# APPLICATION OF MARKOV ANALYSIS TO MANPOWER PLANNING IN A REFINERY: A CASE STUDY OF KADUNA REFINING AND PETROCHEMICAL COMPANY LIMITED (KRPC)

**[1]MOMOH O. A. and [2]SALIHI A.**

**[1]School of Industrial Engineering, College of Engineering, Kaduna Polytechnic**
**okopimomoh@yahoo.com**
**[2]Mechanical Engineering Department, Faculty of technology, Bayero University, Kano**
**profsalihi@yahoo.com**

## ABSTRACT

Manpower disposition in many organizations in Nigeria especially government owned establishments is not usually determined based on Job analysis and corresponding workforce requirements. The paper applies Markov Analysis to aggregate manpower requirements based on analysis of internal staff movements due to retirements, promotions and resignation in the maintenance department of Kaduna refining and Petrochemical Company Limited (K.R.P.C). Basic data on maintenance task duration, Management approved staff disposition, actual staff disposition and estimated maintenance staff requirements determined from manpower utilization analysis and internal staff movement formed the basis for the Markov Analysis and the determination of required workforce. Staff turnover estimated from historical records of staff movement is used as representative of probability transition to determine the number of staff in each category that would leave the system and the subsequent expected vacancies created. Markov analysis of the effects of internal staff movement is used to determine the required workforce and the number to be recruited or laid off.

**SIGNIFICANCE:** The paper provides a basis for effective workforce planning to meet the actual maintenance manpower demands of a petroleum refinery.

**KEYWORDS:** Markov Analysis, Markov Chains, Manpower Planning, Stochastic Models, Semi-Markov Processes

## 1. INTRODUCTION

Every organization needs effective workforce planning because it ensures that adequate supply of trained manpower is available to meet both current and new demands. For our refinery, effective workforce planning means there is sufficient number of personnel with the required competences to deliver the required output to achieve maintenance effectiveness at optimum cost. There is a general manpower planning problem in the refinery, but is more conspicuous in the Maintenance Department due to retirements and retrenchments. Table1 shows the Maintenance Department man-hour utilisation analysis for year 2005. The total available workforce was 3,691 with 487,212 man-hours available. The total utilised man-hours were 627,516 resulting in overtime of 140,304 hours, equivalent to a workforce of 1063 technical staff for the year.

Analysis of year 2005 maintenance activity records (Table 2) shows that a total of 14,553 Maintenance Work Requests (MWR) (Col 3 – Col 5) were to be executed with a monthly workforce of 646 technical staff. The Management approved monthly manning level is 504 workers (Table 3) while the actual manning level is 320 workers (Table 4). There is a need to establish a basis for estimating man power requirements instead of the arbitrary Management approved manning levels. Several Optimization models are used for manpower planning, such as Linear Programming, Integer Programming, Goal Programming and Dynamic Programming. Other Models include Markov Chain models, Computer Simulation models, and Supply Chain Management (Wang, 2004). In this paper, Markov Analysis was used to develop a forecast of the internal supply of human resources in the maintenance department of K.R.P.C. The model tracks past patterns of personnel movements (transitions) and uses them to project future patterns. The analysis begins with the development of a transition matrix in which each cell represents the historical average percentage (probabilities) of employees who move between job categories (states) from one period to another. Using their historical data as representative of the probability of transition in each category, future personnel movement is projected.

A Markov Decision Process (MDP) is a probability model for processes that evolve over time. These stochastic processes take into account uncertainty about many future events. Markov chain theory is used to investigate the behaviour of a system in a discrete time stochastic process in which the time evolution of the system is described by a set of random variables $\{X_n\}$. The random variable changes at specific points in time and its probability distribution depends only on the value it takes at the immediately preceding time instant (Chandra, 1992). Its future depends only on the present state; it has no memory of how the present state was reached. This simplifying assumption creates a wide range of applications for MDPs. A major problem with maintenance workforce disposition in the KPRC is the inability to establish accurate manpower requirement based on maintenance workload. At the Organizational level, Markov Analysis may be applied to describe and forecast the process of human resource flows or movements within, into and out of the Organization. Since there are a finite number of human resource movements which may occur in an Organization (promotion, demotion, transfer, exit and new hire), Markov Analysis may be used for investigating the rates of such movements over time or between two time periods (t and t+k). The application of Markov Analysis helps to forecast shortages of employees and to aggregate manpower requirement over time based on internal staff movement due to retirement, promotion, death and transfer. A more realistic manpower requirement planning may be achieved using Markov Analysis.

## 2. LITERATURE REVIEW

### 2.1 Overview of manpower planning using Markov analysis

The goal of manpower planning is to make future demands and supply in the workforce coincide optimally. Manpower planning takes into account various environmental factors of an industry. The behaviour of a manpower system is predominantly determined by recruitment, promotion and wastage. While recruitment is used to fill vacancies arising from expansion, promotions and wastages, promotion is used to fill vacancies that arise at higher grades due to wastages. Wastages occur when employees leave the organization by discharge, resignation, redundancy and retirement (Setlhare, 2007).

The analysis of manpower systems has become a very significant component of planning in many organizations. Manpower planning, however, depends on the highly unpredictable human behaviour and the uncertain social and business environment in which organizations operate. Hence the study of probabilistic and stochastic models of manpower systems is very much essential. Several stochastic models of manpower systems have been extensively studied in the past (Bartholomew, 1971; Forbes, 1971; Balinsky and Reiman, 1972; Edwards, 1983; Winjigaard, 1983; Gorgiou and Vassiliou, 1997; and Popova and Morton, 1998). According to Wang (2004), Computer Simulation, Supply Chain Management through system dynamics, Optimization and Markov Chain models are Operations Research techniques that can be applied to workforce planning. While computer simulation is based on models that are composed of mathematical or logical relationships among constituent parts of a given system, analytical models such as Markov Chain and Optimization models can be represented by some fundamental equations. There are no universal mathematical or logical relationships to express simulation models since simulation by nature is system specific. A supply chain typically defines a flow process in an organisation through which raw materials are transformed into finished products required by customers. If trained personnel are considered as the product in a workforce supply chain, it is conceivable that techniques used in modelling and analysing supply chain management are readily applicable in workforce planning, especially in training. Heneman and Sandver (1977) describe Markov Analysis and its applications in Human Resources Administration and then identify and discuss its implications. They found out that mathematical problems such as sample size, choice of the time periods (t and t +k) over which rates of personnel movements are investigated, multiple employee moves during the time interval and accuracy of personnel data may limit the usefulness of Markov Analysis for human resources planning purposes. However, they pointed out that Markov Analysis has been successfully used for career planning and development, audit and control, description of an organization's internal labour market and affirmative action planning. Zanakis and Maret (1980) combines Markov Processes with pre-emptive goal programming to solve aggregate manpower planning problems under various restrictions and conflicting objectives. Their model is based on historical probabilities of losses, promotions and gains. The difficulty with this model is the determination of proper weights for the goals and when goal deviations are very many. Mehlmann (1980) uses concepts of dynamic programming within a discrete time Markovian model for the development of a graded workforce population. Optimal recruitment and transition patterns are determined by minimizing unexpected discrepancies between actual states and preferred goals. The proposed models provide optimal recruitment and transition strategies shown to be linear functions of present state and of present and future goals.

In Markov Chain Theory, the manpower system is hierarchically graded into mutually exclusive and exhaustive grades so that each member of the system may be in one and only one grade at any given time. These grades are defined in terms of any relevant state variables. Individuals move between these grades due to promotions or demotions and to the outside world due to dissatisfaction, retirement or medical reasons. Manpower systems are usually observed at specific intervals of time, say, annually. This allows the system behaviour to be described by a Markov Chain. Markov Chain models have been applied in examining the structure of manpower systems in terms of the proportion of staff in each grade or age profile of staff under a variety of conditions and in evaluating manpower control policies. In these works, the control of the expected workforce level in the various states by recruitment control was the major concern. The number of people in such categories changes over time through wastage, promotion flows and recruitment (Kamatianou, 1983). Raghavendra (1991) employed a Markov Chain Model in obtaining the transition probabilities for promotion in a bivariate framework consisting of seniority and performance rating. Georgiou and Vassiliou (1997) introduced phases in a Markov Chain Model and investigated the input policies subject to cost objective functions. Yadavalli and Natarajan (2001) studied a semi-Markov model in which a single grade system allows for wastage and recruitment.

The time dependent behaviour of stochastic models of manpower systems with the impact of pressure on promotion was subsequently studied by Yadavalli et al (2002). Wang (2004) presents the review of workforce planning applications of Operations Research including Markov Chain Models. Some potential limitations of Markov chain modelling in workforce systems are highlighted. The models are classified as “descriptive” or “exploratory” or simply “non optimization models” because of the lack of internal mathematical programming techniques to optimize outcomes such as minimizing operational costs or maximizing productivity. According to Raychaudhuri (2005), the recent Human Resources (HR) trend of referring to the employees of an organization as "Internal Customers" and therefore assumes that manpower attrition is similar to customer switching problems in case of products, has used Markov Analysis as an Operations Research Technique to predict attrition and therefore form the basis for manpower planning. Markov Analysis is applied to manpower planning basically to find out the attrition rate, that is the degree of employee reduction in a particular grade through death, retirement or promotion and predict employment stability within a specified period of time.

## 2.2 Manpower planning model using Markov chain

Workforce systems could be described by the terminology: Stocks and Flows (Wang, 2004). The stock *ni(t)* is the expected number of people in class *i* at time *t*. The flow *nij(t) = ni(t)Pij* denotes the expected number of members moving from class *i* to class *j* in an interval of unit length of time from *t* to *t+1* with *Pij* being the transition probability that an individual in class *i* at the start of the time interval is sitting in class *j* at the end. The basic equation for a K-class workforce system using Markov Chain Theory is (Wang, 2004):

$$n(t) = n(t-1)\{P + w'r\} + \Delta N(t)r \qquad \dots \qquad (1)$$

Where $n(t) = [n_1(t), n_2(t), ..., n_k(t)]$ is the row stock vector and w’ is a column vector and w’ is a matrix with the element $(w'r)_{ij} = w_i r_j$. The number of new positions created due to expansion of the organization is expressed as $\Delta N(t) = N(t) - N(t-1)$, with $N(t) = \sum_{i=1}^{k} n_i(t)$ representing the total number of staff in the system. The row wastage vector $w = [w_1, w_2, ..., ..., w_k]$ and the row recruitment vector $r = [r_1, r_2, ..., ..., r_k]$ are composed of the probabilities of staff losses or gains, constrained by (Wang, 2004)

$$\sum_{j=1}^{k} P_{ij} + w_j = 1 \; ; \; \sum_{j=1}^{k} r_i = 1 \qquad \dots \qquad (2)$$

Where: i - the initial state of the system at time (t); j - the state of the system at time (t+1); k - the number of exclusive and exhaustive states of the system.

Denoting $P_{ij}$ (t) as the transition probability of a system from state i to state j, the transition matrix is defined as (Chandra, 1992)

$$
\begin{array}{c} \\ 1 \\ 2 \\ 3 \\ \dots \\ K \end{array}
\begin{array}{c}
\begin{array}{ccccc} 1 & 2 & 3 & \dots & K \end{array} \\
\begin{bmatrix}
P_{11} & P_{12} & P_{13} & \dots & P_{1K} \\
P_{21} & P_{22} & P_{23} & \dots & P_{2K} \\
P_{31} & P_{32} & P_{33} & \dots & P_{3K} \\
\dots & \dots & \dots & \dots & \dots \\
P_{K1} & P_{K2} & P_{K3} & \dots & P_{KK}
\end{bmatrix}
\end{array}
$$

Figure 1 Transition Matrix

Each element in the matrix is a probability. Since the system will have to move from each state to some state within one time interval, the following restrictions apply to each element.

$$0 \leq P_{ij(t)} \leq 1 \qquad \dots \quad (3)$$

$$\sum_{j=1}^{K} P_{ij}(t) = 1; \text{ where, i,j = 1,2, ... k} \qquad \dots(4)$$

Where, K is the number of exclusive and exhaustive states in the system. Equation (2) could be written in a more aggregated form as (Wang, 2004)

$$n(t) = n(t-1)P + R(t)r, \qquad \dots \quad (5)$$

Where R(t) = $\Delta N(t) + n(t-1)w'$ is total number of recruitment and R(t)r is the vector of new-entrant distribution. The transition probabilities $P_{ij}$ could be estimated from the historical data of stocks and flows using the method of maximum likelihood (Bartholomew et al, 1991):

$$P_{ij} = \frac{\sum_t (t)}{\sum_t n_i(t)} \qquad \dots \qquad (6)$$

Where $n_{ij}(t)$ is the flow, (i.e. the observed number of staff moving from class $i$ to class $j$ during the time interval of *(t, to t+1)*; $n_i(t)$ is the stock, (i.e. the observed number of staff in class $i$ at the beginning of the time period *(t, to t+1)*, and the summation is taken over the time period of available historical data.

The wastage and recruitment probabilities could be estimated in the same way as the estimation for transition probabilities (http://www.rand.org). The Markov Chain Model expressed in equation (1), or its special case $\Delta n(t) = 0$ for a fixed size system, could be used to forecast workforce profiles of organizations, e.g staff distribution in classes *n(t)* for given inputs in initial conditions *n(0)*, policies in internal transitions *p*, recruitments *r* and $\Delta N(t)$ (Wang, 2004).

## 3. MANPOWER PLANNING IN KADUNA REFINING AND PETROCHEMICAL COMPANY LTD

Maintenance Manpower disposition and utilization in the various sections of the refinery and petrochemical plant are given below. A typical manpower utilization analysis is given in table1. The department operates a 22 day month and a 6 hour day for analysis of workforce utilization. Information on maintenance work requests (MWR) and manpower utilization was obtained from maintenance records. `

Table 2 provides a typical performance evaluation based on number of Maintenance Work Requests (MWR) completed. The sum of MWR completed and MWR outstanding is the MWRs that should have been completed in the year. The manpower required is estimated as (MWR completed + MWR outstanding) ÷ (22 * 6) (from tables 1 and 2)

**Table 1: Man Hour Utilization Analysis – 2005**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| S/no | Section | Available Work force | Available Man-hours work Force *22*6 | Total Man-Hours Utilized | Equivalent work Force utilized | Additional work Force utilized |
| 1. | Fuels | 518 | 68376 | 114163 | 865 | 347 |
| 2. | Lubes | 364 | 48048 | 59249 | 449 | 85 |
| 3. | PPU | 428 | 56496 | 70067 | 531 | 103 |
| 4. | LAB | 407 | 53724 | 63360 | 480 | 73 |
| 5. | Off-site | 367 | 48444 | 59533 | 451 | 84 |
| 6. | Common Services | 705 | 93060 | 114752 | 869 | 164 |
| 7. | Workshop | 902 | 119064 | 146386 | 1109 | 207 |
| | Total | 3691 | 487212 | 627516 | 4754 | 1063 |

*Source: Maintenance Log Book, K.R.P.C*

**Table 2: Maintenance Department Performance Evaluation – 2005**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|
| S/N | Section | MWR total | MWR completed | MWR reserved | MWR outstanding | Total man-hours utilized | Av man-hour/ comp MWR | Total estimated man-hours required | Estimated workforce required | Monthly manning Level |
| 1. | Fuels | 2103 | 1492 | 108 | 503 | 114163 | 76.52 | 152657.4 | 1156 | 96 |
| 2. | Lubes | 1496 | 550 | 359 | 587 | 57249 | 107.73 | 122489 | 928 | 77 |
| 3. | PPU | 2378 | 926 | 198 | 1254 | 70067 | 75.67 | 164960.6 | 1250 | 104 |
| 4. | LAB | 1747 | 945 | 130 | 672 | 63360 | 67.05 | 108419.9 | 821 | 68 |
| 5. | Off-site | 713 | 553 | 21 | 139 | 59533 | 107.65 | 74493.8 | 564 | 47 |
| 6. | Common Services | 2600 | 1876 | 86 | 638 | 114752 | 61.17 | 153781.4 | 1165 | 97 |
| 7. | Workshop | 4467 | 2595 | 49 | 1823 | 146386 | 56.41 | 249219.4 | 1888 | 157 |
| | Total | 15504 | 8937 | 951 | 5616 | 627510 | 70.22 | 1026021.5 | 7772 | 646 |

*Source: Maintenance Log Book K.R.P.C*

Col 8 = Col 7/Col 4

Col 9 = (Col 3 – Col 5)* Col 8

Col 10 = Col 9/22*6 (For maintenance work documentation, K.R.P.C uses 22 day month and 6 hour day)

Col 11 = Col 10/12

The approved manning level by management and the actual manning level are given in tables 3 and 4.

**Table 3: Maintenance Department Manpower Dispositions – Management Approved Manning Level**

| S/no | Section | Staff category | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Deputy Manager | Superintendents | Engineers | Planners | Technicians | Crew men | TOTAL |
| 1. | Fuels | 1 | 5 | 11 | 4 | 18 | 22 | 61 |
| 2. | Lubes | 1 | 5 | 11 | 4 | 18 | 22 | 61 |
| 3. | PPU | 1 | 5 | 11 | 4 | 18 | 21 | 60 |
| 4. | LAB | 1 | 5 | 11 | 4 | 18 | 22 | 61 |
| 5. | Off-site | 1 | 5 | 10 | 4 | 12 | 17 | 49 |
| 6. | Common Services | 1 | 5 | 8 | 3 | 27 | 39 | 83 |
| 7. | Workshop | 1 | 5 | 10 | 5 | 39 | 69 | 129 |
| | Total | 7 | 35 | 72 | 28 | 150 | 212 | 504 |

*Source: K.R.P.C Maintenance Department Organisational Structure*

**Table 4: Maintenance Department Manpower Dispositions – Actual Manning Level**

| S/no | Section | Staff category | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Deputy Manager | Superintendents | Engineers | Planners | Technicians | Crew men | Total |
| 1. | Fuels | 1 | 5 | 5 | 3 | 13 | 18 | 45 |
| 2. | Lubes | 1 | 4 | 8 | 2 | 4 | 11 | 30 |
| 3. | PPU | 1 | 5 | 6 | 3 | 11 | 12 | 38 |
| 4. | LAB | 1 | 5 | 8 | 1 | 11 | 11 | 37 |
| 5. | Off-site | 1 | 5 | 6 | 4 | 8 | 10 | 34 |
| 6. | Common Services | 1 | 4 | 5 | 2 | 16 | 35 | 63 |
| 7. | Workshop | 1 | 5 | 5 | 2 | 13 | 47 | 73 |
| | Total | 7 | 33 | 43 | 17 | 76 | 144 | 320 |

*Source: K.R.P.C Maintenance Department Organisational Structure*

The estimated monthly manning level in table 5 which is the required manning level calculated from the maintenance data in table 2 is used with the actual manning level for each staff category in table 4 to produce the estimated manning levels in table 5. The number of Deputy Managers and Superintendents in each section is fixed by Management policy and will not increase with increase in maintenance workload. For other categories of staff, a linear increase in their number is assumed with increase in maintenance workload. For example, Fuels Section has one Deputy Manager and five Superintendents.

Other staff categories = 39 (Table 4); 90(Table 5)

Number of Engineers (Table 5) = 5/39*90 = 12

Number of Planners (Table 5) = 3/39*90 = 7

Number of Technicians (Table 5) = 13/39*90 = 30

Number of Crew Men (Table 5) = 18/39*90 = 41

**Table 5: Maintenance Department Manpower Dispositions – Estimated Manning Level (Computed from Tables 2 and 4)**

| S/no | Section | Staff category | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Deputy Manager | Super-Intendents | Engineers | Planners | Technicians | Crew men | Total |
| 1. | Fuels | 1 | 5 | 12 | 7 | 30 | 41 | 96 |
| 2. | Lubes | 1 | 5 | 22 | 6 | 11 | 32 | 77 |
| 3. | PPU | 1 | 5 | 18 | 9 | 34 | 37 | 104 |
| 4. | LAB | 1 | 5 | 16 | 2 | 22 | 22 | 68 |
| 5. | Off-site | 1 | 5 | 8 | 6 | 12 | 15 | 47 |
| 6. | Common Services | 1 | 5 | 8 | 3 | 25 | 55 | 97 |
| 7. | Workshop | 1 | 5 | 11 | 5 | 29 | 106 | 157 |
| | Total | 7 | 35 | 95 | 38 | 163 | 308 | 646 |

Markov Analysis of the Maintenance Department workforce is given below.

The department utilizes a large number of temporary staff including Engineering Youth Corps members, Four months SIWES students and One year Industrial Training Students. Table 6 provides workforce transitions while table 7 is the transition matrix of probabilities of movement. Table 7 indicates that in any given year, an average of 70 percent of the Deputy Managers remain with the company, while 30 percent leave. 6 percent of the superintendents are promoted to Deputy Manager, while 24 percent leave the company. Multiplying the staffing level in each category at the beginning of a planning period by the transition probabilities and summing the columns yields the net future supply of labour within the organization.

**Table 6: Maintenance Department Vacancy Analysis (Computed from Tables 4 and 5)**

| Level | Available Workforce | Turn Over % | No. Expected To Remain | Additional Workforce Needed | Expected Vacancies | Required Workforce |
|---|---|---|---|---|---|---|
| Deputy Manager | 7 | 30 | 5 | - | 2 | 7 |
| Superintendents | 33 | 25 | 25 | 2 | 10 | 35 |
| Engineers | 43 | 30 | 30 | 52 | 65 | 95 |
| Planners | 17 | 18 | 14 | 21 | 24 | 38 |
| Technicians | 76 | 25 | 57 | 87 | 106 | 163 |
| Crewmen | 144 | 25 | 108 | 164 | 200 | 308 |
| Total | 320 | | 239 | 326 | 407 | 646 |

- 2 Deputy Managers retiring on length of service and old age
- 3 Superintendents going on voluntary retirement
- 6 Youth Corps Engineers finishing NYSC
- 20 SIWES students acting as technicians completing scheme
- 30 Industrial Training (IT) students completing programme

The transition probabilities in Table 7 are applied to the data in table 6 to give the man power profiles in table 8.

**Table 7: Transition Matrix of Probabilities of Movement (Replacement Analysis of Available Workforce)**

| To: From: | Probabilities of Movement | | | | | | |
|---|---|---|---|---|---|---|---|
| | **DM** | **Supt** | **Engrs** | **Planners** | **Technicians** | **Crew men** | **Exit** |
| Deputy Manager (DM) | 0.70 | | | | | | 0.3 |
| Superintendents | 0.06 | 0.70 | | | | | 0.24 |
| Engineers | | 0.12 | 0.58 | | | | 0.30 |
| Planners | | 0.18 | | 0.64 | | | 0.18 |
| Technicians | | | 0.20 | 0.05 | 0.5 | | 0.25 |
| Crew men | | | | | 0.25 | 0.50 | 0.25 |

*Source: K.R.P.C Human Resources Department*

- Engineers and Planners are on parallel grade level.
- 5 Engineers and 3 Planners promoted Superintendents respectively.
- 15 and 4 technicians promoted Engineers and Planners respectively
- Not all existing vacancies are filled from existing manpower disposition

According to equations (2), (3) and (4), the sum of the row vectors is restricted to 1

**Table 8: Markov Analysis – Effects of Internal Movement (Computed from Tables 6 and 7)**

| | **Available Workforce** | **Deputy Manager** | **Supt.** | **Engrs** | **Planners** | **Technicians** | **Crew men** | **Exit** |
|---|---|---|---|---|---|---|---|---|
| Deputy manager | 7 | 5 | | | | | | 2 |
| Superintendent | 33 | 2 | 23 | | | | | 8 |
| Engineers | 43 | | 5 | 25 | | | | 13 |
| Planners | 17 | | 3 | | 11 | | | 3 |
| Technicians | 76 | | | 15 | 4 | 38 | | 19 |
| Crew men | 144 | | | | | 36 | 72 | 36 |
| Net forecasted Availabilities | | 7 | 31 | 40 | 15 | 74 | 72 | 81 |
| Required Workforce | | 7 | 35 | 95 | 38 | 163 | 308 | 646 Total |
| Lay off | | | | | | | | |
| Recruit | | | 4 | 55 | 23 | 89 | 236 | 405 Total |

## 4. DISCUSSION

The study shows that there is no standard approach to manpower planning in the refinery. Management discretion is used to decide on manning levels in the Maintenance Department. The differences among Management Approved Manning Level (Table 3), Actual Manning Level (Table 4) and Estimated Manning Level (Table 5) show the absence of a consistent basis for manpower requirements planning in the refinery resulting in excessive overtime work in the Maintenance Department.

Markov Chain model is applied to track past patterns of personnel movements (transitions) which are used to project future workforce demands. Based on the analysis of the effects of internal staff movements (Tables 6 and 7), the requirements for each category of staff and the vacancies to be filled (Table 8) were established. The estimated manpower demand was found to be 646 against the actual manning level of 320 workers. The model can equally identify manpower surpluses and the need for lay off.

The application of Markov analysis can be extended to other departments in the refinery for effective manpower planning.

## 5. CONCLUSION

Management discretion is used mostly in K.R.P.C to decide on manpower dispositions. Manpower disposition is not done based on any established criteria. Actual manning level is well below the estimated manpower required. The study has shown that Markov Analysis can be used to plan workforce to adequately cope with maintenance work load in a Refining and Petrochemical Plant.

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