Predictive Analytics of Manpower Estimation using Markov Chain Model: A Real time Case on a Manufacturing Plant in Odisha

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Abstract:

Manpower management is one of the core functional area of any business operations. In practice, right deployment of manpower at right positions in right time is very crucial. People usually join their corporate life in multiple times in a calendar year at various positions. They also move across various levels due to usual corporate HR interventions at different times in a year as well. So, optimization and successful prediction of work-force movement in the verticals by aligning its way to reduce surplus and shortage is key to survival in business. Right prediction of work-force position movements at right time is crucial to every organization success.

This article focusses on insight of the optimization of human resources for key success of the organization. Results obtained from this study indicated the model validation when compared to actual data. The study took the data of a large steel making company in the state of Odisha and found this model useful for practice. The results indicated towards some suggestions for the company in employee hiring plans in future. Out of the available models available this 'Markov Chain' model application actually intends to show a positive direction towards decision making in managing and controlling the employee base.

Keywords: Predictive Analytics, Manpower Estimation, Markov Chain Model, Manufacturing Plant.

Introduction:

'Markov Chain Model' is instrumental in forecasting employee's transition from one position to another in both vertical and horizontal way. Modern corporates who are adopting various scientific approaches in corporate human resource planning are always in search of options to operate with minimal time and effort (Abaza, 2015). More algorithms are available to plan the human resources (Huang, 2004). Markov analysis, has got its significance to prove the inflow of manpower to respective positions from external as well as internal sources in different sector like Technical, financial and Logistics. Careful investigation and usage of some algorithm will help in developing various models to predict manpower flow across career levels inside the organization. Large companies often face challenges when they try to track the movement of employees internally. 'Markov Chain Model' was devised in year 1922 by Andrey Andreyevich. Markov is utilized by companies, to predict and validate the internal flow of employees that happened due to HR follow up actions like promotion or superannuation etc., apart from voluntary shedding of responsibilities and jobs by the employees themselves.

All professionally managed organizations should rely upon scientific models like 'Markov Chain Model' while doing manpower forecasting to avoid resource waste, (V. S. Narayan Rao, Economic Times). While tech savvy organizations use various models the 'Markov model' proves handy for even traditional companies. This research is aimed at interpreting the results of model application and compares the organization's actual flow to understand its applicability in Indian context.

The manpower planner has the usual responsibilities to foresee the demand and supply of human resources at different levels in the firm (Herbert G. Heneman, 1997). Effective use of manpower planning always focusses on solving problems on staffing functions including development and deployment of infrastructure facilities in the organizations (Udom, 2014.)

Further to development and deployment, planning includes building organizational hierarchy by assigning profiles of manpower to functional levels (Babu, 2017). Organization structure or hierarchy is paramount to functional effectiveness along with planning and aligning employees to their allocated unit (McClean, 1997). But certain situations like shortage or surplus of manpower always poses challenges the system. To cross over delicate situations like these, 'Markov model' proves an effective tool to support the efficiency and effectiveness of the manpower planning. 'Markov' analysis is considered as an effective model to handle the prioritizing of objectives by using suitable sequences of action with regard to the efficient utilization of labor under reasonable cost and rewards (McClean, 1997). 'Markov' analysis supports various other functions like future manpower requirement through suggested volume of recruitment either in way of outside

invitation or by internal transfer. It identifies the wastage of manpower as well.

Review of Literature:

In absence of required systematic method estimating the manpower requirement, companies may be in a sticky situation facing the hiccups in managing human resource. The absence of deputing right persons at the right time may make matters worse for accomplishment of corporate objectives. There is high possibility of experiencing losses if the organization is unable to utilize the opportunities. All these factors potentially affect both manpower demand as well as supply forecasting (Belhaj, 2013).

Manpower planning includes forecasting personnel inventories for a long-term plan for recruiting, assigning, and developing personnel. (uan Varela and Sergio, 2011).

Quantitative forecasting analysis on internal and external supplies in an organization is indicated by the turnover ratio of enterprise's human resources. Traditionally human resource department in an organization used to rely on manager's personal experience laced intuition and that's usually qualitative in nature. But in practice, often this creates a pseudo professional HR environment eventually resulting in either a shortage or surplus type of situation. On the contrary, an efficient planning based on a scientific model leads to a better understanding of the 'in' and 'out' of an employee. This scientific process would help to resolve any employee shortfall or surplus issue in organization. One of such scientific and quantitative methods preferred by the organizations to solve this type of problem is 'Markov Chain Model'.

This article holds the key element for influencing the organization performance through infrastructure facilities and proper allocation of man power using 'Markov' model for organizational success. (Guerry, 2010). Predicting is the process of making decisions about future events whose actual significances have not been seen yet. Manpower planning dwells up on two serious steps. One is on estimating the manpower demand accurately and the second one is to ensure the manpower supply to meet the demand in future (V.S. Narayanrao, Economic Times). Demand and Supply forecasting of manpower goes concurrently. Manpower planner's job is to take suitable steps to bridge the gap between Demand and Supply. This process is mainly intending to optimize to ensure sound organizational health. (Hugh Courtney, 1997).

Manpower planning is very important task to make use the effective resources as per the company needs. Only if proper manpower resources are planned effectively and efficiently the objectives of the organization can be reached. Human resource planning is the process of getting the right number of qualified people into the right job at the right time. The process of matching takes place with the supply of manpower towards the requirements of the organization.

According to (A.C. Georgiou, 2022) successful attainment of human resource

planning can be possible only taking reference to the existing inventories. (Maurer, Conceptualizing and Measuring The Economic Effectiveness of Human Resource Activities, 1998). The inventory classification takes place with the personal in an organization in addition to counting their number. Main objective of this Markov analysis is to fit the personnel available to various positions in an organization.

Out of various techniques available to forecast internal labor supply 'Markov analysis' is one of the most useful and relevant technique. The processes of 'Markov analysis' helps the organization plan for human resource in the organization. Unsuccessful human resource planning may lead to organization saddled with employees with irrelevant qualification and poor skills or loaded with unwanted employees whose pay and benefits may cost a business dearly.

Methodology and Data interpretation

The research took one Indian large-scale steel manufacturer as sample. 'Rourkela Steel Plant' in Odisha is one of the largest steel producers managed by Government of India owned 'Steel Authority of India Limited'(SAIL). Apart from steel plant in Rourkela, SAIL has other steel manufacturing plants at other places like Bokaro, Bhilai in India. Alike other corporates every year there is a flow of manpower across the levels in the plant. With an intention to test whether the predicted value aligns with the actual real time, value one hypothesis was taken into consideration and the statistical tool of Chi-Square test of significance of 95% was considered for testing the hypothesis. The hypothesis taken into consideration is basically a test of significance to check the real time usage of the model fitness. The concept of the model observed values and the actual flow of manpower is getting compared. The residue year value is getting compared with the predicted value for that year. In this context the historical data of past 5 years is considered and last year data where the actual data is available is compared with the model predicted value and the difference is analysed.

Table – 1 (Data of actual manpower levels of 6 years from 2015 to 2020)

Years Designation	2015	2016	2017	2018	2019	2020	Exit	Total
AGM	38	42	45	46	48	49	163	431
Asst Manager	16	20	22	23	23	30	84	218
Junior Manager	36	37	39	42	49	49	27	279
Junior Officer	186	186	186	186	389	389	72	1594
MTT	300	310	310	326	337	342	80	2005

H_o There is no significant difference between actual and estimated value of manpower flow.

The above table depicts the real manpower flow in the company 'Rourkela Steel Plant'. In total, 7 designated officials are considered for this research. The levels from 'Assistant General Manger' to 'Junior Manager' is considered where people get their position changed due to internal promotions or transfers. Some people come from outside the organization in way of deputation. But a large chunk of people leaves the organization and marked as 'Exit'. Every year a lot of manpower leave across the levels. For example, in the AGM level in year 2015 total number of officials were 38 then 4 people were added within a year to make it 42 in year 2016. So actually these 4 people are not necessarily coming from immediate below level like 'Assistant Manager'. They have come from far below level like 'Junior Manager'; by giving departmental examinations. As it is said earlier the company might have brought people from other corporate houses on 'Deputation' basis for a particular period. So the internal movement of people on actual basis is displayed in next table for two year of 2015 and 2016. Again, in the table the total exit of people in all these six years (2015 to 2020) is 163. So when we calculate the numbers of exit as per level we take a summation of all these years exit.

Table – 2 Data for two years on various positions showing the internal movements.

2015/2016	AGM	AM	JM	JO	MTT	Deletion	Total
AGM	38	2	0	0	2	66	108
AM	0	16	3	1	0	33	53
JM	0	0	36	1	0	14	51
JO	0	0	0	186	0	15	201
MTT	0	1	0	1	300	30	332

While the table -1 showed a composite figure of manpower position for 6 years this table -2 shows the flow for 2 years of 2015 and 2016. The table-2 explains various positions and their movements inside the company. For example, in year 2015 the AGM positions was having 38 people but in next year of 2016 it went up to 42 so we come to know that 4nos of people were added to the position. These 4 people were in fact are promoted from the lower rank. 2 people promoted from 'Assistant Manager level and another 2 joined directly from MTT rank. Similarly, in next year 2017 the position saw 45 people (refer table no-1) indicating 3 more people were promoted from lower ranks. Likewise, the corporate database saw the historical data of various profiles. Internal movements are natural and due to reasons like promotion, demotions, lay off, retrenchment, attrition, or superannuation etc.

Table 3; Transition Matrix (for 2 years from 2015 to 2016)

2015 2016	AGM	AM	JM	JO	MTT	Deletion
AGM	0.351	0.018	0	0	0.018	0.611
AM	0	0.301	0.056	0.009	0	0.622
JM	0	0	0.705	0.019	0	0.274
JO	0	0	0	0.925	0	0.074
MTT	0	0.003	0	0.003	0.903	0.090

As per Markov chain model a transition matrix to be developed to show the real movement of manpower in any standard or trouble free 2 years to get movement weightage so to calculate its future movement predictions. A standard or normal year indicates where the company did not see any huge change either in loss or profit. The movement matrix is calculated for replication in proceeding years to get full movement matrix for all levels. For example, the company manpower flow here is considered for 2 years of 2015 and 2016. In the years 2016 the number of officers is 38 who were at the same position in year 2015 as 38. But the additional numbers of 4 were added to make it 42 in 2016 from 38 in 2015. This happened because of a direct promotional entry of 2 officers from Assistant Manager level and 2 officers from MTT level. The total number of manpower at the level of AGM in year 2016 is 108 including 66 deletions. So it is assumed that from year 2015 to year 2016, 38 people moved in same rank, 2 people promoted from Assistant Manager to AGM rank, 2 people moved from MTT level to AGM rank and 66 people left the organization taking the total number to 108. Now the transition matrix is developed by dividing all these numbers from total number. For example, the 38 number is divided from 108 to get a score of .351. Similarly, the number 2 is being divided from 108 to get a score of .018. The deletion vectors are coming by division of 66 to 108 to get .611. In this way the interim transition matrix is being developed for future use to predict the movement of people. Likewise, all the other levels are also calculated to get a complete transition matrix.

Now the transition matrix will be used for predicting further movement of manpower. As per the record of the company the 2019 actual manpower position is as follows.

AGM – 48, AM – 23, JM – 49, JO – 389, MTT – 336

Now as per the model requirements the manpower position of 2019 will be used to get a predictive position in next year of 2020. Then the 2020 actual value of the company is getting compared with the Markov Chain model estimated value to taste the efficacy of the model in real sense.

Table 4 (Function of Transition Matrix and Base Year2019 to predict for year 2020)

2019 / 2020	AGM (48)	AM (23)	JM (49)	JO (389)	MTT (337)	Deletion	Numbers in year 2020
AGM	0.351 x 48 = 16.848 = 17	0.018 x48 =.864 or 1	0 x 48=0	0 x 48=0	0.018 x 48= 1	0.611 x 48 = 29.328 or 29	**48**
AM	0 x 23=0	0.301 x 23=20.723 or 21	0.056 x 23= 1.288 or 1	0.009 x 23= .207 or 0	0 x 23=0	0.622 x 23=14.306 or 14	**36**
JM	0 x 49=0	0 x 49=0	0.705 x 49=34.545 or 35	0.019 x 49=.931 or 1	0 x 49=0	0.274 x 49=13.426 or 13	**49**
JO	0 x 389=0	0 x 389=0	0x.389=0	0.925 x =359.825 or 360	0 x 389=0	0.074 x 389 = 28.786 or 29	**389**
MTT	0x337=0	0.003 x 337=1.011 or 1	0x337=0	0.003 x 337=1	0.903 x 337 = 304.311 or 304	0.090 x 337=30.33 or 30	**336**

Markov Chain Model prescribed estimated manpower position in year 2020 is a function of transition matrix vectors and real position in the year 2019. See the table above to get the estimated values for year 2020. The position wise numbers of year 2019 are multiplied by the transition matrix values to get a summarized value for each level.

Table – 5: (Chi-square calculation to prove Hypothesis)

Actual Value 2020 (Observed)	Estimated Value (E) 2020	(O – E)	$(O - E)^2$	$(O – E)^2 / E$
49	48	1	1	0.020
30	22	8	64	2.133
49	49	0	0	0
389	389	0	0	0
342	336	6	36	0.105

To test the hypothesis the Chi-square test is considered here. The null hypothesis goes as no significant difference between the observed(O) and estimated (E) value of the manpower position of the company in the year 2020. The actual flow or the position of manpower is available and getting compared with the calculated value or estimated values derived by the model.

From the above (Table.4) observation, it is to infer that, if the critical value is less than the estimated or calculated value at the significance level of .05 then we are to reject the Ho. on the contrary if the critical value is greater than the estimated or calculated value then we are supposed to accept the Ho. As per our calculation here our df is 4 and sig..value is .05 so we get a critical value at 9.488 by referring the statistical value of Chi-square. Now as per the method, when we calculate the value we are getting an estimated value at 2.258 whose detailed calculation is given below.

Estimated or Calculated Value = $\sum (O - E)^2 / E = 0.020 + 2.133 + 0 + 0 + 0.105 = 2.258$

As on principle, if the critical value of 9.488 is greater than the estimated or calculated value of 2.258 then we are going with the null hypothesis, which is happening here. So if we accept the null hypothesis it is statistically proven that there is no significant difference between the observed as well as the estimated or calculated values by the model. So in the company the actual manpower flow is showing the same as per the model estimation or in the statistical meaning there is no difference between the model calculations and actual flow. So this model can be worked out for further predictions.

Discussion and conclusion

As per the above calculation the critical value is higher than the estimated value which should have been reverse if at all the null hypothesis is to be rejected but, in our research, we found it to be opposite. As the critical value of 9.488 is much higher than the model estimated value of 2.258 so we accept the null hypothesis saying that there is no difference between the two values. Hence the Markov Chain model is perfectly working in this research and any company can use it to successfully predict their manpower position by using a previous year actual data. In this process, further yearly calculation can also be done as much as the years required for the company to know its predicted manpower positions to be ready to tackle any shortage or surplus issues of manpower.

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