Markov Chain Method in Calculation of Personnel Recruitment Needs

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Abstract **– The selection of military personnel through the recruitment stage must be under planning. The calculation in this study uses the Markov Chain method with an error calculation which is the result of a comparison with the conditions of the number of recruits in the previous period so that the error value is known and can be used in the next period using a computerized system. This study provides an alternative to determining the error value in predicting the number of recruits more easily and based on previous data by considering various aspects, such as rank, expertise, and job criteria required.**

Keywords **– Markov Chain, recruitment, military personnel, personnel planning**

1. Introduction

Having personnel who can fill various positions in military organizations according to their fields and expertise, can support the organization's development. The demands in the defense and security field have become increasingly complex, so various methods of personnel recruitment are needed. It can use to support obtaining skilled, highly motivated, and loyal personnel, and the other problems are not easy, with more opportunities for young generations to have a career in other fields. [1] In its development, personnel with the same qualifications will be different when it relates to assignment experience, education, skills, and talent development from the personnel themselves, and become affect the placement of positions. [2] In this case, the military sector must also have a conceptual framework, with the integration of the various parts contained in it, including the recruitment section in the field of human resources. [3] Determination of recruitment is part of the task of the Human Resources Department, which also contributes to the evolution or development of the organization/company, so that with the use of information technology, both in planning and determining career patterns, it will be able to change automatically dynamically based on the results of calculations on the system used depending on the input data. [4]

A personnel career begins with recruitment which is carried out by fulfilling various aspects that have been determined because personnel are the most valuable asset and can provide a competitive advantage. [5] Recruitment is carried out based on personnel planning, by covering several areas to fill the shortage of personnel in several existing corps. However, recruitment is also carried out at several levels of rank, which is an early imprint in one's military career. The implementation of recruitment is strongly influenced by the number of vacant positions, with the adjustment of expertise in it. If the recruitment is carried out in general, coming from the high school level, then the next stage will be categorization, based on the corps, education, and expertise that has been provided during early military education and experience from assignments, so those appropriate assignments can be carried out and in accordance with the abilities of each military personnel. [3]

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2. Literature Review

Personnel recruitment planning and the complexity of the procedures carried out are influenced by the nature of the military organization and the positions to be filled. In addition,a good and precise analysis of personnel needs must be carried out in order to achieve efficiency.[6] In addition,the program plans in the recruitment strategy used in the recruitment process must also be prepared properly,because, in the end, it will affect the quality of the performance of the organization which depends on the quality of personnel.[5]

2.1. Recruitment Personnel

The recruitment process is an effort to find potential personnel/employees, armed with certain skills/expertise, abilities, and personal characteristics possessed to fill vacancies in an organization. [5][7] At the planning stage of the recruitment process, there must be a determination of the requirements for potential candidates, which are tailored to the tasks to be performed. In addition, there must also be a description of the work offered, such as the scope, position, main tasks, education, skills, and responsibilities.[8]The planning process is also an effort to place the workforce in the right position, in the right number, so that it can provide good performance and provide benefits to the organization in the long term. [9] [10]

2.2. Markov Chain Method

The Markov Chain method is a model that can be used in various practical problems and for applications in the fields of telecommunications, informatics, economics, and engineering, also can be combined with other methods.[11] In the field of organizational management, the Markov Chain method has been widely applied, including in terms of promotions, demotion in ranks, or career development paths. It also helps calculate the manpower needs.[9] For inference on high data sets, it is a challenge in big data management, but it can use the Markov Chain Monte Carlo (MCMC) algorithm.[12] The Markov process is processed in the form of classical mechanics with analogs probabilistic, and developments for future predictions that can be determined by current conditions.[13]
Calculations in the implementation of recruitment must be appropriate, because it influences the development of the military organization itself, for example, the problem of personnel accumulation at a point at a certain rank. The number of personnel will reflect how well the personnel career pattern is handled, as well as support the implementation of tasks consisting of various missions.[14] This study uses the Markov Chain method which has been used in previous studies for prediction and calculating the number of personnel needed. In addition, in its development, the Markov Chain method has been used on systems in the various calculation according to user needs, which can see in Table 1.

Table 1. The use of Markov Chain Method in several fields

NO.	LITER-ATURE	RESULTS	RESEARCH DEVELOPMENT SUGGESTIONS/DESCRIPTION
1.	[15]	Analysis calculation of the effect of one-way model substitution conditions on the inventory system influenced by policies on the ordering process.	The addition of lead time with positive conditions (ex. stochastic) in the analysis with a better describe the reality condition.
2.	[16]	Using Markov Chain applications in the Management, Mathematics Education, and Artificial Intelligence.	Review papers.
3.	[9]	The recruitment predictions calculation at the Uyo University at Nigeria.	Research development by including controls in the recruitment predictions calculation with case examples.
4.	[17]	Predictive calculations for inventory demand.	Using optimization methods for more comprehensive producing better BPA (Basic Probability Assignment) values.
5.	[18]	Conduct workforce planning that focuses on internal needs for human resources.	Research with a longer time and access to complete information. Calculations on probabilities must use sufficient data to minimize the difference between the predicted results and the actual data.
6.	[19]	The forecasting and estimation of infectious diseases parameters.	Using a population size should be more appropriate so not difficult to identify convergence.
7.	[20]	The daily rainfall behavioral conditions analysis with meteorological data stations in the state of Paraiba, Brazil.	Using the results of this study to calculate the temporal and spatial variability analysis of rainfall.
8.	[21]	The prediction of coal consumption in Gansu Province, China using the gray Markov method.	The impact of using coal on its relation to the environment, and the predictions of the use of energy according to the

			proportional demand for coal.
9.	[22]	Calculation of probability values for periods of natural disasters, which include probability values for floods, landslides, and hurricanes.	With very diverse climatic, geographical and topological conditions, the potential for natural disasters that occur is also diverse, including earthquakes, tsunamis, and hydrometeorological disasters such as droughts, tsunamis, floods, fires, typhoons, and others.

As for the calculation of errors, there are studies that use various methods according to the needs of the research, it can be seen in Table 2 that various forms of error calculations in the Markov Chain method for various needs.

Table 2. Calculation of errors in the use of the Markov chain method in previous studies

NO.	LITER-ATURE	RESULTS	RESEARCH DEVELOPMENT SUGGESTIONS/DESCRIPTION
1.	[23]	The estimation number of personnel shifts that including large companies with complex staff and the need for the number of human resources that can be recruited, using the gray-Markov Chain method, and compare the error rate with the actual data.	Use this method to guide human resource professionals and business managers.
2.	[24]	Calculation of the approximate error in pricing European options on the class jump model originating from diffusion through subordination that can occur in financial applications.	Development and use for classes in other jump models with different representations to get a sharper level of convergence.
3.	[25]	Using the method to inverse hydrogeophysics problems with Bayesian solutions with identification and elimination of component error residues through a projection-based approach.	Application development by testing this methodology in particular on other inverse problems, as well as contexts for other iterative inversion techniques.
4.	[19]	Using bias, RMSE (root mean square error), and coverage in the assessment of the fit model. Bias and RMSE are based on the proportional error as a form of log ratio.	Use of Bayesian Prior suitable for use in real applications.
5.	[26]	Is modeling for errors on communication channels by testing through data errors on IEEE802.11a based on an OFDM (Orthogonal Frequency Division Multiplexing) system.	Implementation of the method with a case of small samples.
6.	[27]	Compared with other models in the error rate, it is concluded that the Markov model algorithm has the highest accuracy rate and the lowest relative error rate.	Markov's model to build a smarter system in human resource management. As well as using more in-depth and accurate predictive analysis on personnel, thus providing a better analysis as a basis for decision making in human resources in future family businesses.

3. Calculation Model in Recruitment

In carrying out the calculation of recruitment, the Markov Chain method will be combined directly by entering the length of service and other error factors. For the error variable, it can consist of death either due to an accident in service or illness and other causes, as well as early retirement that was not taken into account previously, also including being dishonorably or respectfully issued related to problems faced by personnel. The determination of the error value, which is adjusted to the comparison of real conditions in the previous years, will make the

calculation method easier, especially if the aspects that become the error variable do not have clear data values.

3.1. Calculations with Markov Chain

In the Markov Chain method, there are several conditions that must be met, namely: (1) the sum of the transition probabilities in an initial state has a value equal to 1, and (2) the probability conditions will apply to all data in the system, (3) the occurrence of probability transition is always constant, (4) conditions are independent.[28]

Markov chain is a form of a mathematical model using a probabilistic method, with a stochastic process. By characterizing a series of experiments that depend on the results of the last previous experiment. From this situation, a calculation process will be carried out to move to another state. So, if a state is in position s_i, then it will move to position s_j in the next state. Then there is a transition probability denoted P_{ij}, and there is no dependence on the probability state of the last state.[29]

There is a conditional opportunity that exists in a process if it is in a state i to j after an n-step transition occurs, then it becomes:[28]

$$P_{ij}^{(n)} = P\{X_{t+n} = j \mid X_t = i\} \quad \text{----------} \quad (1)$$

If a time from t in the stochastic process is in state i (X_t, with $t = 0, 1, 2, 3, \ldots$), then this state is $X_t = i$. To meet the conditions for the probability of being non-negative on a state change, the following properties must be met:

$P_{ij}^{(n)} = 0$, applies to all i and j with

$$n = 1, 2, 3, \ldots \quad \text{----------} \quad (2)$$

$\sum_{j=0}^{n} P_{ij}^{(n)} = 1$, applies to all i with

$$n = 1, 2, 3, \ldots \quad \text{----------} \quad (3)$$

So that when $n = 1$, then it becomes

$$P = P_{ij}^{(1)} \quad \text{----------} \quad (4)$$

3.2. Calculation with Error Condition

For the number of personnel who are not included in the calculation of the transition matrix, before entering the calculation of the transition matrix, the calculation of the risk of errors that can affect the final result of determining the number of recruitment is carried out first. The risk of errors that occur includes several things, in particular the risk of losing personnel due to various things, in this case, such as entering retirement, passing away, and taking early retirement. The category of taking early retirement is a condition in which personnel applies to quit their service before retirement age, influenced by several aspects, namely health, work, finances, and family.[30]

Thus, in this study, an error ($\in$) value of 0.001 was used, because, after the testing process, it was closer to the final result in the conditions according to reality when compared to the results of manual calculations. It can be seen in Figure 1, the comparison of error value with manual calculations. By using a simple linear regression formula called the LSE (least squares estimators), namely:[31]

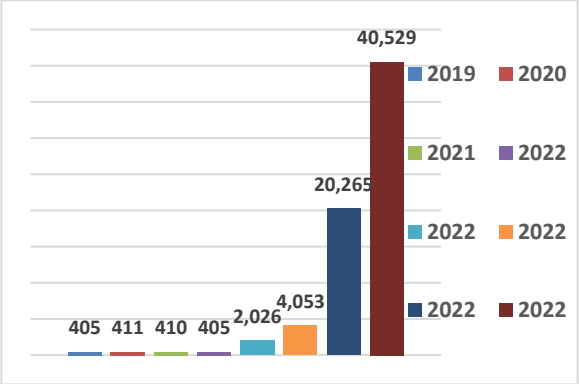

Figure 1. Error prediction comparison

Table 3. Comparison of error prediction

MANUAL DATA			ERROR PREDICTION				
2019	2020	2021	2022				
			0.001	*0.005*	*0.01*	*0.05*	*0.1*
405	411	410	405	2,026	4,053	20,265	40,529

$$b_1 = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sum_{i=1}^{n}(X_i - \bar{X})^2} \quad \text{----------} \quad (5)$$

$$b_0 = (\bar{Y} - b_1\bar{X}) + \in \quad \text{----------} \quad (6)$$

where

X is the independent variable(s), predictor or covariate(s)
Y is the dependent variable(s), and the response
b_1 and b_0 are undefined variables called regression coefficients
b_0 can be called intercept (value of EY when $X = 0$);
b_1 is a variable that shows a change from Y on average when X increases one unit
$\in$ is the error variable

At this stage, the forecast for the number of recruitments in the following year known. The results can change every year depending on the valuable data.

4. Discussion

In this example, the calculation using the Markov Chain method, with six states and carried out at the strata level from high officers to enlisted, with a result to predict the number of recruits for the following year, even though the number used is not the actual number of existing personnel.

There are several stages in the calculation, namely:

- Determine the number and composition of personnel lists

Table 4. Shows the total number of personnel in the previous years

Year	Number of personnel
2019	394.750
2020	398.161
2021	401.803

Table 5. The composition of the number by rank personnel from 2019 to 2021

No.	Category	Periods			Total
		2019	2020	2021	
1	High Officer	7.436	7.503	7.581	22.519
2	Middle Officer	101.797	102.194	102.567	306.558
3	First Officer	45.621	46.344	47.187	139.152
4	Non-commissioned Officer (NCO)	130.833	131.816	132.839	395.488
5	Enlisted	109.063	110.304	111.629	330.996
	Total	394.750	398.161	401.803	

Table 6 shows the addition of personnel each year in the rank category, to form a matrix in predicting the increase in the number of personnel in the following year period in each of the existing rank categories.

Table 6. Additional personnel period 2019-2021

No.	Category	Periods			Total
		2019	2020	2021	
1	High Officer	59	67	78	204
2	Middle Officer	356	397	373	1,126
3	First Officer	824	723	843	2,390
4	Non-commissioned Officer (NCO)	937	983	1,023	2,943
5	Enlisted	1,121	1,241	1,325	3,687
	Total	3,297	3,411	3,642	

The matrix for the addition of personnel is shown in Table 7, this matrix will change as the period of the following year progresses.

Table 7. Matrix Personnel addition period 2019-2021

No.	Category	Periods			Total
		2019	2020	2021	
1	High Officer	0,02	0,02	0,02	0,02
2	Middle Officer	0,11	0,12	0,10	0,11
3	First Officer	0,25	0,21	0,23	0,23
4	Non-commissioned Officer (NCO)	0,28	0,29	0,28	0,28
5	Enlisted	0,34	0,36	0,36	0,36
	Total	1,00	1,00	1,00	1,00

- Calculation of the total recruitment forecasting coefficient value for the following year

Calculation of determining the value of the coefficients b_1 and b_0 based on the values contained in Table 8, using a simple linear regression formula, then found the value of $b_1 = 3{,}527$ and $b_0 = 391{,}185$.

Table 8. Calculation by linear regression method

Year	Period (x)	Total $Y(x)$ personnel	$xY(x)$	x^2
2019	1	394.750	394.750	1
2020	2	398.161	796.321	4
2021	3	401.803	1.205.408	9
Total	6	1.194.713	2.396.479	14

- Performing personnel recruitment forecasting calculations

From the coefficient values b_1 and b_0, then the next year recruitment forecast is calculated, the error value used 0.001, using the formula :

$$x = \left(b_0 + (b_1.t)\right) + \left(\left(b_0 + (b_1.t)\right) * Er\right) \text{ ----- } (7)$$

Adjustment of error level based on the reduction in the number of personnel from the previous year which manually calculated. FIGURE 1 shows a comparison of the error values for several values so that using an error value of 0.001. Table 9 shows the prediction of the number of additional personnel to replace the reduced personnel. The value-added in 2023 and beyond will readjust to the actual data in 2022 and beyond.

Table 9. Forecasting the total recruitment period for the following year

Year	Number of forecasts		
	No error	Additions for errors	Total recruitment
2022	405.291	405,29	405.696
2023	408.817	408,82	409.226
2024	412.344	412,34	412.756

▪ Calculate the details of personnel recruitment

At this stage, the calculation uses the transpose transition probability matrix obtained from the transition probability matrix from state 1 to state 5. Table 10 shows how the transition probability matrix becomes a transpose transition probability matrix.

Table 10. Transformation of transition probability matrix into transpose transition probability matrix

R	1	2	3	4	5
C					
1	1,00	0,00	0,00	0,00	0,00
2	0,00	1,00	0,00	0,00	0,00
3	0,00	0,01	0,99	0,00	0,00
4	0,00	0,00	0,01	0,99	0,00
5	0,00	0,00	0,00	0,01	0,99

R	1	2	3	4	5
C					
1	1,00	0,00	0,00	0,00	0,00
2	0,00	1,00	0,01	0,00	0,00
3	0,00	0,00	0,99	0,01	0,00
4	0,00	0,00	0,00	0,99	0,01
5	0,00	0,00	0,00	0,00	0,99

After that, calculations carried out based on the composition of personnel numbers in the previous years. It will show the personnel composition at the end of 2022 and the number of personnel for each rank category that recruits in 2022.

Table 11. Forecasting the number of personnel before the addition in the year 2022

R / C	1	2	3	4	5		Personnel 2021		Personnel 2022
1	1,000	0,000	0,000	0,000	0,00		7.581		7.649
2	0,001	1,000	0,010	0,000	0,00	**X**	102.567		102.889
3	0,000	0,000	0,990	0,010	0,00		47.187	=	47.606
4	0,000	0,000	0,000	0,990	0,01		132.839		132.867
5	0,000	0,000	0,000	0,000	0,99		111.629		110.634

From the results of the matrix calculation, it found that the number of existing personnel in 2022 at the number before the addition of personnel. When compared with the number of personnel forecasting based on the calculation of the personnel forecasting coefficient value, there is a difference of total 4,051 personnel.

▪ Calculate the breakdown of the overall number of personnel forecasters in 2022

Based on the forecasting calculation and the details of the number of additional personnel in 2022, the composition of the total number of personnel founded.

Table 11. Forecasting the number of personnel and addition in the year 2022

State	Category	Forecasting Number of Personnel before addition	Number of Personnel Addition based on Matrix	Number of Personnel and Additions in the year 2022
1	High Officer	7,649	80	7,729
2	Middle Officer	102,889	441	103,330
3	First Officer	47,606	935	48,541
4	Non-commissioned Officer (NCO)	132,867	1,152	134,019
5	Enlisted	110,634	1,443	112,077
TOTAL		**401,645**	**4,051**	**405,696**

In addition, the use of this error rate also reduces the matrix calculation for the state of personnel reduction. With the implementation of this calculation pattern, it will be able to help the personnel department to determine the number of personnel recruitment, both for initial recruitment personnel and determining the number of personnel who must promote to the next rank or class.

5. Conclusion

Determination of military personnel recruitment must have the correct calculation and error rate. It can assist the organization in recruiting, which affects the personnel positions and throughout the personnel career until termination or retirement. This calculation can more detail in determining the recruitment of military personnel, such as at the level of rank, type of corps, expertise, and others according to the need for the development of military organizations. The use of the Markov Chain Method with adjustments to errors in this research, in the personnel recruitment planning, can provide predictions with results closer to reality, even in this research used data sample for the calculation. Following the data calculated in the previous period, adjustments were made with simple calculations and can easily be applied. However, it is important to develop the calculation method for other needs in the field of personnel that are simple and easy to implement. It is important because the military organization continues developing according to the needs of operations and tasks.

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