

Lensing to employee attrition rate and internal movement in an organization: Application and intervention through Markov chain

Amrita Pratap *

Vijit Chaturvedi [†]

Amity Business School

Amity University

Noida

Uttar Pradesh

India

Prachi Bhat [§]

FORE School of Management

Delhi

India

Abstract

The objective of the paper is to apply Absorbing Markov chain model in the study of employees' attrition rate of an organisation over a discrete time interval. This requires transition probability matrix to be stochastic and Markov network to have at least one 'absorbing state'.

The paper addresses this problem by associating the employees leaving the organisation with a state, hereafter called 'exit state', which is ascribed to 'the absorbing state'. The physical interpretation of the probabilistic characteristic of an absorbing state logically relates it to a 'void'. The state of 'void' has no resource / element in the initial state of the system, and, in the final state, any resource/ element transitioned to this state becomes irretrievable, hence non-contributory to the organisation for all practical purpose. This concept supports the construction of stochastic matrix of Markov analysis.

The dynamics of free markets and prevalent meaning of freedom- freedom from fear, freedom from scarcity and freedom from harsh subordination, as perceived by the present-day digital generation, are the reasons behind their good intention to exercise freedom of choosing and changing organisations. It is, therefore, a matter of concern for corporate

* E-mail: amritapratap11@gmail.com (Corresponding Author)

[†] E-mail: vchaturvedi@amity.edu

[§] E-mail: prachi@fsm.ac.in

leadership to ponder over how to retain talented personnel and keep watch over changing trends of employees quitting the organisations.

The present paper demonstrates the successful application of our conceptual model by a case study of employees' attrition rate of an MNC operating in India, discusses the causes of high attrition rate and provides suggestions to leadership for win-win interaction with the employees.

Subject Classification: 60J20, 90B70, 91D35, 62M02.

Keywords: Absorbing state, Transition probability matrix, Stochastic matrix, Void.

I. Introduction

Markov chain, also known as Markov process, is an infographic stochastic network depicted by a cyclic and undirected flow/ transitions of resources or products or objects. It is also called memory less chain since the next succeeding state of a system depends only on its just preceding state, and no other prior events. In other words, it is the current state only that influences the immediate future state in the chain, and no other events play any role.

Markov chain model is a robust method to assess transition of available manpower and to forecast manpower requirement (**Kivilcim , 1972**) keeping in view company's plans and policies. The paper introduces a conceptual model with the extension of 'absorbing state' for the application of Markov Chain Model in the study of employee's attrition rate and the problems of similar kind. The absorbing Markov Chain Model requires at least one 'absorbing' state which is accessible to each transient state in one step or more, and which once entered cannot be left (**Gagniuc, 2017;Meyen & Tweedie, 1993; Nicholas,2013**),

Further, the transition probability matrix is a stochastic matrix in which all entries in each row/column or both sum to 1. The usefulness of stochastic matrices gets more pronounced while dealing with n-step transition and long run behaviour of the Markov chain. Thus, the very character of the Absorbing State demands that any item/resource transitioning from this state would transition back to only this state with 100% probability.

II. Review of Literature

There have been a strong relationship between Markov chain model and human resource requirements, study conducted found HR

deployment including different levels of deployment affected the future HR prediction and improved forecasting of recruitment, promotion and employees structure which further helped in improvising the hierarchical level and quantity of HR too. **(Banyal, T et.al 2018)**

Markov chain model is found to be a suitable and relevant tool for organization success, it helps in estimating the required manpower both internally and also predicting externally. A study conducted which emphasized on using the model for manpower planning found that level of promotion, demotion, staff movement, appropriate allotment of workload, staff recruitment, all are dependent on a systematic approach to development. It helps in bringing more efficiency, adequacy, clarity and precision in decision making **(Ezugwu, v Ologun, S. 2017)**

The utility and application of Markov chain analysis is not only limited to prediction of manpower planning and estimation but is also applicable for different other issues for effective human resource requirements. Like, conflict management there is a wide application of the method wherein the management conflict behaviour based on different levels of staff conflict and transferring state of probability and constructed transfer matrix demonstrating that this method can develop a new perspective altogether.

Thus, it is a new perspective of research wherein predicting the possible work conflict approach can be achieved. **(Yong, Huang, Jiashun, Liu, 2017)**

From beginning researchers have been exploring better approach predict the future manpower requirements based on an effective mathematical modelling approach. Since this approach is a highly future focussed and helps in taking right hiring decision, employee turnover and maintain productivity it is important to ensure that dataset created for such predictions are suitably taken care of , workforce distribution , stochastic ,cohorts method based on employee records can be effectively utilized for employee excellence and decision making, The research indicates that outputs of these will help HR departments to ensure hiring, training, retention and retirement policies etc. **Garvit Vijai (2022)**

The utility of Markov chain finds equal space in marketing wherein, product marketing prediction helps in calculating and analysing economic prediction, the method and model is used for establishing probability matrix of product state transition and calculating with the Markov chain in a practical, predictable and marketing effectiveness way. **(Chen H, Zhang W, Yang ,C, Cui H, 2022)**

There has been also a strong relationship found between retaining employees at academic institutions due to several reasons, the study helps in understanding how training, career development, job hopping probability affects the chances of employee retention and effective service outcomes for ensuring a well-recognized and good relationship and employee performance. **PC Chukvu(2020)**

There has been a continuous effort to determine how manpower planning has both qualitatively improved outcome in public and private sectors, with the help of Markov chain analysis, levels of promotions, demotions, withdrawals can future manpower requirements can be fulfilled and transition from designation to expected performance can be understood using the model. The study indicated how time required for expected change in the designation can also be executed using the method. **Otieo,O, Oyala, C,2020**

Human resource strategic planning is found to be strongly impacting supply forecasting in the organization, a complete human resource strategic planning is found to be affecting with a competitive advantage internal supply of Human resources as well, this will help organization to predict their internal supply through this method as well and develop an enterprise level human resource plan.

Markov model will help in predicting the right staff replacement models and determining internal supply of human resources and also develop substitutes of enterprise staff replacement planning and staff replacement decision with different transition states., it will help in solving problem of human resource supply at large enterprise level as well (**Du, Wang, Shou,Li,2015**)

Employee engagement levels are largely dependent on how leadership is sustained and developed across the organization to maintain right culture and outcome. In this context the role of communication matters a lot wherein the perceived communication, employee engagement and cognitive, emotional and behavioural engagement affects overall organization outcome. This in turn also affects intrapreneurship, transactional leadership style affects the way in which a leader can attune right behaviour at workplace. (**Madhyvadany, M. & Panboli, S.(2023)**)

With changing expectations and deliverables on the part of employees and rising employer expectation in terms of efficiency and outcome centrality it has become important to identify where and how technology can facilitate in ensuring effective outcome. The role of Artificial Intelligence in making a difference at workplace has reinvented in many ways the ease of work and workplace excellence. It is important to identify

in correct ways how the application of AI in different spheres and aspects of Human capital management can affect better employee outcome (Lilly, A., Rajkumar, R., Kumar, J. Vinoth & Lydia, J.(2023))

The application of Markov chain analysis finds space not only in academic literature but also in practical sense because estimating manpower requirements, placing them effectively into required phases and ensuring no changes in promotion and recruitment policies as well in the salary structures also with different combinations will help in predicting the maintenance factors needed for employee performance. The model can be applied in various perspectives in estimating the descriptive, forecasting and planning model as well. It also will help in forecasting predicting future requirements of manpower supply and estimating average cost without altering the HR decisions, (Soyibo,Adedoyin,1984)

The application and practical applicability of the Markov chain is not only limited to HR aspects and future progression but also makes sense with vendor managed inventory decisions also. It helps in predicting effective inventory management and improving the process as well, based on pilot testing and identifying selected components of an assembly line in a manufacturing company after analysis it was found that series of performance indicators were estimated based on correlation and four important influential parameters were estimated using the model, There were number of switching scenarios which were received and thus based on Markov chain analysis an effective analysis of inventory performance index for these were received and VMI performance were received.(Jyoti, Gupta,N,2020)

III. Research Methodology

Objective of the Study: To develop a modified Absorbing Markov Chain model and validate it by a case study.

Type of Research deployed in the study is exploratory wherein a specific cluster of samples has been chosen for study understanding the objective of model validation based on Markov chain analysis.

Tools used in the study includes vector analysis and Markov chain analysis, probability applications.

IV. Development of Conceptual Model:

Above conditions are met in coherence, when a new state termed as 'exit state' that shows the transition probabilities of the employees, at

different levels, leaving the organisation over a discrete time interval, has been incorporated into the Markov matrix. The 'exit state' exhibits all the features of an absorbing state and supports the construction of the stochastic matrix. The paper uses holistic description of Absorbing state as given in the following:

- Resources / items entering an Absorbing state / Exit state are irretrievable; Organisation cannot count on these resources that have entered the exit state,
- The 'Exit state', is therefore, virtually a void.

Markov chain and its modified versions find wide range of applications in Physical and Bio-Sciences (Kampen. 2007 ; Cinelli, 2020), Operation research and Statistical modelling (Bolch et al. , 2006) and different kinds of real- life problems of migration and movement (Constant & Zimmermann, 2012).

Markov chain is characterised by transition probability matrix (TPM), the elements of which are transition probabilities having nonnegative values between 0 to 1 for one unit of time or one cycle of transition. A stochastic process with discrete- time and discrete -states is termed as Discrete Time Markov chain (DTMC) (Ngo, 2011; Kemeney , 1976) . The current state (S_c) vector (matrix) and the next state (S_n) vector (matrix) relate to each other by the following matrix equation:

$[S_c][TPM] = [S_n]$, where TPM is a right stochastic matrix, S_c and S_n are row vectors defining respectively the current and the next state of the System. If TPM is a left stochastic matrix, then S_c and S_n will get transposed and become column vectors while S_c and TPM will interchange their positions in the matrix equation.

The conceptual model helps us to understand the physical significance of Absorbing state and physical interpretation of its probabilistic character when employees leaving/quitting the organisation are represented by the Exit state. We find that all the properties of the Exit state are appropriately matching with those of an Absorbing state. Further, the inclusion of Exit state as an Absorbing state along with other transient states in the Transition Table complements the construction of Markov stochastic matrix of transition probabilities. The model has been validated by a case study, over one unit of time cycle, of employees' internal movement and their exit from a company operating in Information Technology sector.

Absorbing state vs Exit state:

If probability fraction P_{ii} in the i th row and i th column of the transition matrix is 1, the corresponding state/ level represents an absorbing state. To put it statistically, we say that any transition from an Absorbing state does not go to any other state but returns to the same Absorbing state with 100% probability. Further, each transient state in an Absorbing Markov chain can reach Absorbing state in one step or more. Once any resource or object enters the Absorbing state, it cannot move out; it has practically sunk or frozen into the Absorbing state.

What essentially it means is the following:

- a) Whatever resource or object enters the Absorbing state, it is of no use or no value to the organisation during analysis, if not for ever. This virtually creates a 'void' of nothingness.
- b) Employees from any level or position are free to take exit from the company, hence Exit state is reachable by all other transient states in one or more steps. Then, employees who transition to the Exit state are said to have finally left the company and are not supposed to return during the Markov analysis. Hence, they are rendered practically irretrievable, ineffectual, and non-contributory to the organisation. This is therefore a 'void'. The employees who took exit from the organisation may still benefit the organisation only in their individual capacity, or on invite but not as a member on the roll of the organisation. The present model considers them non-contributory for the purpose of statistical treatment of data during the discrete period of Markov analysis.
- c) In order to meet the condition of Markov TPM, which is an N-by-N square matrix, the Exit state is to be positioned also in the initial state of the System, but its presence is going to be just notional. This may seem little inexplicit at the first instance until we further explain what its inclusion means. This state from the very beginning does not have any resources/ objects to count on and to supply to the organisation, hence it is a 'void' in itself.
- d) It is, therefore, safely inferred that Exit state shown in the transition diagram and in the TPM is factually an Absorbing state, as transition from void to void is 100%.

V. Findings - Application of Model and Validation

The succeeding paragraphs describe the application of model and its validation on the basis of data on employees' internal movement and their attrition rate in a company over a discrete time interval.

Model and Validation:

To validate the proposed model, a case study was carried out and data was collected from one of the units of an Indian MNC operating in Information Technology which is an equal opportunity employer. Employees strength at four levels of hierarchy A to D respectively from top management down to managerial class was segregated and studied in respect of employee's internal movement to other levels as also their exit from the organisation. The company maintains that executives are promoted to next higher level as per HR policy and company's requirements. The company also asserts that it refrains from shifting the executives to lower status or grade.

The study refers to a discrete time interval of 18 months during 2020-2021. Employees who entered the organisation during this period are not counted for the analysis purpose.

Transition probability diagram, state vector, Markov Transition Matrix, and Final state vector:

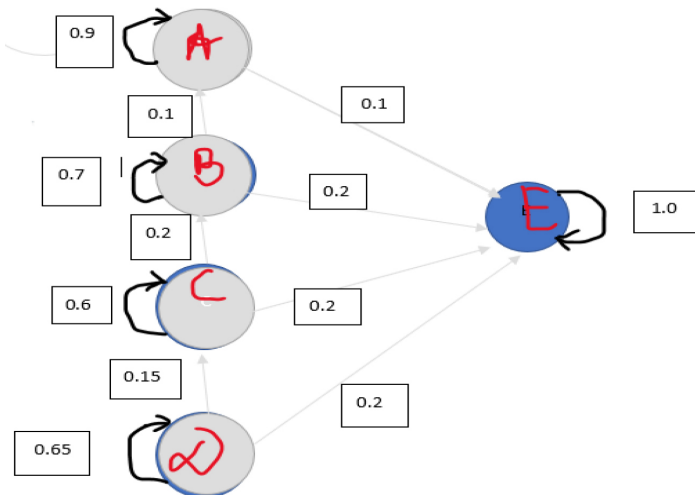


Figure 1

Transition Probability Network from one State to another State

$$\begin{bmatrix} .0258 & .0645 & .1613 & .7484 & 0.0 \end{bmatrix} \times \begin{bmatrix} 0.9 & 0 & 0 & 0 & 0.1 \\ 0.1 & 0.7 & 0 & 0 & 0.2 \\ 0 & 0.2 & 0.6 & 0 & 0.2 \\ 0 & 0 & 0.15 & .65 & 0.2 \\ 0 & 0 & 0 & 0 & 1.0 \end{bmatrix} = \begin{bmatrix} .0296 & .0777 & .2089 & .4864 & .1973 \end{bmatrix}$$

Figure 2**Transition Probability Matrix (TPM) & Matrix equation**

Figure 1 shows transition probability diagram in which arrows indicate the direction of transition and fractions over them are probability of transition.

Table 1

Employees transition probabilities from levels/states A, B,C,D,E (shown vertically) to A,B,C,D,E (shown horizontally)

Levels/States	A	B	C	D	E
A (8)	0.9	0	0	0	0.1
B (20)	0.1	0.7	0	0	0.2
C (50)	0	0.2	0.6	0	0.2
D (232)	0	0	0.15	0.65	0.20
E(0)	0	0	0	0	1
Total (310)	9	24	65	151	61

Table 1 shows sample size, employee's strength at different levels of hierarchy A to D and collective picture of probabilities of transitions from one state or level to another including level E (exit) which is assigned to the employees leaving or quitting the company. From employee's strength distributed initially at different positions in the Initial state of the system in ratio to the sample size, the corresponding probability entries for the Initial State vector were computed. The entries of the Final state vector (matrix) of the system were obtained after solving the matrix equation as given in Figure 2 and discussed earlier. Using this set of probabilities, redistributed number of employees adduced to different levels can be computed.

VI. Overall Findings and Discussion

The key idea in the evolution of our conceptual model is to identify the behaviour of 'Exit' state/ level which describes the probability of company's employees leaving the organisation, and then to draw parallel with the characteristics of the 'Absorbing' state in the Markov chain.

Since it has been established in earlier sections that Absorbing state is a 'void' and 'Exit' state is also a 'void', then by transitive property of equality, Absorbing and Exit states are similar ones. Hence, the Exit state in the Absorbing Markov chain can be treated as an Absorbing state. It also then warrants the construction of Markov stochastic matrix and the application of Markov matrix equation.

The final state row vector of the System would yield the values of probabilities of redistributed strength of employees corresponding to their respective levels. The Model has been validated by a case study of employee's attrition rate and their internal movement in an IT company.

The final state of the system provides information about human resource surplus and human resource deficient jobs which is important to leaders for taking informed decisions. The probability of executives quitting the organisation is found to be 0.1973, that is, 19.73 % which is significantly higher than the normal value 10-12%.

Many reasons can be attributed to such a shoot in value. Leadership needs to examine reasons that are controllable. One obvious reason is that talented employees get offer from other companies for higher grade and better pay-package. Leadership may try to retain them because recruitment process is not only a costly activity but also time-consuming.

The vacancies could directly impact knowledge sharing and timeline of projects completion. Other oft-quoted reason is non-compromising conditions employee faces in the peer circle due to cold relationship with the immediate reporting manager who fears competitive disadvantage from the team member.

The concept can thus help preventing and reducing risk associated in many aspects including the monetary risk, the model and its approach finds equal focus on movement of share prices and its estimation. In different cases after estimating values of alpha and beta values the expectation of monthly increase and decrease of share price was obtained and steady state of probabilities were obtained, the results indicated that monthly share of prices continued to increase to increased activity in stock market and other economic performance parameters as well, based on findings the market authorities should identify and design such policies

that affect forestalls investors' confidence. **Manasseh, C.O., Iroha, N.M., Okere, K.I. et al(2022)**

The application of Markov model finds sense in understanding the aspect of design and strategic aspects as well, In order to overcome the problems of design strategies using a probabilistic model a new design based on certain design strategies using a probabilistic model to generate new designs and solving configuration using Cognitively inspired simulated annealing teams (CISAT)framework was developed that helped in predicting human problem solving in configuration design problems. **(Raina, a,Cagan C, Comb C, 2019)**

Sometimes, the reporting manager purposely overburdens the fellow member with assorted projects by setting unrealistic deadlines, knowing fully well that such incongruent pieces of work would not be completed by any competent person in the organisation. It is intentionally done to make the member appear under performer and non-achiever.

Under such awkward situations, the employee, are unable to find any occasion to register his/her grievances and has no option but to resign from the job and leave the organisation. Such issues can be addressed by the leadership and ensuing problems can be timely resolved.

Force majeure events can also force employees to leave the organisation, and Management cannot do much about it. If the position is relinquished or the organisation is quit for the personal or the family reasons, there is nothing much leadership can do about it. Covid-19 pandemic of 2020-21 is one such event that severely impacted the world at large resulting in loss of lives inflicting traumatic experience and fear perception.

This has disrupted socio-economic order, trade, and commerce. Many companies went for down-sizing and employees lay out. Loss of income and vulnerable societal conditions drove employees seek jobs in the proximity of their native township. However, looking at the reports of first and second quarter of the FY 2022-23 on employee's attrition rate, it is appalling to note that while Covid 19 wave intensity has almost subsided, the IT giants in India could not control the rising trend in attrition rate. TCS reported 21.5 per cent employee's attrition rate for Q2FY22-23; Infosys has reported 27.1 per cent for Q1 FY 22-23, Wipro reported 23.3 per cent for Q1 FY22-23 and HCL Technologies has reported 23.8 per cent. It is indicative of something which is nothing to do with Covid 19.

Similar such findings highlighting the significance of Markov chain model in stabilizing structure of HR and attains central importance in studying population trends, it is indicated from varied studies that

manpower flow based on TPM between one grade to another grade is stationery and over time the staffing structure can be estimated using the model. **(Elangovan, R, N , Panchanathan,2023)**

This research pursuit has evolved into a conceptual model to describe the nature and probabilistic behaviour of an Absorbing state in Markov chain, and the same has been cogently compared with the characteristics of Exit state/ level attached to the group of employees leaving / quitting the organisation and both have been found to be identical. Introducing an Exit level/state has also complemented the construction of Markov stochastic matrix.

Absorbing Markov chain analysis was done to study employee's attrition rate and their internal movement to check and verify the appropriateness of the model. Tracking internal movement is important to identify which jobs are resource surplus and which others are resource deficient. Employee's attrition rate helps to forecast company's manpower future requirement. Incidentally, attrition rate was found to be significantly higher than the normal value and we have accounted it for various reasons. One clear reason for the rise in employee's attrition rate of IT Companies like TCS, Infosys, Wipro and HCL Technologies for Q1 and Q2 of FY22-23 when severity of Covid wave is not felt seems to have come due to the demographic changes in the organisations.

The results were found partible with not only manufacturing, or private owned but also similar trends were found in family run enterprises. Competency analysis of the organization employees indicate that grassroot employees required high level of competence compared with the senior level of employees, prediction accuracy of model algorithm was found to be work predictable and thus inability to achieve homogeneity lied in excellence. **(Jinyang Cao,2022)**

Young adults have their strong personal reasons too; female executives get married and often leave the organisation and may or may not join other as per their convenience; male executives in early years of their career are always in search of better avenues for their growth and perquisites. A demography- based study may unfold the truth more vividly, which is open to researchers to carry out.

The application and utility of the model lies not only in the corporate world but equally in armed forces and related profession, the selection of military personnel right from recruitment to engagement was found that with every passing year the number of recruits and the error value and controlling it thus affecting rank, expertise, job criteria. **(Setyaningrum, L et.al,2022)**

VI. Limitations of Study

The research study though covers the wider aspect of movement of people (Internally) through the model however there are various approaches and theories which equally helps in predicting the human resource and varied aspects of their effective management. However various other aspects related to procurement, development, conflict management, legal aspects and maintaining engagement can also be related to same. Hence further studies can be conducted to understand the scope and relevance of estimating manpower requirements, movement, and sustenance.

VIII. Conclusion and future Scope of Study

Talented persons are to be valued and admired. Companies do look for the talented persons. One obvious reason therefore to quit the organisation is to not get recognition and to get offer for higher grade and better pay package from other companies of consistent credibility. Another oft-quoted intangible reason is the non- compromising condition created in peer group and cold relationship with the high- ups.

When a reporting manager burdens his/her team member with assorted pieces of different projects without proper briefing and set unreasonable deadlines maliciously aiming to prove the member a non-achiever or under performer, the member has no option but to quit the organisation if on repeated attempts she/ he fails to communicate with top management and find redressal of his/ her grievances improbable.

There could be several reasons due to which employees opt for quitting the organisation. We briefly discuss some of the related issues and problematic situations most of which can be controlled by the leadership if timely investigated and strategically resolved.

Unusual rise in employee's attrition rate in the present time could also be attributed to unforeseen Covid -19 pandemic that has severely disrupted the socio-economic order across the globe, drastically slowed down trade and commerce, inflicted traumatic experience and filled people with fear perception. Even in such a force majeure condition, it should have been possible for leadership to take ingenious steps for maintaining functional flexibility and employee's stability.

References

- [1] Bolch Gunter ; Greiner Stefan; de Meer Hermann; Trivedi Kishor S., Networks and Markov Chains: Modelling and Performance Evaluation with Computer Science applications, 2nd edition, Wiley (2006), E-Book 978-0-471-79156-0.
- [2] Banyal, T et. al. 2018, https://www.researchgate.net/publication/328311382_Markov-Chain_Simulation,Based_Analysis_of_Human_Resource_Structure_How_Staff_Deployment_and_Staffing_Affect_Sustainable_Human_Resource_Strategy.
- [3] Cinelli, Mattia. Hidden Markov Chain Model for Biological Sequences [https://towards datascience.com>hidden Markov Chains](https://towardsdatascience.com/hidden-Markov-Chains) (2020).
- [4] Constant A.F. and Zimmermann K.F., *The dynamics of repeat migration-A Markov chain analysis*. The International Migration Review, vol.46 (2), pp 361-387, Sage Publication (2012).
- [5] Du, Wang, Shou, Li, Application of Markov Model in Human Resource Supply Forecasting in Enterprises, International Conference on Computational Science and Engineering (ICCSE 2015), Department of Information Management, The Central Institute For Correctional Police, Baoding ,071000, China (2015).
- [6] Ezugwu, v Ologun, S., Markov Chain: A Predictive Model for Manpower Planning, JASEM, VOL 21 (3), 557-565 (2017).
- [7] Elangovan, R, N, Panchanathan, 2023, FORECASTING HUMAN RESOURCE POTENTIAL USING MARKOV CHAIN APPROACH,VOLUME 14, ISSUE 11, pp 290-299 (2020).
- [8] Gagniuc Paul A., Markov chain: from Theory to Implementation and Experimentation. pp 9-11 (2017), John Wiley & Sons. N.J. USA.
- [9] Garvit Vijai. Workforce Planning using Markov Chain, Thesis submitted for Trinity college of Dublin, University of Dublin, School of computer science and statistics (2022).
- [10] Haiying Chen, Haiyan Chen, Wei Zhang, Chaodan Yang, Hongxiu Cui, "Research on Marketing Prediction Model Based on Markov Prediction", Wireless Communications and Mobile Computing, vol. 2021, Article ID 4535181, 9 pages (2021). <https://doi.org/10.1155/2021/4535181>.
- [11] .Jyoti, Gupta,N,(2020),Development of a Markov chain based tool for studying effectiveness of Vendor Managed Inventory and result analysis from a pilot study, Sādhana, 45:63 Indian Academy

- of Sciences (2020). <https://doi.org/10.1007/s12046-020-1298-3>Sadhana(0123456789(,.-volV)
- [12] Jinyang Cao, "An Analysis of the Optimal Allocation of Core Human Resources in Family Enterprises Based on the Markov Model", *Journal of Mathematics*, vol. 2022, Article ID 7619293, 11 pages (2022). <https://doi.org/10.1155/2022/7619293>.
 - [13] Kivilcim M. U., Markov chain forecasts of Employees replacement needs. *A Journal of Economy and Society*. 11(1), pp 96-106 (1972).
 - [14] Kemeney, J. G. and Snell, J.L., *Finite Markov Chain*. pp 45-55, Springer. NY. USA (1976).
 - [15] Kampen, N. G., *Stochastic Processes in Physics and Chemistry*. 3rd edn., pp 52-95 (2007), Elsevier.
 - [16] Lilly, A., Rajkumar, R., Kumar, J. Vinoth & Lydia, J., Appendage of artificial intelligence in the sphere of refurbishing human capital management, *Journal of Statistics and Management Systems*, 26:4, 975–986 (2023), DOI: 10.47974/JSMS-1115.
 - [17] Manasseh, C.O., Iroha, N.M., Okere, K.I. et al. Application of Markov chain to share price movement in Nigeria (1985–2019). *Futur Bus J* 8, 59 (2022). <https://doi.org/10.1186/s43093-022-00168-y>.
 - [18] Meyen S.P. and Tweedie R.L., *Markov chains and Stochastic stability*. pp 23-79 (1993), Springer Verlag. London.
 - [19] Madhyvadany, M. & Panboli, S., Moderation role of transactional leadership on employee engagement: Recent challenges in Indian start-up companies-SmartPLS analysis, *Journal of Statistics and Management Systems*, 26:2, 379-400 (2023), DOI: 10.47974/JSMS-1020.
 - [20] Ngo, Hung Q., Markov Chains: Foundation and Application, CSE 736, Spring, (2003). <https://cse.buffalo.edu/classes/Markov>.
 - [21] Nicholas P., *Understanding Markov chains: Examples and Applications*. 2nd ed. pp 77- 94 (2013), Springer. Singapore.
 - [22] Otieno, O., Oyala, C., Application of Markov chain model in career progression of university academic staff: A Case Study of the Moi University-Eldoret, Kenya, *Mathematical Theory and Modelling*, Vol.10, No.1 (2020).