Measurement of Perceived Appraisal Fairness: Graph TheoreticandMatrix Approach

Sapna Taneja

*Department of Management Studies, J C Bose University of Science & Technology, YMCA, Faridabad, Haryana 121002
(Orcid: [0000-0002-4391-9303](0000-0002-4391-9303))*

Abstract

Organizations are increasingly using performance appraisal system to make critical human resource management decisions. Having served various purposes, it has become an important practice, however its success largely depends upona multitude of critical variables. This research is an attempt to identify and measure antecedents of fairness perception of PA system. Data was collected from 600 employees of Indian banking industry and with the help of a structured questionnaire and analysed using Graph Theoretic and Matrix approach (GTMA). A fairness perception index has been found out which gives opportunity to the managers to visually compare their organization with the peers and tweak their process to improve the fairness perception index for PA system.

Keywords: *Antecedents, Fairness Perception, Performance Appraisal, GTMA*

Introduction

PA is the most fundamental practice of human resource management because it drives many critical decisions pertaining to an organization such as salary administration, training need identification, feedback, promotion, retention etc.(Cleveland, Murphy, & Williams, 1989). A well-structured and properly executedsystem renders manifold advantage to the organization on financial and productivity fronts(Dello Russo, Miraglia, & Borgogni, 2017)(Yamazaki & Yoon, 2016)(Roberts, 1996).However, in order to deliver the expected results, appraisal has to be perceived fair by its users. Perception of farness has usually been into three major justice dimensions, namely: distributive, interpersonal and procedural(Ngo, Lau, & Foley, 2008). These three terms are collectively known as organisaitonal justice(Greenberg, 1986)(Gu, Nolan, & Rowley, 2020). Distributive justice refers to received outcomes, procedural justice refers to the proceedures adopted to allocate those outcome and, interpersonal justice involes the communication of proceedures adopted to carry out the appraisal(Scholtes, 1998).These fairness dimesnions are determined by veriety of factors, therefore, making its measurement a complextask.(Erdogan, 2002)(Gyekye(Gas) & Haybatollahi, 2015);(Erdogan, 2002);(Thies & Kordts-Freudinger, 2019);(Phuong, 2018);(M. Y. Kim & Park, 2017)(T. Kim & Holzer, 2016).

Graph Theoretic and Matrix Approach (GTMA) has been applied by researchers to measure and calculate a permanent index of multi attribute constructs(Agrawal, Singh, & Murtaza, 2016). GTMA is a technique which coverts the complex and ambiguous models into clear and mesaureable ones. It is a technique that uses digraphs to represent the attributes and their interrelationships. These digraphs can be solved with the help of matrix approach to reach to a permanent index, which can be set as benchmark to compare fairness perception index.Measurement of appraisal's fairness perception is a multi attribute decision making problem, besides, the author has not come across such a research study where GTMA has been applied to calulate the fairness perception index of PA system. Amidst this backdrop, the present study aims to identify antecedents ofappraisal fairness perception and develop interrelationships between them. The study also aims to developPA fairness perception model and measure the fairness perception index using GTMA.

Identification of antecedents of PA fairness perception

Various research studies indicate that perception of fairness is distinctively shaped by various factors. Such antecedents were identified from extensive review of literature and depicted in the following table 1:

<p align="center">Table 1:Identification of antecedents from literature survey</p>

S. No.	Description	Definition	Literature survey
1	Fair hearing (F1)	refers to giving employees enough chance and opportunity to present their explanations and provide inputs before the appraisal decision is made. Allowing them to have a voice in the decision-making process(Erdogan, Kraimer, & Liden, 2001).	(Taylor, Tracy, Renard, Harrison, & Carroll, 1995);(Walsh, 2003);(Narcisse & Harcourt, 2008);(Akhtar & Khattak, 2013);(L. L. Smith, 2017)
2.	Perceived organizational support (F2)	refers to employees' perception concerning the extent to which the organization values their contribution and cares about their well-being. POS has been found to have important consequences employee performance and well-being(R Eisenberger, Huntington, & Sowa, 1986).	(Neves & Eisenberger, 2012);(Shanock & Eisenberger, 2006);(Robert Eisenberger et al., 2014);(Ogochukwu, 2019);(Bohle, Chambel, Medina, & Da Cunha, 2018)
3.	Trust in organization (F3)	Trust in the organization is used to imply how well the features of the organization influence the individual in an effective manner and, employees' perception of the organization's interest in the subordinate's welfare. It also refers to extent superior establishes a trustworthy organizational atmosphere. (Searle et al., 2011)	(Searle et al., 2011);(O'REILLY & ANDERSON, 1980);(Li, Yan, & Jin, 2007)
4.	Performance feedback (F4)	refers to providing employees with continuous, specific and timely knowledge about their performance. It is a process of explaining the evaluation decision, citing the supporting evidence and efficient basis for performance rating so that they feel that the rating they receive is fair and valid(Erdogan et al., 2001).	(Pearce & Porter, 1986);(Jawahar, 2006);(Ryu & Hong, 2020)
5.	Linkage to rewards (F5)	involves rewarding employees on the basis of their performance, results achieved, or contribution made to organisations as individuals or as a part of a group(Folger & Konovsky, 1989).	(Neves & Eisenberger, 2012);(Prowse & Prowse, 2010);(Nurse, 2005)(Somu, Halid, Nasurdin, Lim, & Tan, 2020)
6.	Appraisal training (F6)	is a process of disseminating knowledge needed to carry out the appraisal process consistently and challenge the assessment perceived to be unfair.	(DAVIS & MOUNT, 1984);(DAVIS & MOUNT, 1984);(Woehr &

				Huffcutt, 1994);(D. E. Smith, 1986);(Brown & Heywood, 2005)

GTMA for mathematical modeling of fairness perception of PA system

GTMA helps to evaluate and comprehend the ambiguous and tangible system by describing the system and subsystem up to the level of element. Thus, it is a flexible method used in numerous applications(Agrawal, Singh, & Murtaza, 2016). The mathematical model developed by the theoretical approach to graphs reflects both the contribution of attributes themselves and the degree of dependency between the attributes. Digraph representation is useful for modelling and visual analysis. Matrix representation is used for interpreting the digraph model. The model is characterized by a permanent index. The permanent index represents a unique number that is useful for comparison, ranking and optimal selection of combinations.

Performance Appraisal Fairness perception digraph

The PA fairness perception model digraph is prepared with the literature survey and experts' advice from academia and industry. The Digraph is having nodes N= {n_i}, where i =1, 2, 3, 4, 5...........K and directed edges A= {a_{ij}}. A node n_i signifies the ith antecedent and the edges shows the interrelationships among the various antecedents. There are as many nodes as there are number of antecedents. If a node 'i' has an influence on 'j' then a directed arrow is drawn from 'i' to 'j' and vice-versa. The diagraph for the PA fairness perception model is shown in following figure:
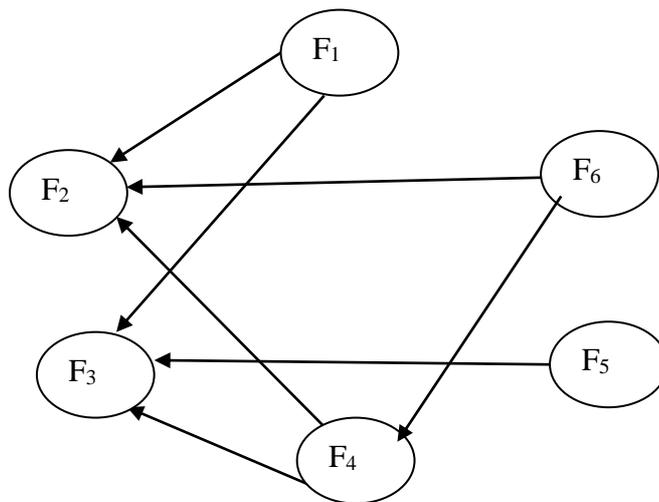

Figure 1: PA fairness perception model digraph

The six nodes represent the six antecedents i.e. Fair hearing (F1), Perceive organizational (F2), Trust in organization support (F3), Performance feedback (F4), Linkage to rewards (F5) and Appraisal training (F6). Interrelationships are shown by directed edges.

PA fairness perception matrix

To overcome the complexity of digraph, it is represented through matrix A = [a_{ij}] as shown in Figure 1. Here a_{ij} shows the interrelationships of the ith antecedent with the jth.

$$a_{ij} = 1, \text{ if 'i' is connected to 'j'}$$

$$= 0, \text{ otherwise}$$

Here $a_{ii} = 0$, because there is no self-loop. PA fairness perception model matrix is square and non-symmetric and is like adjacency matrix in graph theory (Narsingh, 2000).

$$
A = \quad
\begin{array}{c}
Antecedents \\
1 \\
2 \\
3 \\
4 \\
5 \\
6
\end{array}
\begin{array}{cccccc}
1 & 2 & 3 & 4 & 5 & 6 \\
\left[\begin{array}{cccccc}
0 & 1 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 1 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 \\
0 & 1 & 0 & 1 & 0 & 0
\end{array}\right]_1
\end{array}
$$

PA fairness perception characteristic matrix

This matrix is used to characterize antecedents. characteristic matrix can be written as C = [FI-A], where F represents the antecedents and I is the identity matrix.

$$
C = \quad
\begin{array}{c}
Antecedents \\
1 \\
2 \\
3 \\
4 \\
5 \\
6
\end{array}
\begin{array}{cccccc}
1 & 2 & 3 & 4 & 5 & 6 \\
\left[\begin{array}{cccccc}
F & -1 & -1 & 0 & 0 & 0 \\
0 & F & 0 & 0 & 0 & 0 \\
0 & 0 & F & 0 & 0 & 0 \\
0 & -1 & -1 & F & 0 & 0 \\
0 & 0 & -1 & 0 & F & 0 \\
0 & -1 & 0 & -1 & 0 & F
\end{array}\right]_2
\end{array}
$$

Equal values have been assigned to all the antecedents, to overcome this, variable characteristic matrix (VCM) has been made.

PA fairness perception variable characteristic matrix (VCM)

VCM has been constructed to characterize the antecedents and their effects. A matrix D is constructed with off diagonal members as interrelationships on Likert scale of 5 (Table 3). A matrix E represents the diagonal members as effects of antecedents on PA fairness perception at the Likert scale of 9 (Table 2). VCM-F is calculated as H = [E - D]

$$
H = \quad
\begin{array}{c}
Antecedents \\
1 \\
2 \\
3 \\
4 \\
5 \\
6
\end{array}
\begin{array}{cccccc}
1 & 2 & 3 & 4 & 5 & 6 \\
\left[\begin{array}{cccccc}
F_1 & -a_{12} & -a_{13} & 0 & 0 & 0 \\
0 & F_2 & 0 & 0 & 0 & 0 \\
0 & 0 & F_3 & 0 & 0 & 0 \\
0 & -a_{42} & -a_{43} & F_4 & 0 & 0 \\
0 & 0 & -a_{53} & 0 & F_5 & 0 \\
0 & -a_{62} & 0 & -a_{64} & 0 & F_6
\end{array}\right]_3
\end{array}
$$

Determinant of the matrix H gives the effects of antecedents and their interrelationships. it has positive and negative signs with its coefficients, so some information will be lost due to addition and subtraction of numerical values. To overcome this another matrix, PA fairness perception variable permanent matrix(VPM-T) is constructed.

Table 2: Quantification of AMT Implementation Factors

S.No.	Quantitative measure of Implementation Factors	Assigned values for factors
1	Exceptionally low	1
2	Very low	2
3	Low	3
4	Below average	4
5	Average	5
6	Above average	6
7	High	7
8	Very High	8
9	Exceptionally High	9

Table 3:Quantitative measure of interdependencies among Implementation Factors

S.No.	Quantitative measure of interdependencies	Assigned Values
1	Very Strong	5
2	Strong	4
3	Medium	3
4	Weak	2
5	Very Weak	1

PA fairness perception variable permanent matrix (VPM-T)

To overcome the effects of negative terms in H matrix, variable permanent matrix (VPM-T) has all the positive values. This matrix is just the sum of D & E. The determinant of VPM-T gives the effects of antecedents and their interrelationships.

$$
T = \begin{array}{c} \text{\textit{Antecedents}} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array}
\begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \\
\begin{bmatrix} F_1 & a_{12} & a_{13} & 0 & 0 & 0 \\
0 & F_2 & 0 & 0 & 0 & 0 \\
0 & 0 & F_3 & 0 & 0 & 0 \\
0 & a_{42} & a_{43} & F_4 & 0 & 0 \\
0 & 0 & a_{53} & 0 & F_5 & 0 \\
0 & a_{62} & 0 & a_{64} & 0 & F_6 \end{bmatrix}_4 \end{array}
$$

The determinant of VPM-T is calculated as below:

$$VPF - T = per\,T = \prod_{i=1}^{6} F_i + \sum_i \sum_j \sum_k \sum_l \sum_m \sum_n (a_{ij} a_{ji}) F_k F_l F_m F_n$$

$$+ \sum_i \sum_j \sum_k \sum_l \sum_m \sum_n (a_{ij} a_{jk} a_{ki} + a_{ik} a_{kj} a_{ji}) F_l F_m F_n$$

$$+ [(\sum_i \sum_j \sum_k \sum_l \sum_m \sum_n (a_{ij} a_{ji})(a_{kl} a_{lk}) F_m F_n$$

$$+ \sum_i \sum_j \sum_k \sum_l \sum_m \sum_n (a_{ij} a_{jk} a_{kl} a_{li} + a_{il} a_{lk} a_{kj} a_{ji}) F_m F_n)]$$

$$+ [\sum_i \sum_j \sum_k \sum_l \sum_m \sum_n (a_{ij} a_{ji})(a_{kl} a_{lm} a_{mk} + a_{km} a_{ml} a_{lk}) F_n$$

$$+ \sum_i \sum_j \sum_k \sum_l \sum_m \sum_n (a_{ij} a_{jk} a_{kl} a_{lm} a_{mi} + a_{im} a_{ml} a_{lk} a_{kj} a_{ji}) F_n]$$

$$+ [\sum_i \sum_j \sum_k \sum_l \sum_m \sum_n (a_{ij} a_{ji})(a_{kl} a_{lm} a_{mn} a_{nk} + a_{kn} a_{nm} a_{ml} a_{lk})$$

$$+ \sum_i \sum_j \sum_k \sum_l \sum_m \sum_n (a_{ij} a_{jk} a_{kl})(a_{lm} a_{mn} a_{nl})$$

$$+ \sum_i \sum_j \sum_k \sum_l \sum_m \sum_n (a_{ij} a_{ji})(a_{kl} a_{lk})(a_{mn} a_{nm})$$

$$+ \sum_i \sum_j \sum_k \sum_l \sum_m \sum_n (a_{ij} a_{jk} a_{lm} a_{mn} a_{ni} + a_{in} a_{nm} a_{ml} a_{lk} a_{kj} a_{ji}] \quad 5$$

Total 7 groupings have been made, which represents the effects of antecedents and their relative importance.The first group reflects the inheritance level measurement of the antecedents. In the absence of self-loop, second grouping has not been considered. Further, interrelationships are represented in the third grouping that also measure the four remining antecedentsand so on..

PA fairness perception permanent numerical index

Organizations willing to benchmark PA fairness perception, may just compare the permanent index of VPM-T calculated through equation 5.

T*= Permanent value of VPM-T

PA fairness perception numerical index measures the effects of antecedents and theirinterrelationships towards a single numerical value, which can be used to evaluate the PA fairness perception among employees. A higher value of index infers that appraisal is perceived as fair, objective and transparent. This numerical value may be used for self-analysis or to benchmark with their peers.

Methodology

The present study undertakes the measurement of antecedents' effects on PA fairness perception and their interrelationships using graph theoretic approach. The following methodology has been adopted to calculate the single numerical index.

(1) Identification of antecedents of PA fairness perception index using literature survey and discussions with experts from academia and industry.
(2) Utilization of Tables 2 and 3 to provide numerical values for inheritance of antecedents.
(3) Finding out the value of permanent function (PA fairness index) using equation 5 to evaluate the intensity of each antecedent for PA fairness perception.

To calculate the values of antecedents (F_is) and their interactions a_{ij}s, data were collected with the help of a structured questionnaire. The questionnaire was administered on 600 employees of three public and private sector banks of India. Respondents namely officers other than clerical staff and sub staff were selected as sample respondents fromtotal population size of 562472. Multi-stage random sampling technique was adopted to select the sample from universe. The first stage was to select three

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public and three private banks. In the second stage, one training center respective to each bank from the list of training centers was chosen for administering the survey. At the third stage, the equal number of employees from each selected bank were randomly drawn. To collect required study information, formal or informal approvals were taken from respective banks' centers. Step by step methodology discussed in previous section was applied to calculate the permanent numerical index. The values of the diagonal and off diagonal elements are taken from the questionnaire survey and finally permanent index is calculated using equation 5.

$$
VPM - T =
\begin{array}{c}
\textit{Antecedents} \\
1 \\
2 \\
3 \\
4 \\
5 \\
6
\end{array}
\begin{array}{cccccc}
1 & 2 & 3 & 4 & 5 & 6 \\
\begin{bmatrix}
8 & 3 & 2 & 0 & 0 & 0 \\
0 & 6 & 0 & 0 & 0 & 0 \\
0 & 0 & 9 & 0 & 0 & 0 \\
0 & 3 & 4 & 6 & 0 & 0 \\
0 & 0 & 4 & 0 & 9 & 0 \\
0 & 3 & 0 & 4 & 0 & 7
\end{bmatrix}_6
\end{array}
$$

The value of permanent index of above matrix (equation 5) is 1.63×10^5, which shows the intensity of antecedents for PA fairness perception.

To calculate the range of PA fairness perception index, best (9 on Likert scale) and worst (1 on Likert scale) value of antecedents can be used. Table 4 shows the minimum and maximum value of fairness perception index. This range can help experts to decide the threshold values between which fairness perception index can vary. These values may be used for self-assessment.

Table 4: Indicating the range of PM fairness perception permanent index

System/ Subsystem	Current Value	Maximum Value	Minimum Value
Per T	1.63×10^5	5.31×10^5	1

Comparison of organizations

By using the permanent index, two organizations can be compared on fairness perception of PAS. If two organizations are having similar permanent index, then their digraphs will be isomorphic which leads to same number of terms and their values. Considering this, PM fairness perception set for an organization is written as:

$$
\left[\left(I_1^T / I_2^T / I_3^T / I_4^T / .... \right) \left(K_1^T / K_2^T / K_3^T / K_4^T / .... \right) \right] 7
$$

I_i^T and K_i^T represents the total number of terms in the ith grouping.

Coefficient of similarity is used when two organizations are not isomorphic. The coefficient of similarity is calculated from the permanent index and the number of terms in the grouping.

coefficient of dissimilarity is given as:

$$
Cof(ds)_{d-1}^{T} = \left[1 / Y_1 \sum_i \sum_j \varphi_{ij} \right] 8
$$

Where

$$Y_1 = \max \left[\sum_i \sum_j \left| K_{ij}^T \right| and \sum_i \sum_j \left| K{'}_{ij}^{'T} \right| \right]$$

When subgroupings are absent $K_{ij}^T = K_i^T$ and $K{'}_{ij}^{'T} = K{'}_i^{'T}$

Using equations 7, the coefficient of similarity is given as

$$Cof\,(s)_{S-1}^{T} = 1 - Cof\,(ds)_{d-1}^{T} \quad 9$$

Where, $Cof\,(s)_{S-1}^{T}$ is the coefficient of similarity for two organizations under consideration. The range for Cof (s) and Cof (ds) lies between 0 and 1. It can be interpreted as, if two organizations are isomorphic then their Cof (s) and Cof (ds) will be 1 and 0 respectively.

Example for comparison

To demonstrate the above methodology, three antecedents i.e.Fair hearing (F1), Perceive organizational support (F2) and Appraisal training (F3) were used to compare two organizations on similarity and dissimilarity index. These are designated by F_1, F_2, F_3 and F'_1, F'_2, F'_3 for organization 1 and organization 2respectively. As discussed earlier, permanent index is found based upon the inheritance and interaction among antecedents.

$$\begin{matrix} Vertex & 1 & 2 & 3 \\ 1 \\ 2 \\ 3 \end{matrix} \begin{bmatrix} F_1 & F_{12} & F_{13} \\ F_{21} & F_2 & F_{23} \\ F_{31} & F_{32} & F_3 \end{bmatrix} 10$$

Permanent
index for the above matrix is given as below:

$$per\,F_1^{\times} = F_1 F_2 F_3 + F_{12} F_{21} F_3 + F_{13} F_{31} F_2 + F_{23} F_{32} F_1 + F_{12} F_{23} F_{31} + F_{13} F_{32} F_{21} \qquad 11$$

per F_1^{*} contains N +1 i.e. four groups and contains N! i.e. six terms. Based upon equation 11, permanent index for organization 2 is also calculated.

For demonstrate purpose, the values of inheritances and interrelationships, i.e. F_i's and F_{ij}'s are taken from table 2 and table 3 as

F_1=8, F_2=6, F_3= 7, F_{12}=5, F_{13}=3, F_{21}=3, F_{23}=2,F_{31}=4,F_{32}=2.

F'_1=7, F'_2=6, F'_3=5, F'_{12}=4, F'_{13}=3,F'_{21}=4,F'_{23}=3, F'_{31}=3, F'_{32}=1

By substituting the above values in equation 11, permanent indices for the two organisations are calculated as

per F_1^{*}=336 + 105 + 72 + 32 + 40 +18= 603.

per F_2^{*}= 210 + 80 + 54 + 21 + 36 + 12 = 413.

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Based on equation 7, equation 11 and the value of per F_1^* &per F_2^*, the identification set for organization 1 may be written as

$$[1/0/3/2] \ [336/0/209/68]$$

$$[1/0/3/2][210/0/155/48]$$

Based on criterion 1 (equation 7), the coefficient of dissimilarity between the two organizations is 0.315. Thus, the coefficient of similarity is 0.685. The comparison procedure helps organizations to compare different groups in identification sets, based on which they can analyse and improve the weak link in the fairness perception for PA system.Using the above methodology, organizations can be ranked or grouped based upon similarity and dissimilarity index.

Findings of the research study

The present study endeavors to identify the antecedents for fairness perception of PA system. The results report that fair hearing, perceived organizational support, trust in organization, performance feedback and appraisal trainingare major antecedents determining and shaping perception of appraisal fairness. Further, the findings indicate the permanent index of appraisal fairness in the select Indian organisations is 1.63×10^5, as compared to the maximum value of 5.31×10^5. Thus, it may be interpreted from the results that perceived appraisal fairness in the select organisations is low. Measurement of fairness perception index helps organizations to plan performance appraisal system effectively and systematically.Using this methodology, the organisations can carry out self-assessment and, evaluate the effectiveness of appraisal system so that interventions may be introduced to improve the appraisal system. The results also serve the purpose of comparing different attributes and finding relative importance of each factor. It gives opportunity to the managers to tweak the performance appraisal based upon permanent index.The methodology is useful from Kaizen (continuous improvement) point of view as well as for breakthrough improvement.

Limitations and Scope for Future Research

It becomes complex to implement the above methodology when number of factors increases. Inheritance and interactions among antecedents are based upon human judgment that leaves a scope for personal biases. More antecedents can be included in the model to study the interrelations among them enabling organisations to design a PAS in such a way that helps them to improve perception of fairness. Further, more sophisticated multi-attribute decision making techniques can be applied and results can be compared to find optimum model.

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