Application of Principal Component Analysis in Determining Factor Weight in Point-Rating System of Job Evaluation

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Abstract

The point-factor/point-rating system is the most popular method for job evaluation. While allocating the points corresponding to compensable factors through the consensus approach; judgmentally, it is typically a smooth process, provided the degree for each compensable factor is well defined. The allocation of relative weights to each compensable factor is a time-consuming and disputable aspect of the traditional point-rating system. In order to avoid the subjectivity of the weights allocated to factors, this paper aims to demonstrate the application of the principal component analysis (PCA) in determining the relative weights of the attributes/compensable factors in job evaluation. The PCA is also applied to arrive at the aggregated score of each job evaluated as per the point-rating system for determining the relative worth of jobs in an organization. The method has been tested by taking data of 15 jobs from a benchmark job evaluation point-rating study. The results show that the pattern of the scatter diagram with the scores of the jobs using both the systems is quite similar, and the PCA method discriminates the jobs slightly better than the traditional approach. The proposed method may also be called the hybrid method as it is a combination of both the traditional and statistical approach.

Keywords: **job evaluation, point-rating system, principal component analysis, hybrid method**

JEL Classification: C1,M1, L2

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The fundamental principal of compensation is equal pay for equal job and more pay for more important job. This calls for a method of placing jobs of an organization in hierarchical ranks. Job evaluation does just that. Job evaluation is a systematic approach for determining the relative values of different jobs in an organization. The output of job evaluation becomes a basis for making pay differentials among jobs in an organization. It can be used for absolute wage level determination, but it is mainly used for internal wage equity. According to El-Hajji (2011), job evaluation is a systematic rather than a scientific process. Various types of processes exist to make it repeatable with varying degrees of effectiveness.

Background of Job Evaluation and its Relevance in Today's Context

It is not clear when formal job evaluation began. According to Patton, Littlefield, and Self (1964), job evaluation was first used in the United States Civil Service Commission in 1871. However, Pasquale (1969) was of the opinion that it was started by Taylor in 1881. The first point system was developed in the 1920s. The spread of trade unionism greatly influenced the adoption of job evaluation. El -Hajji (2011) presented different survey results on the use of job evaluation. From the findings presented, one can safely say that job evaluation is a universal phenomenon in organizations. The current trend is to have reduced number of layers in organizations. Vertical movement within organizations has slowed down and more and more employees are changing organizations for better pay and job profile. Union activism has been reduced, and individuals are now bargaining their own wages, particularly in the service sectors. While this is true, it is to be kept in mind that union activism is also gaining popularity in different

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parts of the world in the context of the recent economic depression.

According to Atchison, Belcher, and Thomsen (2000) : All this does not mean that organizations ignore the job as a determinant of wages. What has happened is that wage systems have become more flexible, and they weigh both skill and performance more heavily. The use of market wage data for more and more jobs is increasing. Botha (n.d.) commented that organizations and job evaluation systems have become simpler, less formal, and have reduced their complexity. A survey on job evaluation and market pricing practices conducted by WorldatWork (2009) confirmed that the use of market pricing is used as the primary base in making remuneration decisions by organizations in USA. Botha (n.d.) argued that the current recession will force the organizations to consider alternatives such as restructuring and consolidation of roles with consolidation of positions, which will impact relative job worth. Maintaining workplace harmony whilst facilitating change and optimizing costs will be a key challenge. Use of a dynamic job evaluation system will help support the change, and at the same time, create an equitable work environment, which will play a critical role in staff retention. It may be mentioned that The United Kingdom (UK) National Health Service (NHS) job evaluation system for all healthcare jobs was proposed by the Dept. of Health in 2003, which was revised in 2004. NHS appointed PricewaterhouseCoopers to undertake work on job evaluation design for very senior managers in March 2010 (NHS, 2004).

Therefore, it may be concluded that some form of job evaluation will remain as a tool for valuing jobs and as a support tool for fixing rational pay structures. Before we talk about job evaluation methods, it is appropriate to mention that job evaluation is mainly concerned with existing jobs as job evaluation will take into account changes in job content only when the changes have physically occurred (El -Hajji, 2011). Evaluating jobs is a great challenge in today's organizations. More and more organizations will become e-organizations and substantial portion of its manpower, particularly in the service sector, will work from home with freedom for innovation and creativity (Tripathi & Tripathi, 2012).

Methods of Job Evaluation : An Overview

Job evaluation methods may be grouped into two categories: Policy capturing (statistical methods) and traditional methods. There are quite a few proprietary systems, but these have limited use as these schemes use standardized factors with standardized weights, which may not meet the organizational context and values (Fowler, 1996). Traditional systems mainly opt for the following methods: ranking, factor comparison, classification, and point rating. All these methods use compensable factors and the constituent items of all factors and their relative importance (weights) in a particular organization as criteria for determining relative worth of jobs in any organization. It may be mentioned that a group of similar items represent an underline construct and these constructs are called 'factors,' and the constituent members are known as 'items'. In this paper, both these terms have been used interchangeably. Wherever they have been used as a separate concept, it has been mentioned clearly. There is no universally acceptable number of factors/items across the industry. The NHS uses sixteen factors/items in its scheme. Different researchers have used ten to fifteen factors /items in quite a few job evaluation assignments. In each factor/item, usually 4 to 7 levels/degrees are considered (NHS,2004).

Anecdotal evidence suggests that factors and their weights in India are derived through consensus building activity between union representatives and management representatives and are moderated by consultants. Fowler (1996) commented that the use of different factors or factor weights can produce dramatically altered scores for the same jobs, thereby affecting their relative position in the job hierarchy. Therefore, both these aspects need to be carefully understood.

Policy capturing methods aim to capture the policies that lead to levels of jobs historically or established by formal evaluation methodology. These approaches aim to develop a predictor model for job levels using job-related data. Some of the statistical methods are: Multiple regression on factor derived via factor analysis; multiple regression on individual job elements; multiple discriminant analysis; and Charnes, Cooper, and Ferguson's linear programming model (Kahya ,2006). Gomez-Meija, Page, and Tornow (1982) presented a hybrid model that incorporates regression analysis within the framework of the traditional point-factor system. In this model, scores of compensable factors are derived through a linear transformation of the items defining each factor, using a regression equation. Thus, each position obtained a score on each compensable factor. Once the factor scores were attained for each position, the overall grade predictions were obtained in the same way as those under the traditional point-factor system.

Gomez-Mejia (1982) presented a comparative accuracy and practical utility of the policy-capturing and traditional evaluation methods through rigorous research work. Their results showed that both the traditional and hybrid systems are at least as accurate and objective in predicting grade as the statistical policy-capturing methods when based on a standardized job analysis tool. User participation is more in case of traditional and hybrid systems. This is a very important point as acceptability of any job evaluation scheme largely depends on user involvement. In case of linear programming approach, Kahya (2006) commented that this approach cannot tackle the practical problems composed of multiple criteria.

Of all the methods of job evaluation in the traditional approach, point- rating/point-factor is the most popular and the most understandable (Das & Garcia-Diaz, 2001). In India, the National Productivity Council used the point rating scheme while carrying out many job evaluation studies. The authors commented that while establishing the compensable factors was comparatively easy, arriving at the factor weight was a tedious activity and reaching a consensus decision was difficult. In order to decide the factor weight rationally, a proposed hybrid model is presented, combining the concept of the point rating system and principal component analysis, which will also be easy to understand by all the stakeholders.

The Point-Rating/Point-Factor System

The point-factor system involves identification of compensable factors/characteristics and their weights, keeping in mind the importance of each factor with respect to the objective of the organization. For each factor, several levels/degrees are defined and point values are assigned to each degree of each factor. Each job is examined against the scheme and an appropriate factor wise level/degree is allocated to each job. The score obtained in each factor is multiplied by the respective factor weight, and a weighted score is obtained for each job for each factor. These scores are summed up to arrive at a total score for each job. Each job is placed under a grade, which is determined based on cluster analysis and considering the number of grades to be considered (Maynard,1971). The system may be expressed mathematically by the following expression:

$$S(j) = \Sigma^{n}_{i=1} L_{ij} * W_i \text{ .... (1)}$$

Where,
S = Score of Job j,
L_{ij} = Level/degree of factor i for job j,
W_i = Weight of factor i .

Factor-wise (we will call these factors as variables hereafter to avoid confusion between component/factor and the factors against which each job is rated), the degree/level must be defined with utmost care so as to achieve repeatability and reproducibility among the trained evaluators, and at the same time, it should be understood by the union and management representatives. Once the scale is established, it is applied to benchmark jobs, and the validity of the scale is tested and fine tuning is done if required. It may be mentioned that in practice, no statistical test is carried for repeatability and reproducibility and also for the validity of the scale. These are based on judgment. The NHS provides an elaborate definition of different factors/criteria, which may be used for defining factor levels.

Principal Component Analysis

➲ **Factor Loading and Rotation :** Principal component analysis (PCA) is essentially a data reduction technique. This method extracts a few underlying dimensions also known as factors from the values of different variables. PCA works out factor loadings for each combination of extracted dimensions and the variables. Factor loadings are similar to the correlation coefficients, and thereby represent which variable is associated more with which factor. Ideally, a variable with high factor loading with a dimension should get low loadings on other dimensions. In order to achieve this concept, rotation is often used, which maximizes high correlation and minimizes low correlation and hence, helps in identifying the factor-variable association better.

➲ **Eigenvalue and Scree Plot :** To identify the key factors, Eigenvalues and scree plots are used. Eigenvalue is the measure of the amount of total variance in the data explained by a factor. An Eigenvalue of less than 1 demonstrates that the factor explains less variance than a single variable and thereby, does not represent a factor/dimension. A scree plot is a graphical representation of Eigenvalues of all the dimensions/factors initially considered for extraction.

Use of Eigenvalues and Loadings in Determining Variable Weights and its Application in the Proposed Model of Job Evaluation

The eigenvalues after rotation indicates the percentage of total variance explained by the respective factors/dimensions and variable loadings indicate the correlation of the variable with a dimension/factor. Both these values together may be used as the weight of a variable while summing up the aggregated score of a candidate. This principal may be used while calculating the score of a job against a particular compensable characteristic/variable. All jobs may first be evaluated as per the job evaluation plan as per the point-rating system by the assessors using their judgment for each identified criteria. While summing up the aggregated score of a job, weighted score against each criterion can be worked out as per expression 1. Later, the job grades may be identified as per the traditional approach. This concept can be applied in a set of benchmark jobs, which have been evaluated as per the point-rating plan. The results of the weighted scores for each job by considering the criteria weights were arrived at judgmentally and by using the PCA method, and the results are compared for drawing conclusions.

Applying the Concept

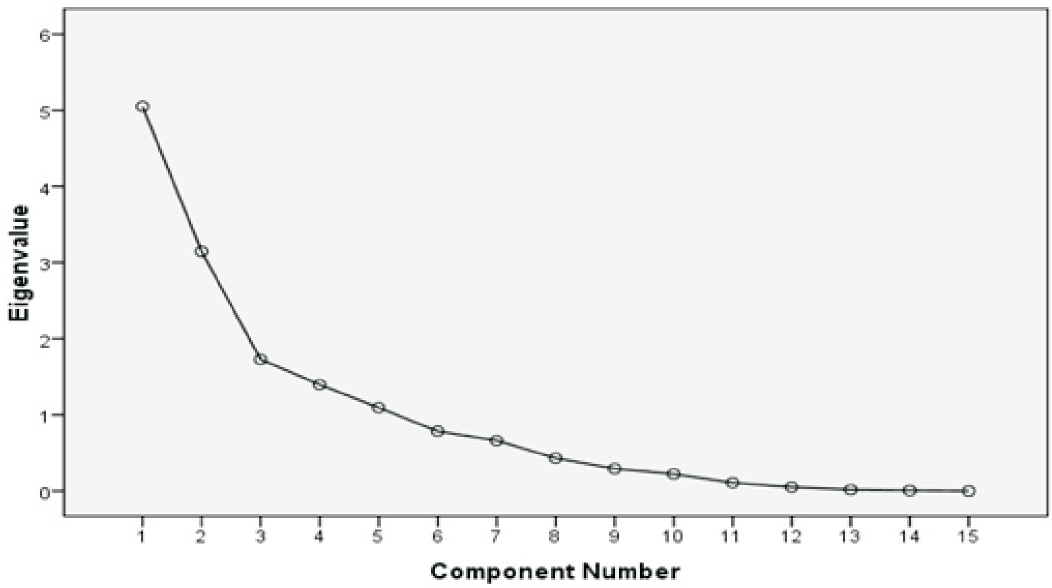
➲ **Methodology :** This study uses the data of a job evaluation study carried out during October to December 2010. But this conceptual study was carried out during February 2013. Annexure 1A contains data from a job evaluation study using the point-rating system for 15 benchmark jobs- helper, die changing operator, furnace operator, impregnation operator, scraper, loader/unloader, crane operator, packer, turner, boiler attendant, welder, sr. fitter, machinist, electrician, and sr. electrician. The jobs were identified by the management and are representative of the labor union. The Annexure IA shows the job wise and variable wise score. These scores were arrived at after studying

Table 1. Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.051	33.677	33.677	5.051	33.677	33.677	3.901	26.010	26.010
2	3.148	20.983	54.660	3.148	20.983	54.660	2.899	19.325	45.335
3	1.729	11.525	66.185	1.729	11.525	66.185	2.211	14.739	60.074
4	1.398	9.320	75.505	1.398	9.320	75.505	1.750	11.667	71.741
5	1.094	7.296	82.801	1.094	7.296	82.801	1.659	11.060	82.801
6	.786	5.239	88.040						
7	.661	4.407	92.447						
8	.432	2.878	95.325						
9	.293	1.956	97.281						
10	.223	1.488	98.769						
11	.109	.726	99.495						
12	.052	.345	99.840						
13	.017	.117	99.957						
14	.007	.043	100.000						
15	5.349E-17	3.566E-16	100.000						

Extraction Method: Principal Component Analysis. (Software output)

Figure 1. Scree Plot



Software output

Table 2. Component Matrix[a]

Variable	Component				
	1	2	3	4	5
Education	.836	-.116	-.224	.225	.357
Trade knowledge	.913	-.004	-.055	-.211	.096
Experience	.295	-.566	.134	.294	-.197
Judgment & dexterity	.882	.114	.188	-.294	.154
Physical effort	-.321	.249	.657	-.041	.497
Concentration	.727	.199	.289	-.122	-.428
Dust	-.672	.538	-.009	-.346	.172
Fumes	.094	.405	-.021	.877	.155
Heat	-.355	.787	.029	.220	.019
Hazard	-.148	.724	-.355	-.308	-.148
Responsibility for operation	.407	.745	-.106	-.022	-.010
Responsibility for assets	.753	.271	-.286	-.032	.431
Responsibility for safety of others	.481	.634	-.031	.222	-.446
Impact on work of others	.078	.267	.897	.065	-.063
Supervision needed	.665	-.031	.285	-.163	-.011

Extraction Method: Principal Component Analysis.

[a]. 5 components extracted.

Table 3. Rotated Component Matrix

Variable	Component				
	1	2	3	4	5
Education	.852	-.321	.003	-.205	.265
Trade knowledge	.854	-.160	.323	-.105	-.142
Experience	.028	-.728	.111	-.086	.008
Judgment & dexterity	.857	-.077	.365	.167	-.188
Physical effort	-.061	.208	-.284	.845	.062
Concentration	.404	-.136	.803	.102	-.111
Dust	-.363	.799	-.241	.227	-.095
Fumes	.046	-.017	.062	.072	.978
Heat	-.253	.656	.119	.213	.492
Hazard	-.035	.830	.230	-.210	.011
Responsibility for operation	.423	.525	.439	.005	.290
Responsibility for assets	.908	.148	.036	-.147	.200
Responsibility for safety of others	.207	.237	.788	-.101	.391
Impact on work of others	-.049	-.075	.396	.850	.060
Supervision needed	.545	-.232	.366	.193	-.170

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization. Software output

these jobs and interviewing the incumbents of these 15 jobs at the time of the initial study. Fifteen compensable variables have been considered. The data were analyzed using PCA in SPSS 16.

Analysis and Results

The Table 1 summarizes the total variance explained by the PCA solution and indicates the number of useful factors/components. This table has three parts. The first part, titled 'Initial Eigen Values' gives the variance explained by all the factors/components (PCA uses component instead of factors). Factors and components are used interchangeably in this paper. These components/factors are arbitrarily allotted numbers by the software and shall not be taken as the compensable variables mentioned in the Table 2. The first column under 'Initial Eigenvalues' gives the Eigenvalues of all the possible components in decreasing order. This is followed by the variance as a percentage of all the variance and cumulative variance. Percentage of variance of each component will be the same as its Eigenvalue divided by the total number of variables, 15 in this case. The values are presented for each factor whose Eigenvalue is more than 1. As explained earlier, components having less than 1 Eigenvalue are omitted.

The second part, titled 'Extraction sums of Squared Loadings' gives information for factors with Eigenvalues greater than 1. The first five components account for approximately 83.0% of the total variance in the variables. For further clarity, it may be mentioned that the components mentioned in the Table 1 are different from the 'variables' mentioned in the Tables 2 and 3. The percentage of variance explained by each component represents its relative importance. The last part titled, 'Rotated Sums of Squared Loadings' gives information for extracted factors after rotation. There are only five factors with Eigenvalues greater than 1, suggesting a five- factor solution.

The scree plot shown in Figure 1 is the graphical representation of the factor wise Eigenvalues. It is evident from the plot that after factor 5, the slope of the plot changes from steep to shallow, suggesting five important factors. The Table 2 gives the factor loadings before the rotation is carried out. It may be mentioned that loading more than 0.4 is considered reasonably high (Gaur & Gaur, 2006). The Table 3 shows the rotated loadings. For a good component solution, a particular variable should load high on one factor and low on all other factors in the rotated factor matrix. Rotation removes such confusion. It can be seen that this was reasonably achieved in this case.

The Table 4 (excluding loadings below 0.4) gives the "rotated" loadings of each variable on each component after omitting loadings smaller than 0.4. Variable weight was worked out as per the following expression:

$W(j) = \Sigma^{n}_{i=1} L_{ij} * V_i$ .... (2)

Where,
$W(j)$ = Weight of variable j,
L_{ij} = Loading of variable j on component i,
V_i = Variance explained by component i.

For example, weight of 'Responsibility of Operation' = 0.423*.26 + 0.525*.19 + 0.439*.15 = 0.08
In the case of the variable "Experience," the loading has come out to be negative. As we are not interested in developing a predict model, the absolute value is considered.

Table 4. Rotated Component Matrix Excluding Loadings of .4 and Below

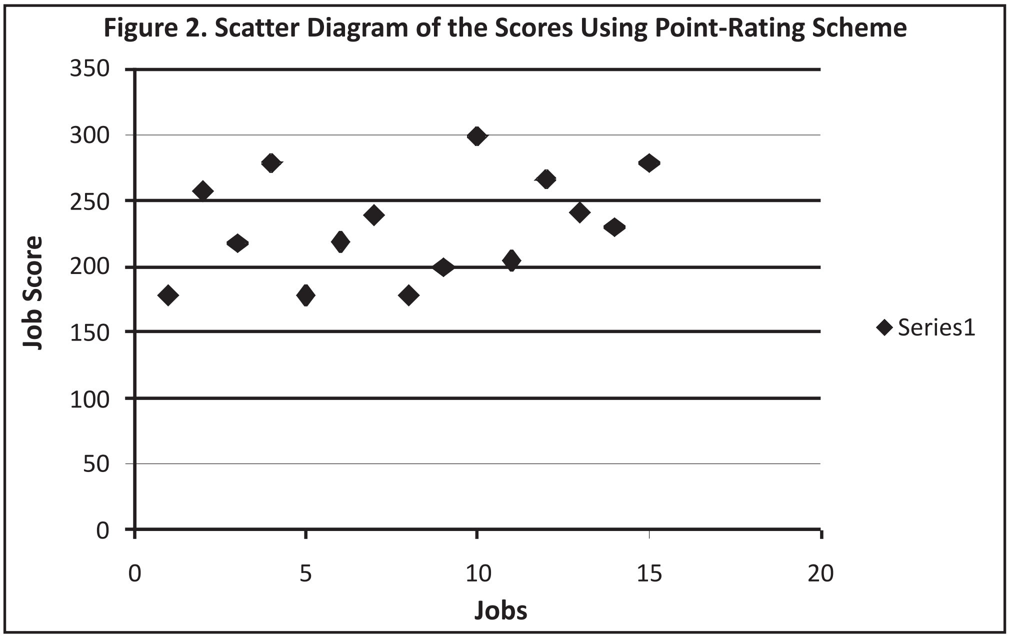
Rotated Component Matrix excluding loading of .4 and below						Variable weight
	Component/Factor					
	1	2	3	4	5	
Variance explained	.2601	.19325	.14739	.11667	.1106	
Variables						
Education	0.851586					0.22
Trade Knowledge	0.854033					0.22
Experience		-0.7279				0.14
Judgment & dexterity	0.856765					0.22
Physical effort				0.845163		0.1
Concentration	0.404211		0.803444			0.14
Dust		0.799481				0.15
Fume					0.977689	0.11
Heat		0.655895			0.492481	0.07
Hazard		0.830286				0.16
Responsibility for operation	0.423269	0.525072	0.438846			0.08
Responsibility for assets	0.90801					0.24
Responsibility for safety of others			0.787848			0.12
Impact on work of others				0.849529		0.1
Supervision needed	0.545362					0.14

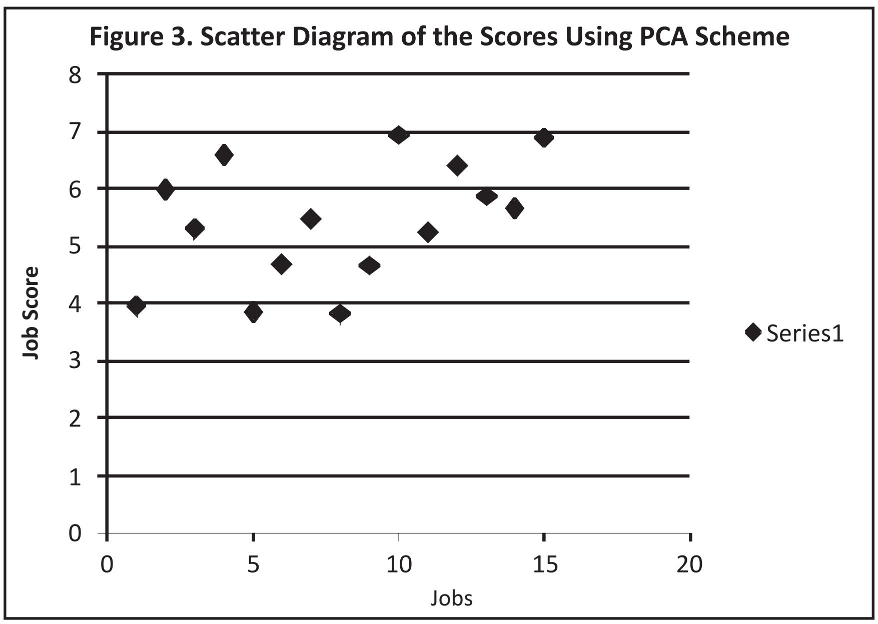
The Annexure 2A presents the scores of each job using variable wise weights. The Annexure 3A gives the job wise codes which are used in the Annexures 1A and 2A.The score of each job on each variable is multiplied by the respective variable weight and the sum total of these weighted scores across all variables gives the grand score value of each job as per the expression (1). Scatter diagram of the scores obtained both by the point-rating scheme and using PCA are presented in the Figure 2 and Figure 3 respectively. The detailed variable wise score as per the point-rating is not presented in the paper as it is beyond the scope of the present paper. A close look at these figures reveals that the pattern of distribution of scores is similar in both the graphs.

Under the point-rating scheme, 4 grades of jobs were created with the following point range:

Grade I 144-180
Grade II 181 - 220
Grade III 221-260
Grade IV 260-300

With the PCA score, we can also have 4 grades:





Grade I 3.8-4.7
Grade II 5-6
Grade III >6-6.6
Grade IV >6.6

The coefficient of variation of the point-rating score is 0.194, and with PCA score, it is 0.17, thus creating more differentiation among the job scores.

Conclusion

This study results show that using weights from application of PCA produces similar results as obtained from conventional point rating methods without bringing subjectivity into the compensable variable/factor weight.

Managerial Implications

The methodology presented in this paper was explained to the personnel executives who accepted its logic. As this is a post assignment exercise, discussions with the union representatives have not been done. It may be done after applying the approach across all the jobs. The concept of principal component analysis may be difficult to sell to union representatives. But the task of carrying out job evaluation is always given to consulting organizations; hence, it may be explained to them by the consultants. It is envisaged that once the plan is understood by the union and management representatives, the factor weights can be more easily agreed upon by both the stakeholders.

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Annexure 1A. Job Wise, Variable Wise Score

Job code	Education	Tradeknowledge	Exp	Judgement	Physicaleffort	Concentration	Dust	Fumes	Heat	Hazard	Resp.op	Resp.tools	Resp.safety	Impactonwork	Sup.needed
1	1.00	1.00	1.00	2.00	2.00	1.00	4.00	1.00	3.00	4.00	2.00	1.00	1.00	1.00	3.00
2	2.00	2.00	1.00	4.00	4.00	3.00	3.00	2.00	3.00	4.00	2.00	2.00	2.00	3.00	4.00
3	3.00	2.00	1.00	3.00	2.00	2.00	2.00	2.00	2.00	4.00	3.00	2.00	2.00	1.00	4.00
4	3.00	4.00	2.00	4.00	2.00	4.00	1.00	3.00	3.00	3.00	3.00	2.00	4.00	2.00	4.00
5	2.00	1.00	1.00	2.00	3.00	2.00	3.00	2.00	3.00	3.00	1.00	1.00	1.00	1.00	1.00
6	2.00	2.00	2.00	2.00	3.00	2.00	3.00	2.00	3.00	3.00	2.00	1.00	1.00	2.00	3.00
7	2.00	2.00	1.00	3.00	3.00	4.00	2.00	2.00	3.00	3.00	3.00	1.00	4.00	2.00	4.00
8	2.00	1.00	3.00	2.00	2.00	2.00	1.00	2.00	1.00	2.00	1.00	1.00	1.00	2.00	3.00
9	3.00	3.00	1.00	3.00	3.00	1.00	1.00	2.00	1.00	2.00	1.00	2.00	1.00	1.00	4.00
10	3.00	5.00	2.00	5.00	2.00	3.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	4.00
11	2.00	4.00	1.00	4.00	2.00	4.00	1.00	1.00	1.00	3.00	1.00	1.00	2.00	2.00	4.00
12	3.00	5.00	2.00	5.00	3.00	4.00	2.00	1.00	1.00	2.00	3.00	2.00	1.00	2.00	4.00
13	3.00	4.00	3.00	4.00	2.00	4.00	1.00	1.00	1.00	3.00	1.00	2.00	2.00	1.00	4.00
14	3.00	4.00	2.00	4.00	2.00	3.00	1.00	2.00	2.00	3.00	1.00	2.00	1.00	1.00	4.00
15	3.00	5.00	1.00	4.00	2.00	4.00	2.00	2.00	2.00	4.00	4.00	3.00	4.00	1.00	3.00

Annexure 2A. Job Score

Job code	Education	Tradeknowledge	Exp	Judgement	Physicaleffort	Concentration	Dust	Fumes	Heat	Hazard	Resp. op	Resp. tools	Resp. safety	Impacton-work	Supervision-needed	Variable weight	Job Score
1	1	1	1	2	2	1	4	1	3	4	2	1	1	1	3	0.22	3.96
2	2	2	1	4	4	3	3	2	3	4	2	2	2	3	4	0.22	5.98
3	3	2	1	3	2	2	2	2	2	4	3	2	2	1	4	0.14	5.3
4	3	4	2	4	2	4	1	3	3	3	3	2	4	2	4	0.22	6.59
5	2	1	1	2	3	2	3	2	3	3	1	1	1	1	1	0.1	3.86
6	2	2	2	2	3	2	3	2	3	3	2	1	1	2	3	0.14	4.68
7	2	2	1	3	3	4	2	2	3	3	3	1	4	2	4	0.15	5.47
8	2	1	3	2	2	2	1	2	1	2	1	1	1	2	3	0.11	3.82
9	3	3	1	3	3	1	1	2	1	2	1	2	1	1	4	0.07	4.66
10	3	5	2	5	2	3	2	2	3	3	3	3	2	2	4	0.16	6.93
11	2	4	1	4	2	4	1	1	1	3	1	1	2	2	4	0.08	5.23
12	3	5	2	5	3	4	2	1	1	2	3	2	1	2	4	0.24	6.4
13	3	4	3	4	2	4	1	1	1	3	1	2	2	1	4	0.12	5.87
14	3	4	2	4	2	3	1	2	2	3	1	2	1	1	4	0.1	5.65
15	3	5	1	4	2	4	2	2	2	4	4	3	4	1	3	0.14	6.88

Annexure 3A. Job Wise Code

Code	Job title
1	Helper
2	Die Changing Operator
3	Furnace operator
4	Impregnation Operator
5	Scraper
6	Loader/Unloader
7	Crane Operator
8	Packer
9	Turner
10	Boiler attendant
11	Welder
12	Sr.Fitter
13	Machinist
14	Electrician
15	Sr. Electrician