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Stability of Karman Vortex Street and Drag Coefficient for the Various Shapes of Obstacles

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Abstract

The purpose of this paper to derive the stable condition of Karman vortex street and drag coefficient for the various shapes of obstacles by theoretically. An then we compare the theoretical results by laboratory results and the actual results of the atmospheric vortex street pattern behind the Madeira and Porto Santo Island in the Atlantic Ocean.

Keywords: s*tability, vortex street, complex potential, complex velocity, periodic, atmospheric, meteorologically.*

1. Introduction

A circular cylinder of some radius ‘r’ be at rest in a fluid of kinematic viscosity ν. Consider now the real viscous situation. During a very short initial phase, which is over by the time, the cylinder has moved with speed U and a distance comparable to its radius. A vortex street of two parallel infinite rows of the same spacing is shed behind a circular cylinder. We have to find the stable condition of this vortex street pattern.

And then we have to find the estimate of drag D per unit length. An alternative method of computing drag, utilizing the difference between the upstream and downstream mean pressure yields another estimate for Drag D. We get the drag coefficient C_D which is depends upon the obstacle shape.

2. Stability Of Kámán Vortex Street

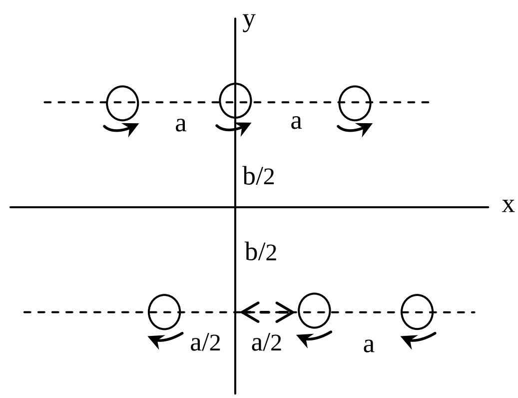

Figure 1. Karman vortex streets produced by obstacle of diameter d in two dimensional flow

We now model a fully formed vortex street by two parallel infinite rows of the same spacing, say a, but of opposite strength k and – k, so arranged that each vortex of the upper row is directly above the mid-point of the line joining two vortex of the lower row, Fig1.Taking the configuration at time t = 0, we take the axes as shown in the distance b apart. At this instant the vortices in the upper row at the points $ma+\frac{1}{2}ib$ and those in the lower at the points

$(m+\frac{1}{2})a-\frac{1}{2}ib$, where $m=0, \pm 1, \pm 2, \ldots$ .We assume that each line vortex moves at the local flow velocity due to everything other than itself.

Consider any vortex. The local flow velocity due to the others in the same row is zero, because their contributions cancel in pairs. The y- components of velocity due to those in the other row also cancel in pairs, but the x-components reinforce each other to give a certain velocity U to the right (if k>0). This velocity is common to all the vortices, so the whole array moves to the right at this speed, while maintaining its form.

The complex potential at the instant $t=0$ is therefore,

$$W = ik \log \sin \frac{\pi}{a}(z-\frac{ib}{2}) - ik \log \sin \frac{\pi}{a}(z-\frac{a}{2}+\frac{ib}{2}).$$

Since neither row induces any velocity in itself, the velocity of the vortex at

$z=\frac{1}{2}a-\frac{1}{2}ib$ will be given by

$$u_1 - iv_1 = -\left[\frac{d}{dz} ik \log \sin \frac{\pi}{a}(z-\frac{ib}{2})\right]_{(z=\frac{1}{2}a-\frac{1}{2}ib)}$$

$$= -\frac{ik\pi}{a}\cot\left(\frac{\pi}{2}-i\frac{\pi b}{a}\right)$$

$$= \frac{k\pi}{a}\tanh\frac{\pi b}{a}.$$

Thus the lower row advances with velocity

$$U = \frac{k\pi}{a}\tanh\frac{\pi b}{a}. \qquad (1)$$

and similarly the upper row advances with same velocity. Thus the whole street will advance the distance a in time $\tau = \frac{a}{U}$ and the configuration will be the same after this interval as at the initial instant.

To examine the stability of the arrangement, we observe that at time t the vortices the upper row will be at the point $ma+Ut+\frac{1}{2}ib$ and those of the lower at the point $(n+\frac{1}{2})a+Ut-\frac{1}{2}ib$, where m and n take all integral values including zero from - ∞ to ∞.

If we displace each vortex slightly, those in the upper row will move to $ma+Ut+\frac{1}{2}ib+z_m$, and those in the lower row to $(n+\frac{1}{2})a+Ut-\frac{1}{2}ib+z'_n$,where $|z_m|$, $|z'_n|$ are all small initially. The system will be stable if these quantities remain small. Now the complex velocity of the vortex for which m= 0 will be

$$U+\frac{d\bar{z}_0}{dt}. \qquad (2)$$

Now the complex potential of the vortices corresponding to 0, ± m in the upper row will be

$$W_U = ik\left\{\log\left[z-\left(Ut+\frac{1}{2}ib+z_0\right)\right]\right.$$

$$+\log\left[z-\left(ma+Ut+\frac{1}{2}ib+z_m\right)\right]$$

$$\left.+\log\left[z-\left(-ma+Ut+\frac{1}{2}ib+z_{-m}\right)\right]\right\}.$$

Complex potential of the vortices corresponding to n, -n- 1 in the lower row will be

$$W_L = -ik\left\{\log\left[z-\left((n+\frac{1}{2})a+Ut-\frac{1}{2}ib+z'_n\right)\right]\right.$$

$$+\log\left[z-\left(-(n+\frac{1}{2})a+Ut-\frac{1}{2}ib+z'_{-n-1}\right)\right]\Bigg\}.$$

The complex velocity of the vortex for which m=0 due to the vortices corresponding to ± m in the upper row and n, - n - 1 in the lower row will be

$$-\frac{d}{dz}\left\{(W_U+W_L)-ik\log\left[z-\left(Ut+\frac{1}{2}ib+z_0\right)\right]\right\}_{z=Ut+\frac{1}{2}ib+z_0}$$

$$=\left\{-ik\left[\frac{1}{z-\left(ma+Ut+\frac{1}{2}ib+z_m\right)}+\frac{1}{z-\left(-ma+Ut+\frac{1}{2}ib+z_{-m}\right)}\right]\right.$$

$$\left.+ik\left[\frac{1}{z-\left((n+\frac{1}{2})a+Ut-\frac{1}{2}ib+z'_n\right)}+\frac{1}{z-\left(-(n+\frac{1}{2})a+Ut-\frac{1}{2}ib+z'_{-n-1}\right)}\right]\right\}$$

$$=-ik\left[\frac{1}{z_0-z_m-ma}+\frac{1}{z_0-z_{-m}+ma}\right]$$

$$+ik\left[\frac{1}{z_0-z'_n-(n+\frac{1}{2})a+ib}+\frac{1}{z_0-z'_{-n-1}+(n+\frac{1}{2})a+ib}\right]$$

$$=ik\left[\frac{z_0-z_m+z_0-z_{-m}}{m^2a^2}-\frac{z_0-z'_{-n-1}}{\left((n+\frac{1}{2})a+ib\right)^2}-\frac{z_0-z'_n}{\left((n+\frac{1}{2})a-ib\right)^2}\right]$$

$$-ik\left[\frac{1}{(n+\frac{1}{2})a-ib}-\frac{1}{(n+\frac{1}{2})a+ib}\right] \qquad (3)$$

If we put $z_m=r\cos m\theta$, $z'_n=r'\cos(n+\frac{1}{2})\theta$, where r, r′are small complex numbers, because these correspond to a displacement of an undulatory character of the rows, the above contribution becomes

$$=ik\left\{\frac{2r-2r\cos m\theta}{m^2a^2}-\frac{r-r'\cos(-n-\frac{1}{2})\theta}{\left((n+\frac{1}{2})a+ib\right)^2}-\frac{r-r'\cos(n+\frac{1}{2})\theta}{\left((n+\frac{1}{2})a-ib\right)^2}\right\}$$

$$-ik\left[\frac{2ib}{(n+\frac{1}{2})^2a^2+b^2}\right]$$

$$=\frac{2ki}{a^2}\frac{r(1-\cos m\theta)}{m^2}-\frac{2ki\left(r-r'\cos(n+\frac{1}{2})\theta\right)\left((n+\frac{1}{2})^2a^2-\kappa^2a^2\right)}{\left((n+\frac{1}{2})^2a^2+\kappa^2a^2\right)}$$

$$+k\frac{2\kappa a}{(n+\frac{1}{2})^2a^2+\kappa^2a^2}$$

where $\kappa=\frac{b}{a}$

$$=\frac{2ki}{a^2}\left\{r\left[\frac{1-\cos m\theta}{m^2}-\frac{(n+\frac{1}{2})^2-\kappa^2}{\left((n+\frac{1}{2})^2+\kappa^2\right)^2}\right]\right.$$

$$\left.+\frac{r'\left((n+\frac{1}{2})^2-\kappa^2\right)\cos(n+\frac{1}{2})\theta}{\left(\left(n+\frac{1}{2}\right)^2+\kappa^2\right)^2}\right\}$$

$$+\frac{k}{a^2}\frac{2\kappa a}{(n+\frac{1}{2})^2+\kappa^2}. \quad (4)$$

Now it is known that

$$\sum_{a=0}^{\infty}\frac{k}{a^2}\frac{2\kappa a}{(n+\frac{1}{2})^2+\kappa^2}=\frac{k\pi}{a}\tanh\kappa\pi = U \quad (5)$$

and $\frac{d\bar{z}_0}{dt}=\frac{d\bar{r}}{dt}$ Thus, summing and using (2),

the disturbing effect on the vortex for which m = 0 is given by

$$\frac{d\bar{r}}{dt}=\frac{2ik}{a^2}(Ar+Cr'). \quad (6)$$

$$\text{where } A=\sum_{m=}^{\infty}\frac{1-\cos m\theta}{m^2}-\sum_{n=0}^{\infty}\frac{(n+\frac{1}{2})^2-\kappa^2}{\left[(n+\frac{1}{2})^2+\kappa^2\right]^2},$$

$$C=\sum_{m=}^{\infty}\frac{\left[(n+\frac{1}{2})^2-\kappa^2\right]\cos(n+\frac{1}{2})\theta}{\left[(n+\frac{1}{2})^2+\kappa^2\right]^2}.$$

For a vortex in the lower row we put

–k for k and interchange r and r´, which gives

$$\frac{d\bar{r}'}{dt}=-\frac{2ik}{a^2}(Ar'+Cr). \quad (7)$$

to solve these equations, differentiation

theconjugate complex of (6) gives

$$\frac{dr}{dt}=-\frac{2ik}{a^2}(A\bar{r}+C\bar{r}').$$

$$\frac{d^2r}{dt^2}=-\frac{2ik}{a2}(A\frac{d\bar{r}}{dt}+C\frac{d\bar{r}'}{dt})$$

$$\frac{d^2r}{dt^2}=\frac{4k^2}{a^4}(A^2-C^2)r, \quad (8)$$

by using (6) and (7) again.

Let $\quad r=h\exp\left(\frac{2k\lambda t}{a^2}\right).$

Then $\quad \frac{dr}{dt}=h\exp\frac{2k\lambda t}{a^2}.\frac{2k\lambda}{a^2},$

$$\frac{d^2r}{dt^2}=h\exp\frac{2k\lambda t}{a^2}.\frac{4k^2\lambda^2}{a^4}=\frac{4k^2}{a^4}\lambda^2 r. \quad (9)$$

From (8) and (9)

$$A^2-C^2=\lambda^2$$

Therefore λ is real and the motion is unstable if $A^2>C^2$. On the other hand λ is purely imaginary and the motion is periodic and therefore stable if $C^2>A^2$.

But when θ= π, we get C = 0 , for every term vanishes . Thus we must have A=0, when θ= π as a necessary condition of stability for this type of displacement.

To find A, differentiating (5) with respect to κ,

$$\sum_{n=0}^{\infty}\frac{k}{a^2}\frac{2a\left[(n+\frac{1}{2})^2-\kappa^2\right]}{\left[(n+\frac{1}{2})^2+\kappa^2\right]^2}=\frac{k\pi^2}{a}\frac{1}{\cosh^2 k\pi}$$

$$\sum_{n=0}^{\infty}\frac{\left[(n+\frac{1}{2})^2-\kappa^2\right]}{\left[(n+\frac{1}{2})^2+\kappa^2\right]^2}=\frac{\pi^2}{2\cosh^2\kappa\pi} \qquad (10)$$

and it is easily verified by applying the rule for expansion in Fourier series that

$$\sum_{n=0}^{\infty}\frac{1-\cos m\theta}{m^2}=\frac{1}{4}\theta(2\pi-\theta)$$

and therefore when $\theta=\pi$,

$$A=\frac{\pi^2}{4}-\frac{\pi^2}{2\cosh^2\kappa\pi}.$$

Thus A=0 if $\cosh\kappa\pi=\sqrt{2}$, so that

$$\kappa=0.281.$$

Therefore b= 0.281 a, (11)

and the vortex street cannot be stable unless this condition is satisfied [4][5][6][7].

3. Drag and Spacing Ratio

In a coordinate system fixed to the obstacle, let u_0 be the speed of undisturbed fluid and u_e be the speed of propagation downstream of the eddy pairs. The time interval τ (called period) between the shedding of two successive eddies of similar circulation is given by,

$$\tau=\frac{a}{u_e} \qquad (12)$$

or the rate N of shedding (called frequency) of the vortex pairs is given by,

$$N=\frac{1}{\tau}=\frac{u_e}{a}=\frac{1}{a}\left(\frac{u_e}{u_0}\right)u_0 \qquad (13)$$

The speed u_e of propagation of eddies and the circulation of strength k bear the following relationship,

$$u_0-u_e=\frac{k}{2a}\tanh\frac{\pi b}{a}. \qquad (14)$$

The rate at which the circulation is discharged downstream from each side of the obstacle is then give by,

$$Nk=2u_e\left(u_0-u_e\right)\coth\frac{\pi b}{a}. \qquad (15)$$

The drag D on obstacle is equal to the rate at which the momentum is transferred to the wake by the obstacle. This argument gives the estimate of D per unit length,

$$D=\rho b\,NK=\rho b\left(\frac{u_e}{a}\right)k$$

$$=2\rho b\,u_e\left(u_0-u_e\right)\coth\frac{\pi b}{a}. \qquad (16)$$

An alternative method of computing drag, utilization the difference between the upstream and downstream mean yields an estimate

$$D=\frac{\rho k^2}{2\pi a}+\frac{\rho kb}{a}\left(2u_e-u_0\right) \qquad (17)$$

Since the two expressions (13) and (14) for drag D are identical, therefore

$$\rho kb\left(\frac{u_e}{a}\right)=\frac{\rho k^2}{2\pi a}+\frac{\rho kb}{a}\left(2u_e-u_0\right)$$

$$bu_e=\frac{k}{2\pi}+b\left(2u_e-u_0\right)$$

$$bu_e = \frac{2a(u_0 - u_e)\coth\frac{\pi b}{a}}{2\pi} + b(2u_e - u_0)$$

$$b(u_0 - u_e) = \frac{a(u_0 - u_e)\coth\frac{\pi b}{a}}{\pi}$$

$$\left.\begin{aligned} \coth\frac{\pi b}{a} &= \frac{\pi b}{a} \\ \frac{\pi b}{a} &= 1.2 \\ \frac{a}{b} &= 0.39. \end{aligned}\right\} \quad (18)$$

A dimensionless parameter, drag coefficient C_D is related to drag by

$$C_D = \frac{D}{\frac{1}{2}\rho d u_0^2} \quad (19)$$

Where d is a cross-stream diameter of an obstacle. Substituting (14) into (16),

$$C_D = \frac{\frac{\rho k^2}{2\pi a} + \frac{\rho k b}{a}(2u_e - u_0)}{\frac{1}{2}\rho d u_0^2}$$

$$= \frac{k^2 + 2\pi k b (2u_e - u_0)}{\pi a d u_0^2}$$

$$= \frac{k[k + 2\pi b (2u_e - u_0)]}{\pi a d u_0^2}$$

$$= \frac{2a(u_0 - u_e)\coth\frac{\pi b}{a}\left[2a(u_0 - u_e)\coth\frac{\pi b}{a} + 2\pi b(2u_e - u_0)\right]}{\pi a\, d u_0^2}$$

$$= \frac{4a\left(1 - \frac{u_e}{u_0}\right)\coth\frac{\pi b}{a}\left[\left(1 - \frac{u_e}{u_0}\right)\coth\frac{\pi b}{a} + \frac{\pi b}{a}\left(\frac{2u_e}{u_0} - 1\right)\right]}{\pi d}$$

$$= \frac{4a\left(1 - \frac{u_e}{u_0}\right)\coth\frac{\pi b}{a}}{\pi d}\left[\coth\frac{\pi b}{a} - \frac{\pi b}{a} - \frac{u_e}{u_0}\left(\coth\frac{\pi b}{a} - \frac{2\pi b}{a}\right)\right].$$

Substitution of previously obtained numerical values of the parameter,

$\coth\frac{\pi b}{a} = 1.2$, $\frac{\pi b}{a} = 1.2$, $\frac{u_e}{u_0} = 0.85$, $\frac{b}{a} = 0.39$ yields

$$C_D = 0.5997\frac{b}{d} \sim \frac{b}{d} \quad (20)$$

and it depends upon the obstacle shape. This coefficient is known only for certain well-defined shapes. In reference with the values obtained by many investigators through laboratory experiments [2] and considering the fact that the value of C_D for an obstacle of an irregular shape would be larger than a simple shaped one like a cylinder or sphere, the probable value would be somewhere between 0.9 and 1.5 and the values greater than 2.0 for irregular bodies.

4. Application to Meteorologically Mesoscale Eddies

Table 1. Dimensions of atmospheric vortex street of Madeira and Porto Santo islands.

a_1 = 187 km	b_1= 82 km	d_1=46km
a_2 = 193 km	b_2= 84 km	d_2=40km
a_3 = 190 km	$\bar{b}$= 83 km	
$\bar{a}$ = 190 km	ℓ = 126km	
The diagonal distance "ℓ" is computed by $\ell = (\bar{b}^2 + \bar{a}/4)^{\frac{1}{2}}$		

The values of bandwidth $\bar{b}$ and $\bar{a}$ used in the following computations are average values of dimensions provided weather satellite which revealed the existence of mesoscale eddies [2] indicated on Figure. 2 and tabulated in Table 1.

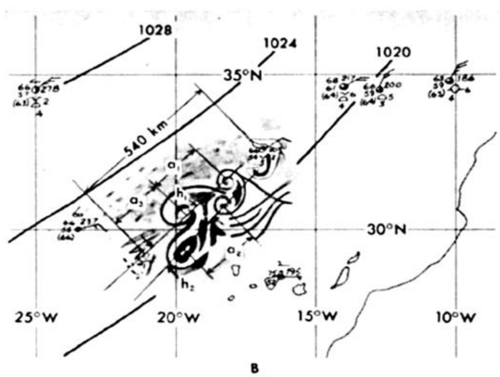

Figure 2.Eddy pattern superimposed on surface analysis 1200 GCT, 19 May 1963

The island cross-stream diameter d has been measured from the 1000-ft contour (see Figure 3) rather than the distance across the island at sea level, because the former is probably a more representative width of the obstacle that affects the layer from the surface up to the inversion. Two diameters are shown because it is not obvious whether the combined effect of Madeira and Porto Santo Islands is the effective obstacle or if only Madeira Island should be considered. The J-shaped cloud appears immediately downstream from Porto Santo, but it is possible that this eddy was produced by Madeira but displaced eastward by a local wind disturbance. As shown below, both values of d give satisfactory correspondence with laboratory results, so this question is not critical. These dimensions provide a means of comparing the atmospheric eddies with laboratory wake eddies.

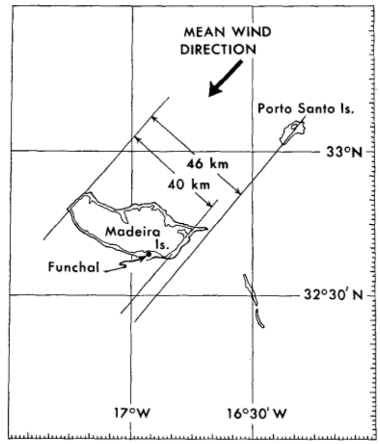

Figure 3. Large-scale map of Madeira and Proto Santo Islands indicating measurement of obstacle size

From Table 1,

$$\frac{\bar{b}}{a} = \frac{83}{190} = 0.43,$$

According to von Kármán theoretical formulation, the ratio of the lateral spacing and the longitudinal spacing between the vortices $\frac{b}{a} = 0.28$, for neutrally stable dimensions. In actual laboratory situations, however, this ratio is depending upon the shape of the of the obstacle, the characteristics of the flow and the distance along the wake, and is observed to lie in the range

$$0.28 < \frac{b}{a} < 0.52$$ [1][2][3][8][9][10].

So the value of

$$\frac{\bar{b}}{a} = 0.43$$

is satisfactory result.

Also,

$$C_D \sim \frac{\bar{b}}{d_1} = \frac{83}{46} = 1.8.$$

$$C_D \sim \frac{\bar{b}}{d_2} = \frac{83}{40} = 2.1$$

The drag coefficient of irregular bodies is not known, in general, but theory and experiment indicate they are larger than the coefficient for a cylinder. The values of either 1.8 or 2.1 are quite plausible [2].

5. Conclusion

We can find the stable condition of Karman vortex street and Drag coefficient C_D which is depend upon the obstacle shape theoretically. An then we can find the actual results of these from the large scale map of the atmospheric vortex eddies patterns behind the Madeira and Porto Santo island in the Atlantic Ocean and these actual results give satisfactory correspondence with laboratory results. Finally we can compare these results theoretically, practically and experimentally and we found that the results from the atmospheric vortex eddies behind the Madeira and Porto Santo island are quite plausible.

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Optimal Order Quantity System By Using Demand Forecasting Techniques

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Abstract

This paper has primarily focused on the wholesalers and retailers who maintained the optimal inventory level to reduce the total cost. The aim of this paper is when and how much to replenish their inventory by using inventory policy. The study is based on using simple model, basic Economic Order Quantity (EOQ) model to determine the optimal number of quantity to order. Using the demand forecasting techniques such as simple moving average, least square method to determine the forecast demand and is used as a constant demand when calculating the economic order quantity. In this paper a case study at retailer (T&H) is considered and calculated as optimal order quantity with minimizing the total cost by using EOQ model. This system is intended to recommend avoiding stock-out, large bath orders and then comparison the total cost.

keywords: Inventory, EOQ model, simple moving average, least square method .

1. Introduction

Inventory means stocks of goods being held for future use or sale. Maintaining inventories is necessary for any company dealing with physical products, including manufacturers, wholesalers, and retailers. Both wholesaler and retailer maintaining inventories of goods to be available for purchase by customers or else lose a customer [1]. Stock control, otherwise known as inventory control, is used to show how much stocks you have at any one time, and how you keep track of it. Efficient stock control allows you to have the right amount of stock in the right place at the right time. For accounting purposes, counting inventory items are done generally once a year, but for stock, the numbers are tracked daily. Stock-out inventory is casing not only loses a customer but also reduces the annual return. The retailer notices that consumers demand what items need to be stocked. Need to avoid holding too much stock to decrease holding cost. So we want to determine the optimal number of units to order that we minimize the total cost associated with the purchase and storage of the items [2]. We must manage our inventory by applying scientific inventory management techniques which consist of the following steps:

1. set up a mathematical model describing the behavior of the inventory system.
2. seek an optimal inventory policy.
3. use a record of the current inventory levels.
4. use this record of applying the optimal inventory policy to signal when and how much to replenish their inventory [1].

There are several methods of controlling stock, which are the following;

1. Just In Time (JIT) is a methodology to reduce costs by cutting stock to a minimum. Items are delivered just what is needed and when it is needed and what amount is needed. There is a risk of running out of stock.
2. Re-order leads time allows for the time for placing an order and receiving it.
3. Economic Order Quantity (EOQ) [2].

In this paper, case studies at the commodity retailer (T&H). Every day, every person is using many kinds of commodities. A consumer's goods or final goods are any commodity that is produced or consumed by the consumer to satisfy current wants or needs. Consumer goods are goods sold to consumers for use of the home or school or for recreational or personal use. Consumer products are classified into four related sets of products, namely: Convenience products (Toothpaste, soap, and shampoo, coffee, fruit and vegetables, flowers, etc), Shopping products (computer, mobile phone, clothing, kitchen utensils, choice of restaurant, etc), Specialty products (special jewelry, an expensive car, some types of computer software, etc), Unsought products (Some types of exercise equipment, Life insurance and funeral insurance, Raffle tickets, etc)[3].

2. Economic Order Quantity (EOQ) Model

In inventory management, Economic Order Quantity (EOQ) is the order quantity that minimizes the annual holding cost and ordering cost. EOQ is essentially an accounting formula that determines the point at which the combination of order costs and inventory carrying costs are the least. The result is the most cost effective quantity to order. In purchasing this is known as the order quantity, in manufacturing it is known as the production lot size. The model was developed by Ford W. Harris in 1913 but R.H Wilson, a consultant who applied it extensively, and K Andler are given credit for their in depth analysis. Placing a few orders for a year with large baths makes increasing the annual holding cost but minimize the annual ordering cost [4]. Placing an order for small baths, decreases the holding cost although increases the ordering cost [5]. The basic EOQ model is an inventory model. These models is applied to situations where the inventory level is reduced over time and each time the inventory level reaches zero the same quantity Q is ordered.

The basic assumptions of EOQ are

1. A known constant demand rate of a units per unit time.
2. Each time the inventory level reaches zero, the same quantity Q is ordered.
3. c is unit cost for producing or purchasing each unit.
4. h is holding cost per unit per item of time held in inventory.
5. k is a fixed cost (set up cost) each time the quantity Q is ordered.
6. Planned shortages are not allowed [1].

formula of EOQ is $Q^* = \sqrt{\frac{2ak}{h}}$ (1)

Total cost T = annual ordering cost +
annual holding cost +
purchase cost

$$\textit{annual ordering cost} = \frac{ak}{Q} \quad (2)$$

and $\textit{annual holding cost} = \frac{hQ}{2}$ (3)

$$\textit{number of orders in a year} = \frac{a}{Q} \quad (4)$$

The optimal order quantity Q^* which makes the total cost to minimize [1]. Using all costs associated with your purchasing and receiving departments to calculate order cost or using all costs associated with storage and material handling to calculate carrying cost. The holding cost is the cost of storing unsold goods in warehouse or in shop. These costs include cost of storage space, insurance, taxes, protection and so on. Generally, holding cost run of 20 % and 30% of the total cost of inventory, although it varies depending on the industry and the business size [6]. Ordering cost is the expenses cost, incurred when an order. Ordering cost includes expenses for a purchase order, labor costs of the inspection of goods received, labor costs of placing the goods received in stock, labor costs of issuing a supplier's invoice and labor costs of issuing a supplier payment [7]. After knowing the optimal order quantity, we can find the reorder point (i.e) it is the inventory levels at which the order is placed [1].

3. Research Methodology and Data Analysis.

In this study case, sales behavior can be analyzed by the historical sales data. The demand can be forecasted by using simple moving average, least square method, season index, mean absolute deviation. And then the predicted demand is used in EOQ model which calculates the optimum order quantity. The comparison is done between these two forecasting methods of the cost saving and recommended to ordering.

3.1 Collecting Data

T&H sales about 200 items of consumer goods from Unilever com. Ltd. Choose 4 items which high revenue level items from the retailer's database which are clear male shampoo 170 ml, lux shower cream (pink) 200 ml, ponds pure white facial foam 50g and signal toothpaste cavity fighter 160g. From January 2018 to August 2019 of historical data is obtained in order to see the products sales behavior due to its demand to help with establishing a forecasting trend for each product. Along with the products historical data, the products ordering cost, purchasing cost and unit cost is collected to calculate the total annual cost. These costs are used in EOQ model. In the following table is the data onto Quarter-1 for January to March, Quarter-2 for April-Jun, Quarter-3 for July-Sep, Quarter-4 for October-December (2018) and Quarter-5 for January to March, Quarter-6 for April-Jun, Quarter-7 for July-Sep (2019).

Table 1. Historical data for 4 items in quarters(3 months)

items name	Qty pcs	Qty pcs	Qty pcs	Qty pcs	Qty pcs	Qty pcs	Qty pcs
	Qtr-1	Qtr-2	Qtr-3	Qtr-4	Qtr-5	Qtr-6	Qtr-7
Clear	929	943	1001	1227	1520	1140	803
Lux	1081	558	894	802	749	1039	1616
Pond	1323	1020	1387	1731	957	426	1214
Signal	11265	8150	18691	17748	12853	12080	12380

3.2 Demand Forecasting

Based on forecasting method for the items, the forecasting result are used for prediction of the demand and for economic order quantity. The demand is forecasted by using the following methods.

3.2.1 Procedure for Simple Moving Average

step1. Calculate the demand based on the time period (quarter).

step2. Moving average is calculated by adding a stock over a certain period and dividing the sum by total number of period,

$$F = \frac{\sum_{i=1}^{n} s_{i-1}}{n} \quad (5)$$

where F = the forecast , s = sales of the periods (i=1,2,..,n) step3. Calculate the mean absolute deviation from each forecast.

Mean Absolute Deviation (MAD) = $\frac{\sum|Actural-Forecast|}{n}$ (6)

Table 2. Demand forecast result for clear male shampoo by using simple moving average

clear	Qtr-1	Qtr-2	Qtr-3	Qtr-4	Qtr-5	Qtr-6	Qtr-7	foreca	Mad
	929	943	1001	1227	1520	1140	803		
n=2			936	972	1114	1374	1330	972	8.63
n=3				958	1057	1249	1296	1154	32.58
n=4					1025	1173	1222	1173	14.42
n=5						1124	1166	1138	173.60
n=6							1127	1106	323.67
n=7								1080	

Demand forecast results of other items are1328,820, 12230 and Lux shower, Pond facial form, Signal toothpaste, respectively.

3.2.2 Procedure for Least Square Method [8]

step1. Fit a straight line curve,

$$y = a + b\,x \qquad (7)$$

where x_j are time period (quarter) and y_j are sales data in that period. Using normal equation,

$$an + b\ \sum_{j=1}^{n} x_j = b\ \sum_{j=1}^{n} y_j \qquad (8)$$

$$a\sum_{j=1}^{n} x_j + b\ \sum_{j=1}^{n} {x_j}^2 = \sum_{j=1}^{n} x_j y_j \qquad (9)$$

step.2 Calculate the forecast demand at x_j period.

step.3 Calculate seasonal index = $demand/forecast$

Table 3. Demand forecast for Clear male shampoo by least square method

year	Qtr	Qty pcs	forecast	seasonal index	Avg
2018	1	929	1023	0.91	1.14
	2	943	1042	0.90	0.96
	3	1001	1061	0.94	0.82
	4	1227	1080	1.14	
2019	5	1520	1100	1.38	
	6	1140	1119	1.02	
	7	803	1138	0.71	

Coming 2020 (Jan-March), the forecast demand is (1004+(19.11×8))×1.14 = 1319 (10) Demand forecast results of other items are 1479, 812, 12950 and Lux shower, Pond facial form, Signal toothpaste, respectively.

3.3 Determination of EOQ Model

The prediction demands by forecasting method is used in EOQ model and calculate the order quantity to the minimum the total cost. The calculation is used by EOQ excel template.

Table 4. Optimal order quantities for 4 items by SMA

item	a	k	h	unit pric	Q*	No.of order	total cost
clear	972	240	20%	1800	36	27	12960
Lux	1328	168	20%	1200	43	31	10348
Pond	820	230	20%	1250	39	21	9710.8
Signa	12230	100	20%	600	143	86	17132

Table 5. Optimal order quantities for 4 items by Least square method

item	a	k	h	unit price	Q*	No. of order	total cost
clear	1319	240	20%	1800	42	31	15097
Lux	1479	168	20%	1200	46	33	10921
Pond	812	230	20%	1250	39	21	9663
Signal	12950	100	20%	600	147	88	17630

4. Cost Comparison

The original demands in the current method of T&H is applied in EOQ model to compute the total cost for coming 2020 (Jan-March). Then compare the total cost which method is more appropriate.

Original demand for items is adding demand data of Qtr-1 and Qtr-5.

Table 6. Total cost of original demands in current method

item	forecast demand	ordering cost	holding cost	unit price	EOQ	total cost
Clear	4898	240	20%	1800	80.8	29093
Lux	3660	168	20%	1200	71.6	17180
Pond	4560	230	20%	1250	91.6	22900
Signal	48236	100	20%	600	284	34024

Table 7. Comparison for total cost

items	Total cost		
	Current method	Recommended method	
		Sample moving average	Least square
Clear	29093	12960	15097
Lux	17180	10348	10921
Pond	22900	9710	9663
Signal	34024	17132	17630
total	103197	50150	53311
Saving percent		51%	48%

5. Conclusion

Retailer, wholesaler and manufacturer must applied basic EOQ model to recover storage cost, stock out, back order, loss of customers' goodwill, obsolescence etc. But they must record the data to know the holding cost and ordering cost. They must use this method instead of the old method of the best control their inventory. In this case study, using sample moving average for demand forecasting reduces the total cost more than least square method when the two forecasting techniques are compared. But using the data from current method causes some disadvantage in the result. Moreover this real world problem may be useful in my teaching lesson.

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Application of Markov Chain to Foretell Watches Sales on Specific Periods

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Abstract

In choosy market, the company must be smart in managing finance in competitions. Markov chain is very helpful to get the exact Marketing plans. In this paper, watches sales were estimated and computed by using Markov chain. Numbers of goods in duration were conditioning calculated demand. It was based idea finding promotion of Markov chain. By used Markov chain, he can calculate demand in this paper. If forecast computation by using Markov chain was estimated, he can predict the economic conditions. By computing like this, he will possess the business market without being loss. So, Markov chain's methods are principally used for marketing problems. This paper will provide the marketing plan to deal with Markov by the appropriate processes. The key issue to be addressed in this work is to analyze consumers' behaviors for saving cost and time for successful managing marketing problems.

Keywords: Stochastic process, Poisson distribution, Markov modeling, Marketing, steady-state probability,

1. Introduction

To get achievement of economy, it must be applied successful marketing methods. Even being a moneybags, if he invested in the unsystematic investment, then he can be a beggar. But if he also invested in systematic computed business market, he can be a rich man. Markov chains are used in various modeling problems in real world such as behaviors of a business or economy, flows of traffic, progresses of an epidemic, a leading managerial issue for the practitioners and various computer applications and so on. Markov chains can be used to model the randomness, when predicting the value of an asset. A Markov chain, a probability model, is describing the processes that evolve over time in a probabilistic manner. Depending on the problems we considered, the states may be the names of products or watches. The main problem in this work is to calculate of market share can be done after the data acquisition and losses are met well. Myanmar, Our mother land, is built up that progressive business or modern developed country. It is important that the country's economy is matters of great importance. This paper will provide the successful marketing method by Markov chain.

2. Resources and Method

Markov was a Russian mathematician and professor in Saint Petersburg University in 1878. He worked on number theory, limits of integrals, convergences of series, and continued fractions application to probability theory. He remembered for his study of Markov Chains. The Markov chains are used as a standard tool in medical decision making [1]. The Markov started the theory of stochastic processes. Markov probability model is the process, which is referred to as being a discrete time stochastic process with a finite state space. An indexed collection of random variables $\{X_t\}$ is a stochastic process, where the index time t runs through a given set T, that is taken to be the set of nonnegative integers and X_t is a measurable characteristic of interest at time t. [2] A stochastic process $\{X_t\}$ is said to have the Markovian property if $P\{X_{t+1} = j/X_1 = k_1, X_2 = k_2, \ldots, X_{t-1} = k_{t-1}, X_t = i\}$ and every sequence $i, j, k_0, k_1, \ldots, k_{t-1}$. That is the (one-step) transition probabilities are said to be stationary. Markovian property predicting the conditional probability of any future "event,". Given any past "event" and the present state $X_t = i$, is independent of the past event and depends only upon the present state [3]. So you need to choose the successful marketing method by Markov chain to save your money and time.

2.1. Problem Definition

The problem of computing is five periods as the comparative material of the market share of transition matrix in practice. For example, a strategy in watches sales will be involved in this paper. In this paper, we collect the data from agencies of watches in Yangon. There are six watches brands, romanson, omega, citizen, GP, Q&Q, and Rado. The number of users is taken from May to June and from June to July, 2019. There are 400 respondents who serve as initial data to solve the problem. Although basic ideas will be explained and illustrated by Markov chains in this paper, the real-life problems may often involve many thousands or even millions of products [4].

2.2. Markov Chain Process

Probability models for processes that evolve over time in a probabilistic manner. Such processes are called stochastic processes. A stochastic process $\{X_t\}(t = 0, 1, \ldots)$ is a Markov chain if it has the Markovian property [2]. We obtain the following transition probability matrix

$$P^n = \left(p_{ij}\right)_{M\times M}^{(n)} = P^{(n)} = \begin{bmatrix} p_{00}^{(n)} & p_{01}^{(n)} & \cdots & p_{0M}^{(n)} \\ p_{10}^{(n)} & p_{11}^{(n)} & \cdots & p_{1M}^{(n)} \\ \cdots & \cdots & \cdots & \cdots \\ p_{M0}^{(n)} & p_{M1}^{(n)} & \cdots & p_{MM}^{(n)} \end{bmatrix}$$

Where p_{ij} is the conditions probability from state i to state j which satisfy the following conditions $0 \le p_{ij} \le 1$ *and* $\sum_{i\in I} p_{ij} = 1$[2]. The n-step transition probability matrix P^n can be obtained by computing the *n*th power of the one-step transition matrix P. that is

$$P^n = PP^{(n-1)} = P^{(n-1)}P$$
$$= PP^{n-1} = P^{n-1}P = P^n$$

There exists one distribution $\{\pi_j, j \in I\}$, *such that* $\pi_j = \sum_{i\in I} \pi_i p_{ij}$ *and* $\sum_{i\in I} \pi_i = 1$, *then* $\{\pi_j, j \in I\}$ is called its stationary distribution [3]. Steady-state probability π means that the probability of finding the process in certain state by Long-run properties of Markov chains.

3. Results and Discussion

In this paper, the application of Markov chain is to predict sales on specific periods. The main problem in this work is to calculate of market share can be done after the data acquisition and losses are met well. Myanmar, Our mother land, is built up that progressive business or modern developed country. It is important that the country's economy is matters of great importance. To get achievement of economy, it must be applied with successful marketing methods. This paper will provide the successful marketing method by Markov chain. Table 1. is a list of watches used as experimental materials.

Table 1. Initial data

No.	Name	Usage (June)	Usage (July)	Proportion (June)
1	Omega	95	84	0.24
2	Romanson	86	85	0.22
3	Rado	74	75	0.19
4	Citizen	57	66	0.14
5	Q&Q	49	72	0.12
6	GP	39	49	0.10

There are as many as 5 criteria that become the benchmark of this marketing. These are C1 (comfort), C2 (practice), C3 (price), C4 (quality), C5 (design).Table 2 describes the distribution of answers from respondents based on listed criteria. 400 people are ready to agree to be respondents to run the process of market share analysis. There are six brands of watches that are in comparison with 5 criteria.

Table 2. Respondents' data

No.	Name	C1	C2	C3	C4	C5	Total
1	Omega	18	28	20	18	11	95
2	Roman	18	26	14	18	10	86
3	Rado	20	18	12	15	9	74
4	Citizen	17	9	10	13	8	57
5	Q&Q	15	7	7	12	8	49
6	GP	12	6	5	12	4	39

Based on the displacement data collected over the course of a period, each watch company gets acquisitions from other brands. Table 3 is a data transfer performed by other brands against existing watches brands.

Table 3. Customer acquisition data for one period & loss data on various watches brands

No.	Name	Om	Rom	Rd	Ctz	Q	Gp	Acq
1	Omega	0	8	7	4	3	3	25
2	Romans	8	0	8	2	2	1	21
3	Rado	7	5	0	3	2	0	17
4	Citizen	3	5	2	0	3	2	15
5	Q&Q	7	4	0	2	0	1	14
6	GP	3	2	0	2	2	0	9
	Loss	28	24	17	13	12	7	

Table 4 is the result of the acquisition and loss of consumers for each watches company over a period. **B** = before where this is the beginning of period while **N** = New where this is the next period or the end of the earlier period. Gp achieved an increase over the previous period. It gets 9 new acquisitions and 7 consumer losses, resulting in an increase in purchases by 2 consumers.

Table 4. Brand transition for one period

No.	Name	B	Ac	Lo	N
1	Omega	95	25	28	92
2	Romanson	86	21	24	83
3	Rado	74	17	17	74
4	Citizen	57	15	13	59
5	Q&Q	49	14	12	51
6	GP	39	9	7	41

Table 5 states that not all consumers in the past period did the brand shifting, some among those who did not make a move. There are as many as 305 that still remain in the old company, Omega =70, Romanson =65, Rado =57, Citizen =42 Q&Q =35, GP =30.

Table 5. Brand transition data

No.	Name	Om	Rom	Rd	Ctz	Q	Gp	Rn
1	Om	70	8	7	4	3	3	95
2	Rom	8	65	8	2	2	1	86
3	Rado	7	5	57	3	2	0	74
4	Citi	3	5	2	42	3	2	57
5	Q&Q	7	4	0	2	35	1	49
6	Gp	3	2	0	2	2	30	39
	Rb	98	89	74	55	47	37	400

$$\text{Omega} = \frac{70}{95} \times 100\% = 73.68\%,$$
$$\text{Romanson} = \frac{65}{86} \times 100\% = 75.58\%$$
$$\text{Rado} = \frac{57}{74} \times 100\% = 77.03\%,$$
$$\text{Citizen} = \frac{42}{57} \times 100\% = 73.68\%$$
$$\text{Q\&}Q = \frac{35}{49} \times 100\% = 71.43\%,$$
$$\text{GP} = \frac{30}{39} \times 100\% = 76.92\%$$

The following percentage calculation results explain some companies lose the market share, and some just get it. Omega (-3.15%) and, *and* romanson (-3.49%)have decreased in the next period. Q&Q (4.10%), GP(5.12%) and Citizen(3.51%) have increased in the new period. Rado has stabled in the next period.

$$\text{Omega} = \frac{95-98}{95} \times 100\% = -3.15\%, \text{Romanson} = \frac{86-89}{86} \times 100\% = -3.49\%$$

$$\text{Rado} = \frac{74-74}{74} \times 100\% = 0\%, \text{Citizen} = \frac{57-55}{57} \times 100\% = 3.51\%$$

$$\text{Q\&}Q = \frac{49-47}{49} \times 100\% = 4.10\%, \text{GP} = \frac{39-37}{39} \times 100\% = 5.12\%$$

The calculation of market share can be done after the data acquisition and loss are met well. There are three periods as the comparative materials of the market share. There are five variables in this calculation, MS1, MS2, MS3, MS4, MS5 represent the market share period one, two, three, four and five respectively. The calculation of the matrix to obtain market share can be seen as follows.

$$D = \begin{bmatrix} 70 & 8 & 7 & 4 & 3 & 3 \\ 8 & 65 & 8 & 2 & 2 & 1 \\ 7 & 5 & 57 & 3 & 2 & 0 \\ 3 & 5 & 2 & 42 & 3 & 2 \\ 7 & 4 & 0 & 2 & 35 & 1 \\ 3 & 2 & 0 & 2 & 2 & 30 \end{bmatrix}, Rb = \begin{bmatrix} 98 \\ 89 \\ 74 \\ 55 \\ 47 \\ 37 \end{bmatrix}$$

The following formula is used to the transition probabilities.

$$TP(colum, row) = \frac{D(coloum, row)}{Rb(row)}$$

That is $TP(2,1) = \frac{D(2,1)}{Rb(1)} = \frac{8}{98} = 0.08$. So, we get

$$TP = \begin{bmatrix} 0.71 & 0.08 & 0.07 & 0.04 & 0.03 & 0.03 \\ 0.09 & 0.73 & 0.09 & 0.02 & 0.02 & 0.01 \\ 0.09 & 0.07 & 0.77 & 0.04 & 0.03 & 0 \\ 0.05 & 0.09 & 0.04 & 0.76 & 0.05 & 0.04 \\ 0.15 & 0.09 & 0 & 0.04 & 0.74 & 0.02 \\ 0.08 & 0.05 & 0 & 0.05 & 0.05 & 0.81 \end{bmatrix}$$

This calculation starts with M (1, 1) to M (6, 6). The result obtained is the transition probability (TP) of company at a given period as seen in earlier matrix.

$$MS1 = \begin{bmatrix} 0.24 \\ 0.22 \\ 0.19 \\ 0.14 \\ 0.12 \\ 0.10 \end{bmatrix}$$

$$MS2 = \begin{bmatrix} 0.71 & 0.08 & 0.07 & 0.04 & 0.03 & 0.03 \\ 0.09 & 0.73 & 0.09 & 0.02 & 0.02 & 0.01 \\ 0.09 & 0.07 & 0.77 & 0.04 & 0.03 & 0 \\ 0.05 & 0.09 & 0.04 & 0.76 & 0.05 & 0.04 \\ 0.15 & 0.09 & 0 & 0.04 & 0.74 & 0.02 \\ 0.08 & 0.05 & 0 & 0.05 & 0.05 & 0.81 \end{bmatrix} \begin{bmatrix} 0.24 \\ 0.22 \\ 0.19 \\ 0.14 \\ 0.12 \\ 0.10 \end{bmatrix} = \begin{bmatrix} 0.21 \\ 0.21 \\ 0.19 \\ 0.16 \\ 0.18 \\ 0.12 \end{bmatrix}$$

MS3= TP.MS2
MS4= TP.MS3, and so on.

Table 6. Comparison of market share value in five periods

Name	MS1	MS2	MS3	MS4	MS5
Omega	0.24	0.21	0.19	0.18	0.17
Romans	0.22	0.21	0.20	0.19	0.18
Rado	0.19	0.19	0.19	0.19	0.19
Citizen	0.14	0.16	0.17	0.18	0.19
Q&Q	0.12	0.18	0.19	0.20	0.20
GP	0.10	0.12	0.14	0.16	0.17

Table 7. Comparison for the result in Table 6.(column 3) with actual data

Name	MS2	Usage	Usage (actual)	Error
Omega	0.21	84	84	0
Romans	0.21	84	85	0
Rado	0.19	76	75	-1
Citizen	0.16	64	66	2
Q&Q	0.18	72	72	0
GP	0.12	48	49	1

Figure 1. Column chart showing the comparison for the result in Table 6. (column 3) with actual data

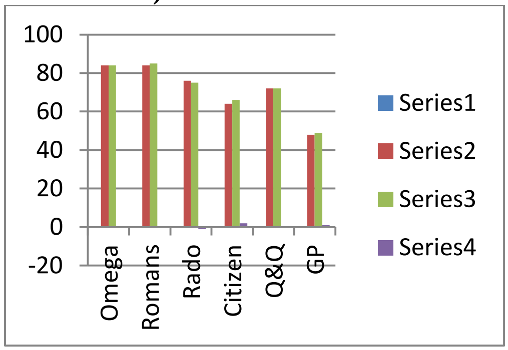
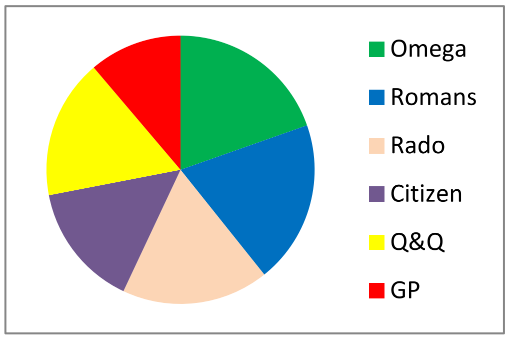


Figure 2. Pie chart of comparison for the result in Table 6.(column 3) with actual data Table 7.



The results of Markov chain can be used to analyze marketing techniques that can undertake company. A company can think of the next strategies based on the customer's acquisition and estimation. Although these results are not necessarily accurate, this can at least be a motivation for developing future promotional techniques.

4. Conclusions and Future Works

In this work, Markov chain is used to get this method can predict the market share in the future so that company can optimize promotion cost at the certain time and to analyze consumers' behaviors for saving cost and time for successful managing marketing problems. For further studies, this can also be applied to find the various modeling problems in real world such as behaviors of a business or economy, flow of traffic, progresses of an epidemic, a leading managerial issue for the practitioners and various computer applications and so on. Moreover, based on the detail calculation procedure, one can create computer codes such as C/C++, or JAVA, MATLAB running these codes by using actual data and information to solve general marketing problems.

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