiplying the scaled value given to the alternative of that attribute with the weights of relative importance directly assigned by decision maker followed by summing of the products for all criteria. But in this method, reflective factors (opportunity factor and optimum contribution factor) are not accounted. Accordingly, SAW method found to be less representative because of biasing effect due to personal liking disliking, lack in the level flat condition related to opportunity, unexpected gap in assessed scores due to varying assessors and perspectives, inherent lack in taking cognizance of individual contribution over the years, and finally lack in scope of utilizing individual expertise related to job specifications.

To address the issues for making the PS more representative and unbiased, a new mathematical model, called Cumulative Average Weighing (CAW) Method proposed, where reflective factors are accounted. Three variables (aptitude, attitude and ability) have been postulated to derive PS formula. Each variable evaluated by weighted values of the corresponding set of

attributes using well known 9-point Likert scale. This formula realized by software, named Computer Based Personal Appraisal System (CB-PAS), which has been developed in visual basic (VB) at the front and MySql at the back end in the bottom up approach as shown its tree algorithm. It has the options to calculate PS by both the methods. A case has been studied to supplement the proposition. The findings are analyzed using conventional statistical tools (SD, MAD and AD). The CAW method found to be more representative due to accounted reflective factors in PS calculation. Hence, the objective of this paper is to introduce algorithm of the CAW method, comparison with SAW method and Graphical Model for Score Interpretation (GMSI) approach for screening out and selecting the best option.

Objective and Methodology

Objective with specific aim

As mentioned above, the main purpose of this paper is to familiarize algorithm of CAW method with the specific aim to have a comparison between CAW and SAW methods in terms of representativeness of individual PS.

Approaches

In its frame work, two approaches are made namely mathematical approach and algorithmic approach to formulate CAW method and to design and develop computer based performance appraisal software (CB-PAS) and implementing it to calculate individual PS both in CAW and SAW methods for analysis. Firstly, mathematical approach is used to develop formula for the score calculation based on some relevant postulates. These postulates encompass the score determining variables, attributes, mathematical operation like cumulative average and arithmetic mean, and reflective factor. The reflective factor refers to the opportunity factor and optimum contribution factor. The opportunity factor is related to the expertise of individual whether it is fitted to the job specifications or not. It is considered in PS calculation to ensure level flat condition for the employees to be assessed. On the other hand, optimum contribution factor refers to the contribution of the individual over the tenure of services taking in cognizance for the calculation of PS. In the algorithmic approach, the computational model has been developed as a conceptual model to derive

logical sequence for the tree algorithm where an arbitrary case has been considered for the purpose. Then an entity relationship diagram (ERD) has been evolved for the logical design of Computer Based Performance Appraisal software (CB-PAS).

A Case study

Finally, CB-PAS has been developed and implemented to calculate the PS of three persons (X, Y and Z) for five years on three variables (aptitude, attitude and ability). Each variable is evaluated by weighted values of corresponding set of attributes using well known 9-point Likert scale as a case study to analyze the representative PS both in CAW (proposed) and SAW (popularly used) methods. Conventional statistical tools have been used to ascertain the repetitiveness of PS and GMSI approach used for score interpretation, screening out and selecting the best option for the individual incentive like promotion, award and annual increment to ensure unbiased and unquestioned judgment in performance appraisal.

Research Frame Work

Mathematical Approach

Postulates

The postulates to develop the mathematical model of CAW method are given below:

a. Aptitude, attitude and ability are variables to determine performance score. These have been considered as independent variables for the purpose, though they are complexly related to each other.
b. Each variable has a set of attributes[i], which will be weighted using 9 point Likert Scale.
c. Each variable is 1 - degree function of attributes, when they are weighted.
d. Performance Score (PS) over a year is the summation of the averages of these variables.
e. Opportunity factor has been calculated based on logical assessment and thereby accounted in aptitude variable by translation[ii] as to bring balance in effects.

f. Optimum Contribution[iii] factor has been accounted by translation as cumulative effect in annual assessment i.e. in the assessment of current year to remove effects of over or under assessment.

g. Performance score ρ_t of current year will be additive as following in the SAW method.

h. Performance Score, ρ_y at quiescent year will be the average of last year performance score, ρ_{y-1} (is called here optimum contribution factor) and performance score of current year ρ_t, which is termed here as cumulative average[iv].

j. Performance appraisal will have to be done by Team-Based Appraisal (TAB) technique. TAB is a technique to ensure unbiased inputs (data) of at least 3 assessors from the same department or organization on the same assesses. This almost resembles to the phenomenon of multi-source feedback, where data are taken from the superiors, colleagues and subordinates.

k. Arithmetic Mean (AM) is used for determination of performance indices.

l. GMSI approach used for trend analysis of individual performances over the years. Trend lines may also be used to determine performance indices as an alternative to verify correctness.

Formula

In CAW method, the formula, derived for performance score calculation based on the postulates, is given in the sequence below:

The formula for the quiescent year

$$\rho_y = \frac{1}{2}[\rho_{y-1} + \rho_t] \text{----------(1)}$$

Where,

p_t = The performance score of current year.

ρ_y = The performance score at quiescent year.

ρ_{y-1} = Performance score of last year for taking account of optimum contribution of individual employee.

The formula for the performance score of the current year (excluding optimum contribution)

$$\rho_t = \frac{1}{3}(a_{avp} + a_{avt} + a_{avb}) \text{----------(2)}$$

Where,

a_{avp}= Overall average of aptitude score (opportunity factor integrated), done by j assessors.

a_{avt}= Overall average of attitude score, done by j assessors.

a_{avb}= Overall average of ability score, done by j assessors.

Performance Indices

There are two significant parameters namely Overall Performance Index (OPI) and Aptitude index (API) in Performance Indices. They can be used as tools to select candidates or employees for appointment, promotion and even for retention. OPI and API are mathematically defined here as the arithmetic mean (AM) of series of respective scores, assessed over the years. As such their mathematical formula will be as: $\mathrm{OPI} = \frac{1}{m}\sum_1^m \rho_y$ and $\mathrm{API} = \frac{1}{m}\sum_1^m a_{avp}$ [where *m* is the number of assessed years.] Notable here, that they may also be determined by the value at Q point[v] (as shown in figure-1) on the respective trend line from the graph in GMSI approach as an alternative method. These two parameters will give true and unbiased reflection of performance on individual scores. Standard Deviation[vi] (SD) may be used to verify their representativeness as and when required.

However, OPI will be compared with the expected standard of the position as set by the organization to determine the range of selection for the purpose and thereby it may be termed as screening factor. API, on the other hand, will be used as tool to select the best option in the selected range and therefore, may be termed as selection factor. Besides, the slop of trend line, drawn for aptitude variable, will give the rate of change in aptitude of the subject employee over the years, which facilitates to have insight of talent management[vii]. Similarly, trend lines for other variables, will help to identify the area of weakness of the subject employee. Moreover Absolute Deviation (AD) as calculated by the formula $\Delta P = \rho_y - \rho_{y-1}$ may help to

pin point the individual lapses in performance as well as error occurred during assessment.

Algorithmic Approach

Algorithm is a common language for nature, human and computer. It replaces mathematical model in a logical sequence to solve any problem that to a computational model. Let us now proceed to develop algorithm for score calculation in sequence as described below:

Computational Model

In order to derive computational model, let us consider the attributes of aptitude, attitude and ability are a_i, b_i and c_i respectively where, i indicates the number of attributes. All these attributes will be weighted using 9 point Likert Scale by the assessors. Now, if 'j' is the number of assessors for performance appraisal using Team Based Appraisal (TBA) technique. Then the computation model for evaluating of each variable will be as in the following sequence:

In 1st step: Weighting attributes by j assessors.

$a_i = a_1, a_2, a_3, - - - - a_i$ *- i x attributes for aptitude.*

$b_i = b_1, b_2, b_3, - - - - b_i$ *- i x attributes for attitude.*

$c_i = c_1, c_2, c_3, - - - - - c_i$ *- i x attributes for ability*

In 2nd step: Averaging of attributes over *i* attributes.

$a_{avi} = \frac{a_1 + a_2 + a_3 +}{i} = \frac{1}{i}\sum_1^i a_i$ *- i x attributes for aptitude.*

$b_{avi} = \frac{b_1 + b_2 + b_3 +}{i} = \frac{1}{i}\sum_1^i b_i$ *- i x attributes for aptitude.*

$c_{avi} = \frac{c_1 + c_2 + c_3 +}{i} = \frac{1}{i}\sum_1^i c_i$ *- i x attributes for aptitude.*

In 3rd step: Averaging of attributes over *j* assessors.

$a_{avj} = \frac{a_{av1} + a_{av2} + a_{av3} +}{j} = \frac{1}{j}\sum_{i=1}^j a_{avi}$ *- j x assessors.*

$b_{avj} = \frac{b_{av1} + b_{av2} + b_{av3} +}{j} = \frac{1}{j}\sum_{i=1}^j b_{avi}$ *- j x assessors.*

$c_{avj} = \frac{c_{av_1} + c_{av_2} + c_{av_3} +}{j} = \frac{1}{j}\sum_{i=1}^{j} c_{avi}$ *- j x assessors.*

In 4th step: Averaging of each variable over current year.

$a_{avc} = \frac{a_{av_1} + a_{av_2} + a_{av_3} +}{n} = \frac{1}{n}\sum_{j=1}^{n} a_{avj}$ *- n x no. of appraisal.*

$a_{avt} = \frac{b_{av_1} + b_{av_2} + b_{av_3} +}{n} = \frac{1}{n}\sum_{j=1}^{n} b_{avj}$ *- n x no. of appraisal.*

$a_{avb} = \frac{c_{av_1} + c_{av_2} + c_{av_3} +}{n} = \frac{1}{n}\sum_{j=1}^{n} c_{avj}$ *- n x no. of appraisal.*

$a_{avp} = avc + (1 - y)$ Within close limit $0 \leq y \leq 1$ -taking Opportunity factor, where, y is the opportunity factor as determined from the logical weighting (1 or 0) to the attributes of opportunity. Here 1 – means "yes" and 0 – means "No". Accordingly, this is defined as the ratio of number of 1s to the total number of attributes, k, postulated for opportunity. Mathematically, it can be expressed as: $y = \frac{\sum 1}{\mathbf{k}}$. This is one of the reflective factors, which has been brought in the above formula to ensure level flat conditions and perspectives in the working environment for the employee under assessed.

In 5th step: Averaging of variables for final score of current year.

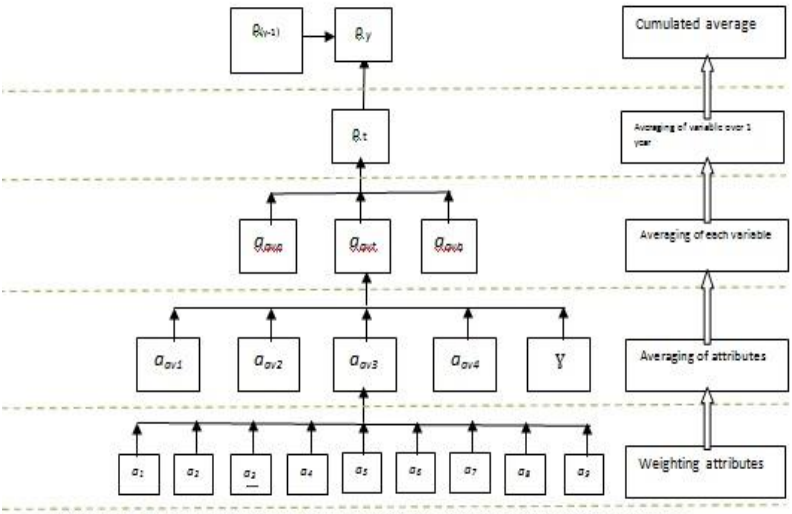
$\rho_t = \frac{1}{3}\left(a_{avp} + a_{avt} + a_{avb}\right)$ *- 3 x variables (aptitude, attitude and ability).*

In Final step: Cumulated average.

$p_y = \frac{1}{2}[\rho_{y-1} + \rho_t]$ -This is the "performance score" for the quiescent year. Note that it will be taken as the "performance score" of last year (ρ_{y-1}) for subsequent year's assessment.

Tree Algorithm

Now, to convert this computational model to tree algorithm, let us consider an arbitrary case. Suppose, an employee is going to be assessed by a committee of 3 members and 9 in number attributes for each variable is chosen as convenience though this number may differ from organization to organization. Likert scale has been used to weighting these attributes. Hence the tree algorithm to show sequential steps in bottom-up approach will be as:



Note: Here 1 x assessor has been shown in weighting attributes for simplicity in drawing.

Result and Discussion

Representativeness

A case has been studied in small scale for verifying representativeness of PS and to supplement the proposition in this paper. In that three (X, Y and Z) employees of same position and having almost same length of service are considered to evaluate PS at the quiescent year. 35 attributes (10 x personal traits and 25 x demonstrated traits) have been weighted using 9-point Likert scale against each employee over 05 (2010 to 2014) years. Individual PS has been calculated by both CAW and SAW methods using CB-PAS software, which has been developed basing on the above algorithm. The analysis, using conventional statistical tools (SD, MAD and AD) reflects that the PS as calculated by CAW method is more representative than that of calculated by the SAW method. The findings, based on SD and MAD, are presented in table-1.

Table-1: Study Result based on SD and MAD

Employee	CAW Method		SAW Method		Remark	
	SD	MAD	SD	MAD	SD	MAD
X	0.109	0.006	0.139	0.226	0<0.109<0.139	0<0.006<0.226
Y	0.115	0.152	0.236	0.378	0<0.115<0.236	0<0.152<0.378
Z	0.150	0.107	0.177	0.607	0<0.150<0.177	0<0.107<0.607
Inference: Both SD and MAD found to be closer to 0 for CAW than SAW method						

Absolute deviation (AD) has also been used here to find the difference between consecutive PS in order to ascertain its correctness and to have the insight of causes if such deviation (+ or -) greater than ± 1. Because, representativeness in value of PS refers to the open limit {AD:$-1 < AD < 1$} that to confirm correctness in assessment, yielded it from the concept of expressing any error in %. But its $-ve$ value pin points to individual lapses as like for X in the year of 2010 and 2012 as shown in table-2, which helps to focus subsequent corrective measures.

Table-2: Study Result on AD

Year	Absolute Deviation, ΔP					
	CAW Method			SAW Method		
	X	Y	Z	X	Y	Z
2010	-0.264	0.432	0.007	0.72	0.72	0.8
2011	0.008	0.216	0.204	0.14	0.29	0.4
2012	-0.011	0.37	0.088	0.12	0.14	0.62
2013	0.037	-0.225	0.087	-0.08	0.49	0.63
2014	0.06	0.018	0.058	0.09	0.49	0.68
2015	0.208	0.432	0.2	0.37	0.14	0.51

Score Interpretation

In performance appraisal, Graphical Model for Score Interpretation (GMSI) may be used to visualize performance trend of employees over the years for making a decision on retention, promotion, requirement of training and talent management. This GMSI is just a graph or bar chart over years fitted with trend lines as shown in figure-1(using data from the case study). These trend lines lead to the following interpretations:

a. If the trend line goes up that means the performance of the subject employee increases over the times. So, he is still having capability to render service and effectiveness as well. The observations of associated trend lines may determine the state of aptitude and attitude, and also to find components having more effects on the performance score. This fact will help to ascertain talents and contribute to the talent management.

b. If the trend line goes down that means performance of the subject employee decreases over the times. So, his capability is in question.

Close observation will enable to find the domain of weakness of the subject employee.

c. If the trend line is constant over reasonable times, then the subject employee may be retained but may not have chance to go up position or promotion.

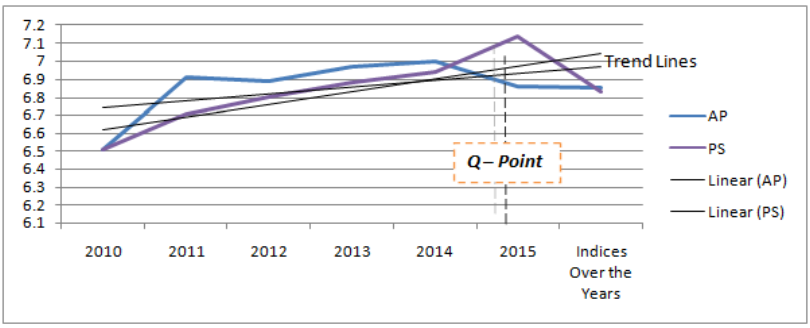


Figure 1: AP and PS vs. Year Graph for Z employee

However, these interpretations should be compared with the expected Standard for the position. Notable here that the expected standard of performance indices for each position may be determined either by corresponding average of performance indices (API and OPI) over assessed employees at the quiescent year [The formula is as: $\mathrm{ESOPI} = \frac{1}{w}\sum_{i=1}^{w} \mathrm{OPI}$ and $\mathrm{ESAPI} = \frac{1}{w}\sum_{i=1}^{w} \mathrm{API}$, where 'w' is the number of assessed employees of the same status] or by promulgated guideline basing on job description suited to achieve the organizational goal

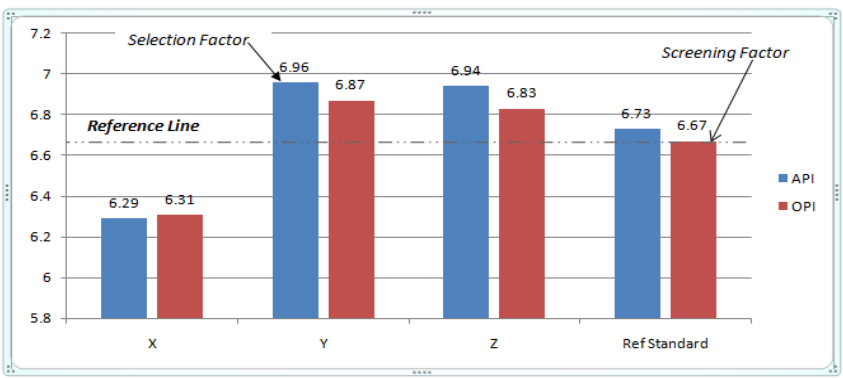


Figure 2: Bar chart of API and OPI

A bar chart of API and OPI along with corresponding set standard of performance indices is presented in figure-2 (using data from the case study). It leads the selection committee to screen out the non-prospective candidates or employees in one hand; on the other hand, comparing API of the prospective candidates or employees helps to select the best option using their judgment focusing on other two attributes as well as set policy with other tracing factors (if any).

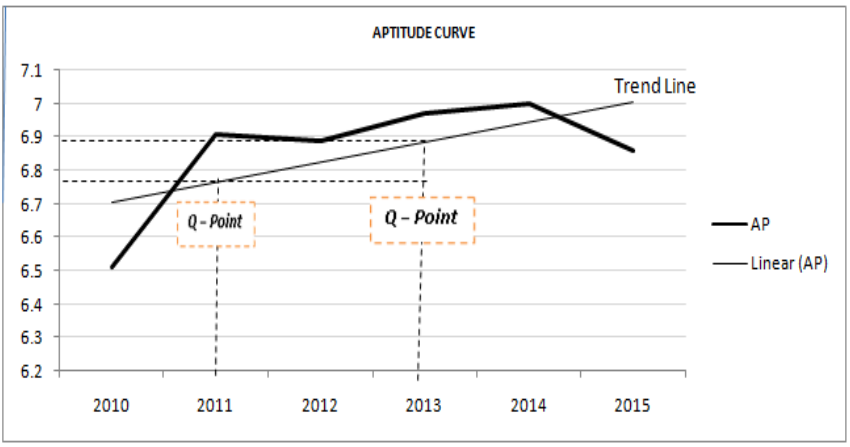


Figure 3: Slop determination of API for Z employee

The slope (fist derivative with respect to time if the line is non-linear) of trend lines for API and OPI will measure corresponding rate of changes. These rates will vary from employees to employees. So, the slope for API may be used as tools for talent assessment and ranking. The formula and technique for slope determination is described here using GMSI for API only as shown in figure-3:

Now, the formula for slope determination will be as:

Slope for API (rate of change of aptitude) = $\frac{\Delta y}{\Delta x} = \frac{6.89 - 6.78}{2013 - 2011} = \frac{0.11}{2} = 0.055$ per year.

A comparison of this figure (0.055) may be used to identify the employee having potentiality to drive the organization to meet the challenges in the days to come. Similarly, the slope for OPI (not shown) may lead to sort out employees who need counseling and training to increase their standards. By thus, these slopes may contribute to the talent management.

Significances

The significances of CAW method are, therefore, as under:

a. The proposed model as well as formula for PS calculation is more representative. But its accuracy in performance reflection mostly depends on identified variables and attributes, suited to the subject organization.

b. Opportunity of working situation and contributions to the organization of individual over the years, by rendering services, has been taken into account as reflective factors.

c. The maintenance of level flat condition in performance score, ρ_y done by translation of opportunity factor, γ in aptitude score, $a_{avp} = avc + (1 - \gamma)$ within close limit $0 \leq \gamma \leq 1$.

d. The contributions rendered by the individual to the organization over the years have been taken in effect in the performance score, $\rho_y = \frac{1}{2}[\rho_{y-1} + \rho_t]$ by translation of optimum contribution factor, ρ_{y-1} (last year's PS).

e. Overall Performance Index, OPI and Aptitude Index, API, determined from the arithmetic mean (AM), ensures unbiased (balance between under and over assessment) performance of individual at the quiescent year.

f. Moreover, it sets limits not to deviate much from the range of selection in case of promotions, appointments and retentions as applicable.

g. The slop of trend line will give the rate of change in aptitude per year, which will be useful in talent management for the organization.

h. Close observations and analysis of trend lines will enable the concerned to find the area of weakness of the subject employee and thus be able to determine whether training may compensate these lapses or weakness in his performance or he or she should not be retained.

Conclusion

The analysis to develop this mathematical model for performance appraisal is done on sample data from a case study. The variables and attributes are

postulated from logical thoughts out of experiences, and studying relevant documents. The formula for performance score, ρ_y calculation is based on the simple arithmetical averaging concept and Simple Additive Weighting (SAW) method. Opportunity factor and optimum contribution factor have been considered here as reflective factors basing on observations and practical experiences. These factors have been brought in performance score calculation formula and also taken into account by translation in SAW method using Taylor's philosophy. This mathematical model is proposed here as "Cumulative Average Weighting" (CAW) method. Notable here that the PS, calculated by this method is more representative than that of SAW method as revealed from the SD and MAD measurements as stated above. Besides, AD measurement facilitates to find the errors or lapses in performance score for subsequent corrective measures.

However, there are scopes for testing the said model taking more real data by surveying any suitable organization. Moreover, the postulated variables and corresponding attributes may not be same for all categories, rather depend on the perspectives and objectives of the organizations. As such, flexibility of choosing variables and attributes remains on hands of the organization. They can choose variables and attributes by job analysis and also set standard for each position in the hierarchy of the organization. Accordingly, the accuracy in performance score and organizational success mostly depends on these variables and attributes. Besides, there are rooms to put thoughts regarding optimum and opportunity factors to take into account for performance appraisal. Thereby, the concerns are encouraged to do more research in these aspects.

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End Notes

[i]***Attributes*** may vary from organization to organization, which will have to be determined by the concern beforehand.

[ii]***Translation*** is one type transformation of function manipulation

[iii] The immediate last year ***performance score*** ρ_{y-1} is accounted for optimum contribution factor.

[iv] The term ***Cumulative*** is used here to take effect of previous value to the newly calculated value in average.

[v] The ***value*** of ***performance indices***, determined from ***trend lines*** may vary from that of ***AM*** at quiescent year, but it ensures removal of errors at each year to help the assessors.

[vi]***SD*** is a ***statistical parameter*** to measure the dispersion from the ***mean*** or ***average*** value. Its ***0*** value indicates 100% accurate, which is not practically possible. But its value less than ***1*** indicates that the determined ***mean*** or ***average*** value is in agreement and acceptable. So the ***mean*** or ***average*** value will be ***representative*** as much as ***SD***'s value closer to ***0***.

[vii] A new concept of ***HR functions***.

Apendix-1