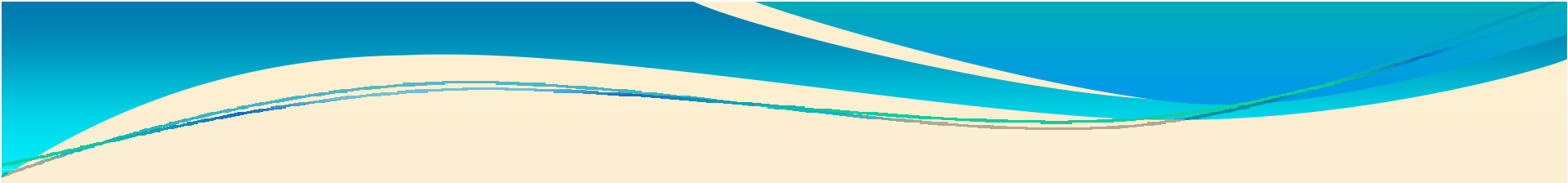


## ***NARAYANA MEDICAL COLLEGE & HOSPITAL, NELLORE – A.P***



# ***NARAYANA MEDICAL COLLEGE & HOSPITAL, NELLORE – A.P***





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*Associate professor, Dept of Hosp . Admn*

*Addl. Medical Superintendent*

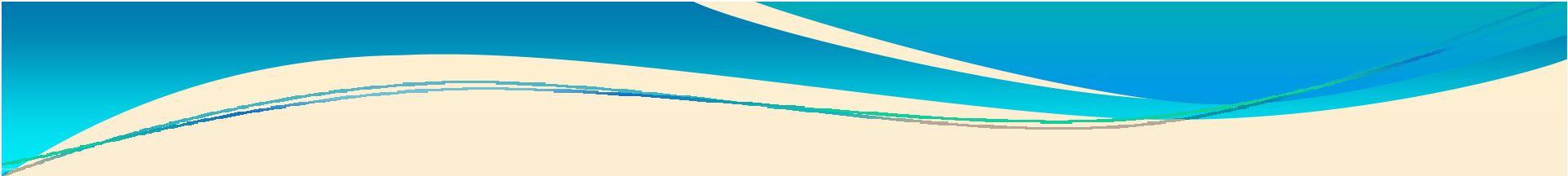
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*Ph: 09490795836*



***Application of OR technique for effective  
utilization of the service in a tertiary care  
teaching hospital***

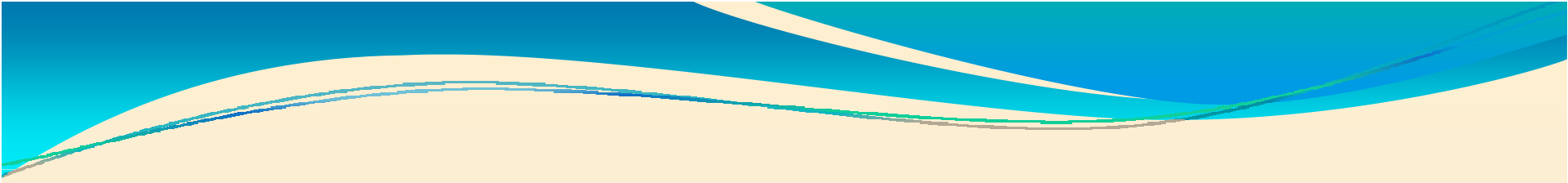


*The Operations Research (OR) can be defined as “Scientific method for providing, executing departments a quantitative basis for decisions regarding the operations under their control”.*

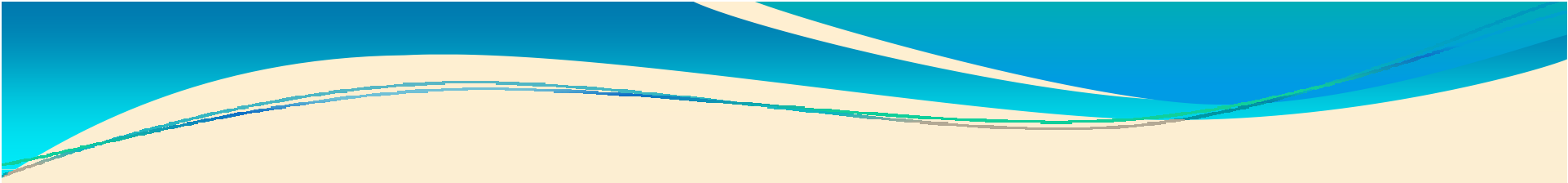
*Operational research deals with the problem of providing adequate but economical services involving unpredictable numbers and times or similar sequences.*

*Inventory control techniques like EOQ, and ABC analysis, JIT, Distribution logistics.*

*Waiting line model or queuing theory.*



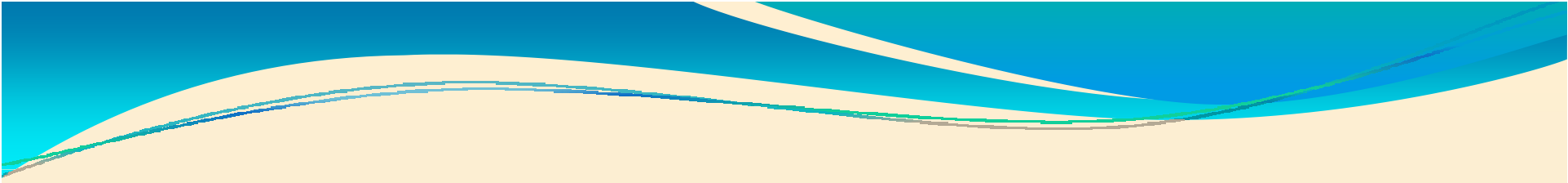
*Queuing theory is a product of mathematical research that grew largely out of the need to determine the optimum utilization of the scarce resources.*



*A queue is a waiting line, and queuing involves, dealing with items or people in sequence. Thus queuing problem consists either of determining what facilities to provide or scheduling the use of them. The cost of providing the service and the WT of users are minimized.*



*The goal of queuing analysis and its application in healthcare organizations is to “minimize costs” to the organization – both tangible and intangible. The costs that are considered are capacity costs, waiting costs, the costs of waiting space, cost to the society and the effects of loss of business to healthcare organization if patients refuse to wait and decide to go elsewhere.*



*The queuing theory as applied OR technique is utilized for the benefit of the incoming customers i.e. the patients arrived to the out patient department waiting at different registration counters (New, Old and Review OP's) wait for the service over a period of time in a day.*

## Single Channel, single phase system

Arrivals



Queue  
○○○

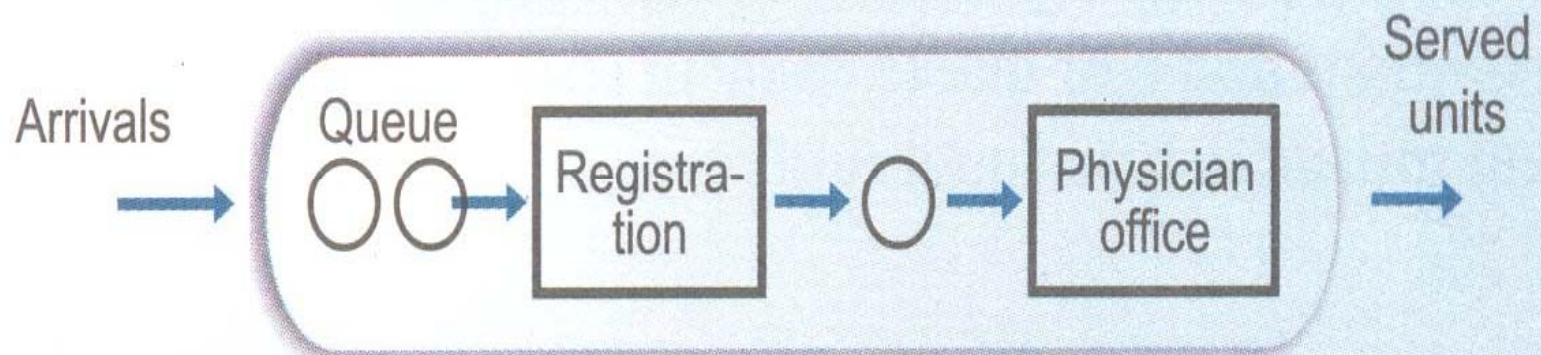


Doctor

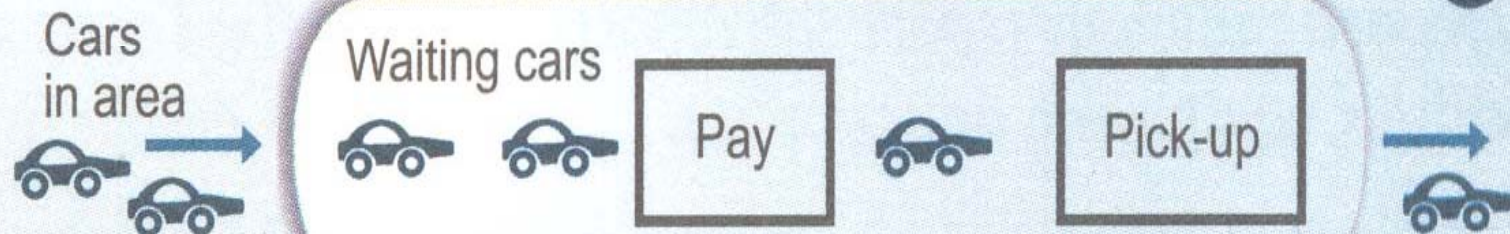
Served  
units



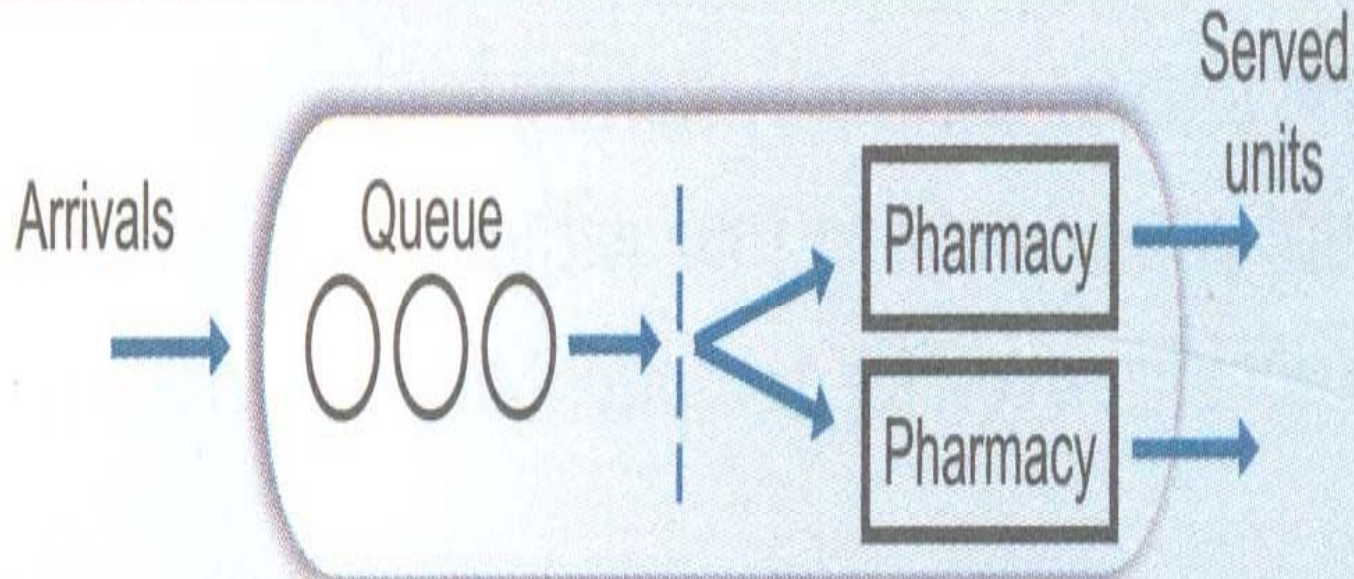
## Single Channel, multi-phase system



## McDonald's drive-through

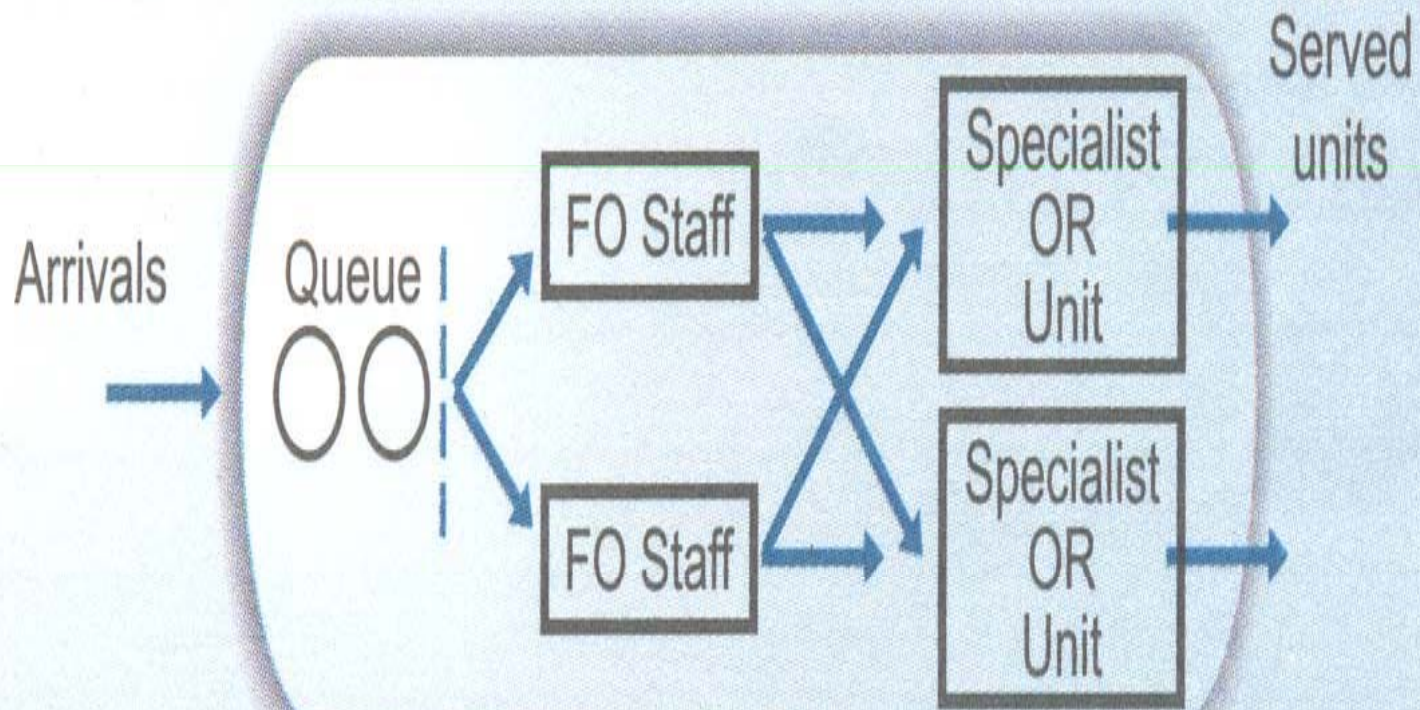


## Multi Channel, single phase system

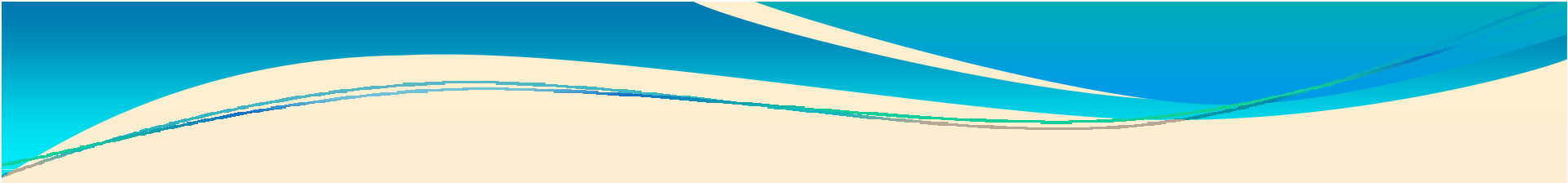


Example: Patients waiting in queue at hospital pharmacy

## Multiple Channel, multi-phase system



Example: Multi-specialty, outpatient clinic of a hospital



*The study has been done in the out patient department of a tertiary care 1000+bed teaching hospital having medical college with general broad and super specialties. Cross sectional study method is utilized for a period of one week excluding Sunday.*



*The two items of interest in study are*

- 1. The utilization of the servers or the time of the receptionist*
- 2. How long do the patients wait for the service., so that better decisions were made of the staffing and the no. of servers*



**AIM:**

*To estimate the waiting times in the queues of the out patient registration counters in a tertiary care teaching hospital and suggest the means to optimize the processing time for the patients and rationalizing the utilization of the servers for effective utilization of human resource.*



## Objectives of the study:

1. *To evaluate the QT and ST in the registration counter of OPD*
2. *To characterize the distribution of QT and ST in a week*
3. *To characterize the arrival rate at hourly intervals in a day*
4. *To identify the effective utilization of the service counters of the system*



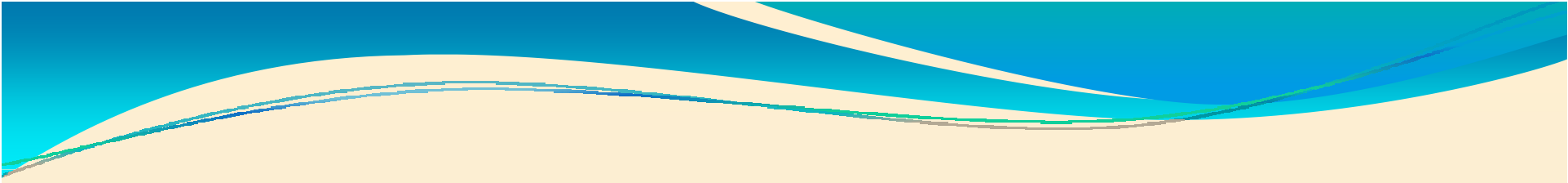
## ***Materials and Methods:***

*In this observational study, the traffic intensity of the out patients at registration counters such as arrival rate, service rate and number of servers was measured at hourly intervals. The queuing time of the patient's and the service time per each patient registration have been noted down starting from 8:00 AM to 5:00 PM every day (total of 9 hours).*

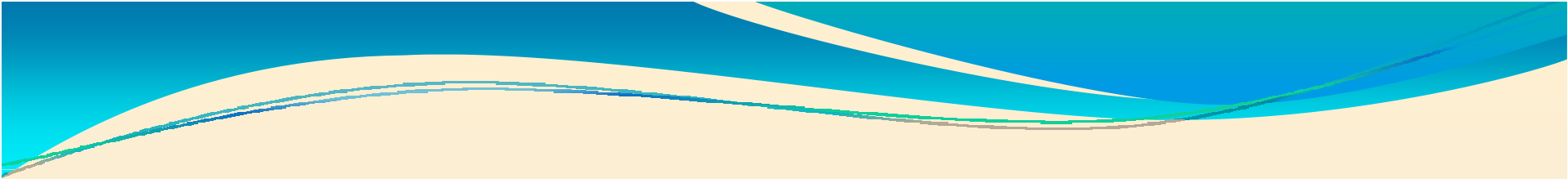


## **Limitations:**

*Study limited to one block having op registration to general specialties only. The registration is done at another two areas of the hospital, 2<sup>nd</sup> counter at 1<sup>st</sup> floor new block and 3<sup>rd</sup> area at ground floor new block.*

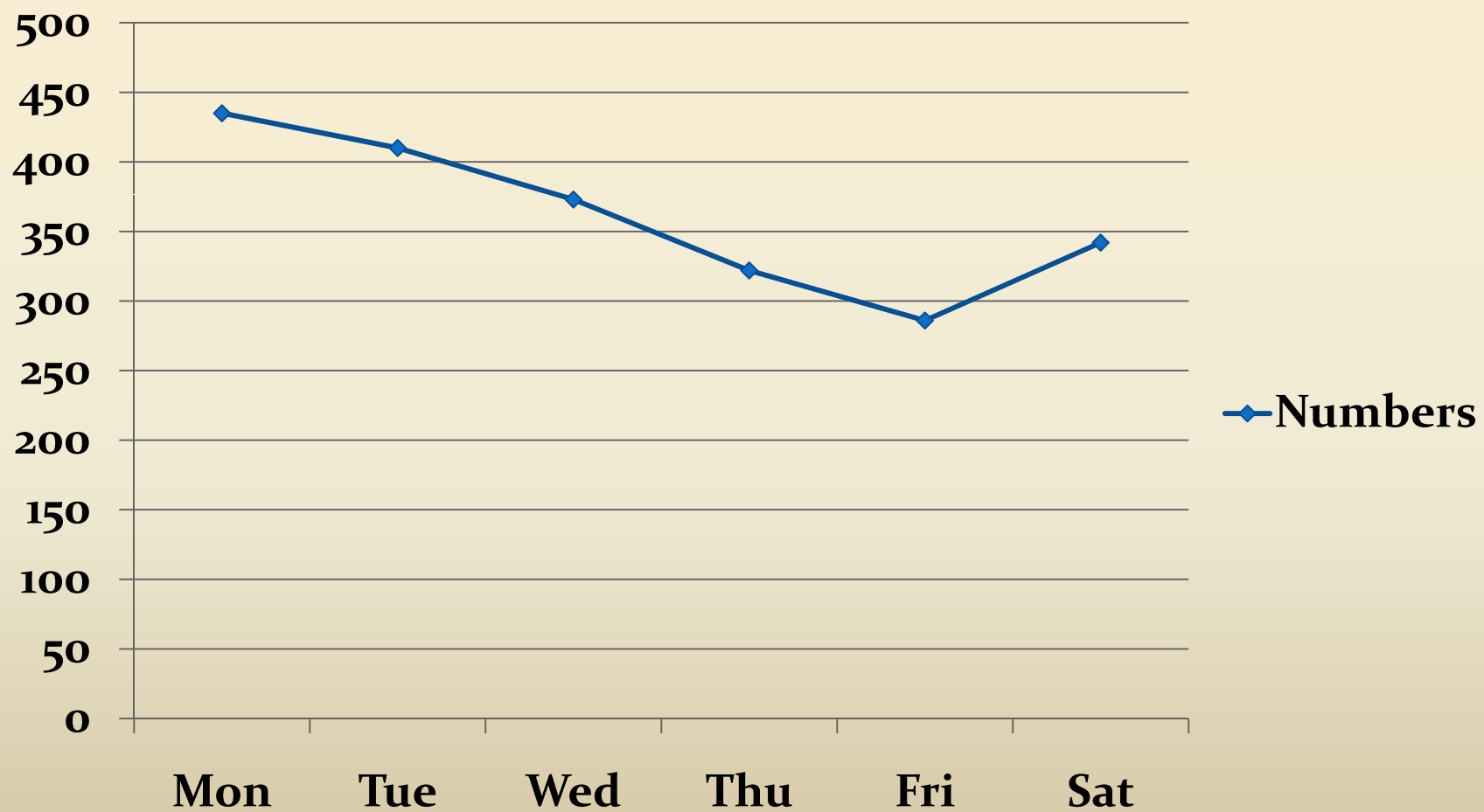


*Observational study of the cross section of patients coming to the out patient department of the General specialties covering one third of the registrations was done.*



| Day   | n    |
|-------|------|
| Mon   | 435  |
| Tue   | 410  |
| Wed   | 373  |
| Thu   | 322  |
| Fri   | 286  |
| Sat   | 342  |
| Total | 2168 |

## Arrival Pattern





## Analysis of data:

*The queue discipline is FIFO (first and first out)*

## Kendal notation; $P/Q/R: x/y/z$

*P* - Arrival rate distribution

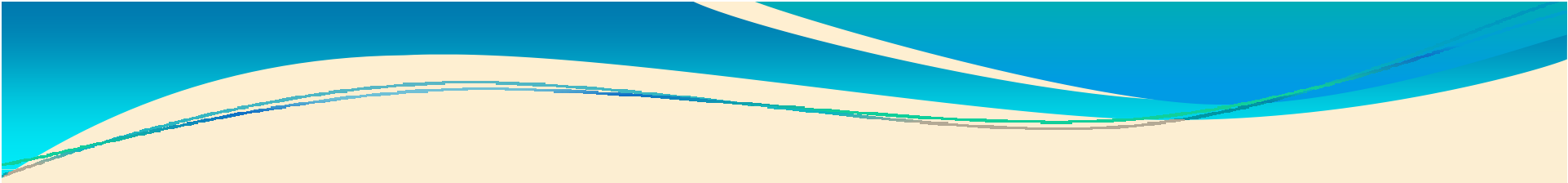
*Q* - service rate distribution

*R* - No. of servers

*X* - Service discipline

*Y* - maximum no of customers permitted in the system

*Z* - size of the calling source



## **Results and discussion:**

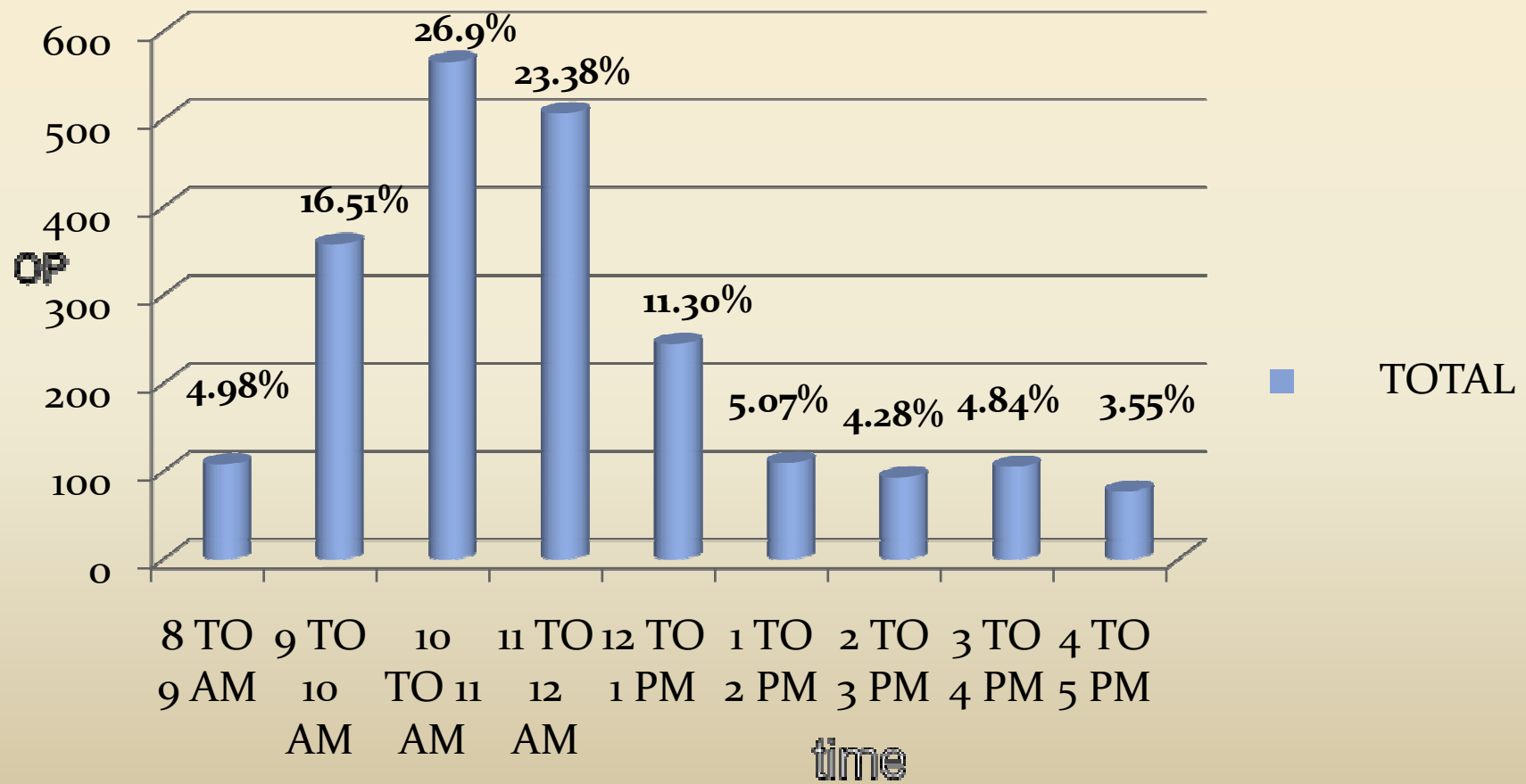
*The arrival pattern shows maximum of 77.25% during 9:00 AM to 1:00 PM, 4.98% during 8 – 9 AM, mainly of master health checkup and emergencies and 17.74% during 2 PM to 5 PM of the total registrations in the week.*

### *Arrival Pattern per hour from Mon - Sat*

| HOURS WISE   | MON        | TUE        | WED        | THU        | FRI        | SAT        | TOTAL       | PERCENTAGE |
|--------------|------------|------------|------------|------------|------------|------------|-------------|------------|
| 8 TO 9 AM    | 25         | 20         | 20         | 14         | 10         | 18         | 108         | 4.98%      |
| 9 TO 10 AM   | 85         | 72         | 42         | 45         | 44         | 70         | 358         | 16.51%     |
| 10 TO 11 AM  | 106        | 86         | 95         | 96         | 78         | 102        | 565         | 26.09%     |
| 11 TO 12 AM  | 83         | 97         | 99         | 79         | 72         | 80         | 507         | 23.38%     |
| 12 TO 1 PM   | 58         | 52         | 40         | 41         | 30         | 24         | 245         | 11.30%     |
| 1 TO 2 PM    | 24         | 30         | 15         | 16         | 15         | 10         | 110         | 5.07%      |
| 2 TO 3 PM    | 19         | 15         | 24         | 9          | 14         | 12         | 93          | 4.28%      |
| 3 TO 4 PM    | 18         | 20         | 20         | 16         | 15         | 16         | 105         | 4.84%      |
| 4 TO 5 PM    | 17         | 18         | 18         | 6          | 8          | 10         | 77          | 3.55%      |
| <b>TOTAL</b> | <b>435</b> | <b>410</b> | <b>373</b> | <b>322</b> | <b>286</b> | <b>342</b> | <b>2168</b> |            |

## Arrival pattern

### TOTAL

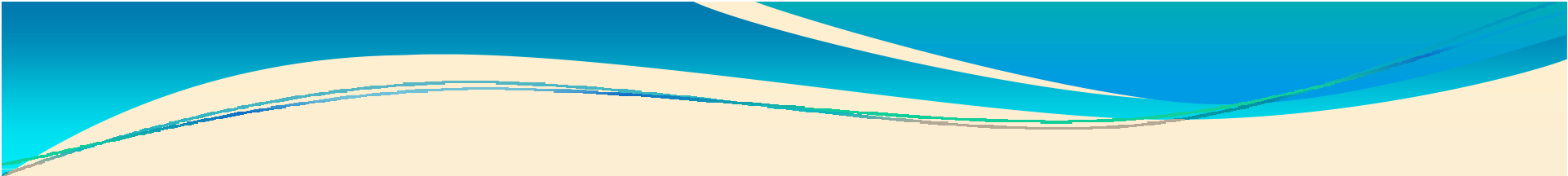


## Results and discussion:

*The data observed was presented as mean, SD, median and range for QT, ST and PT. The variations were observed during the week day were compared.*

*The total number of registrations (n=2168) for the week period reveals an arrival rate of 40.14 / hr and service rate 40.8 / hr and an average service time of 1.47 min with four service counters operating for the registration of out patients.*

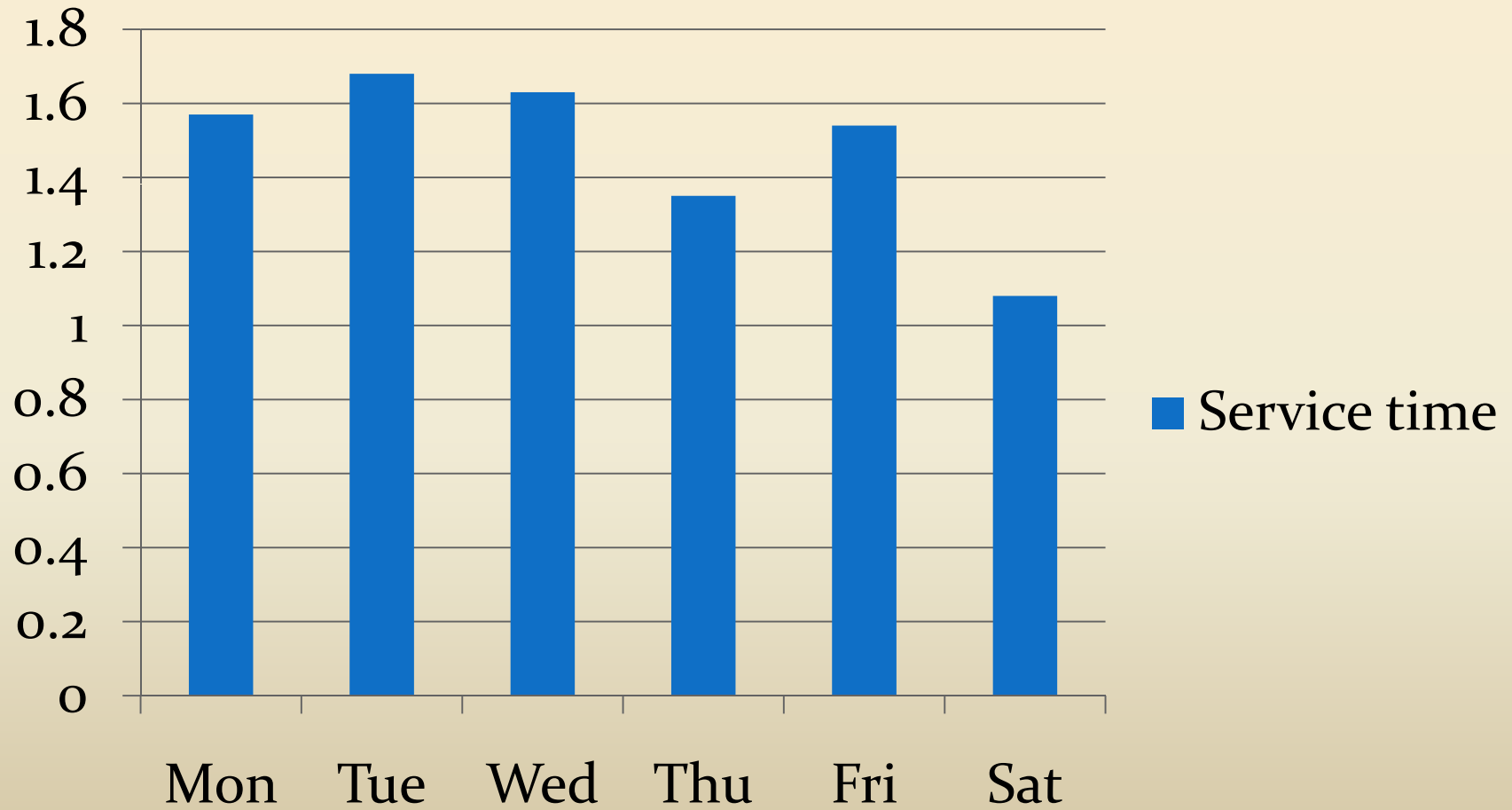
*The evaluation of QT, ST and PT shows a mean value of 1.73 mts, 2.56 mts & 3.56 minutes respectively with mean  $\pm$  SD  $1.73 \pm 2.16$ ,  $2.56 \pm 1.38$  and  $3.56 \pm 2.51$  respectively.*



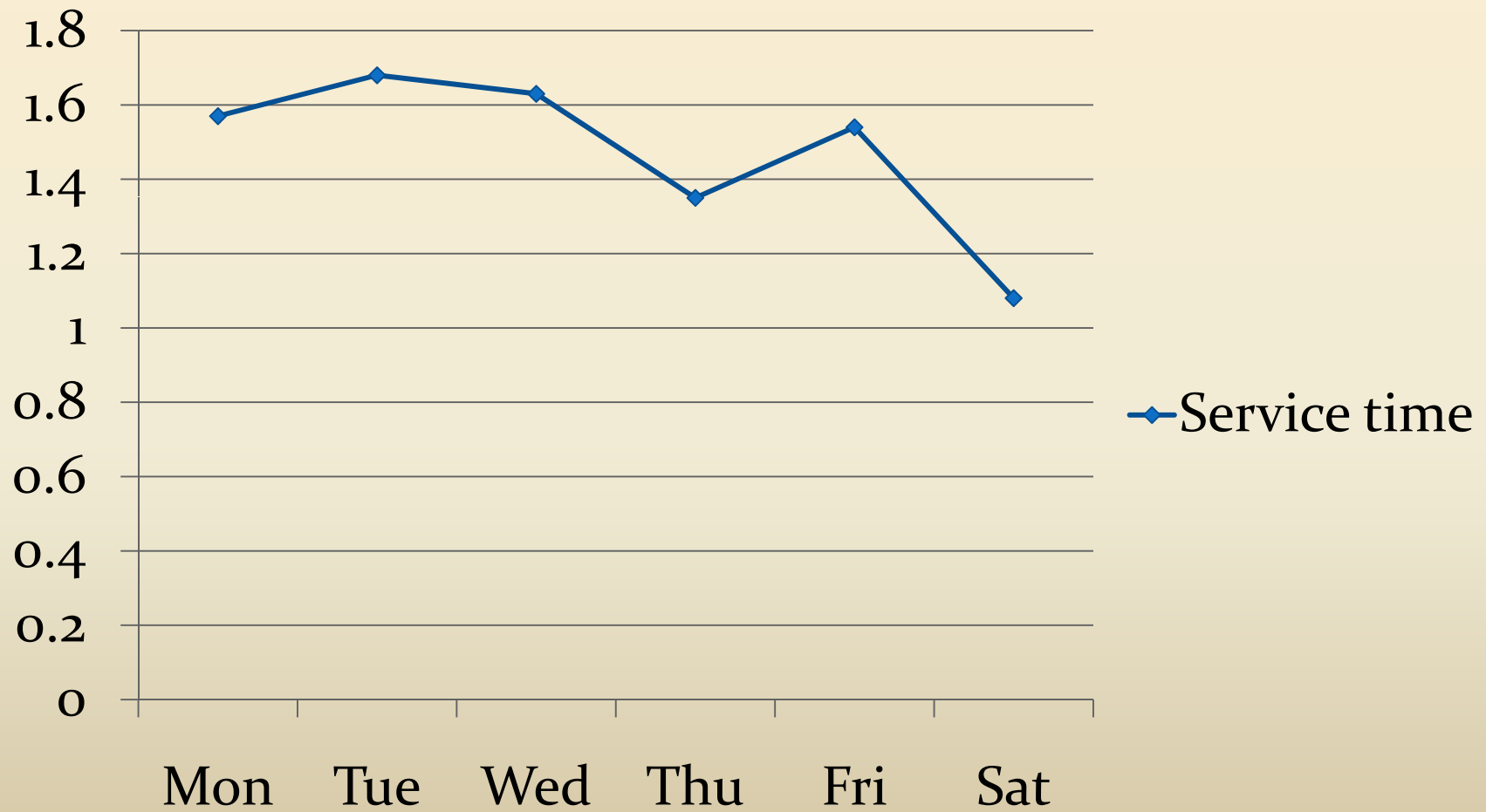
## Average Service time

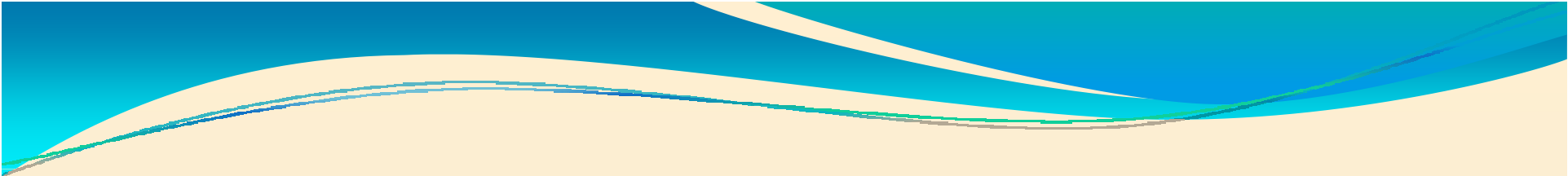
| Day | Service time |
|-----|--------------|
| Mon | 1.57         |
| Tue | 1.68         |
| Wed | 1.63         |
| Thu | 1.35         |
| Fri | 1.54         |
| Sat | 1.08         |

## Service time



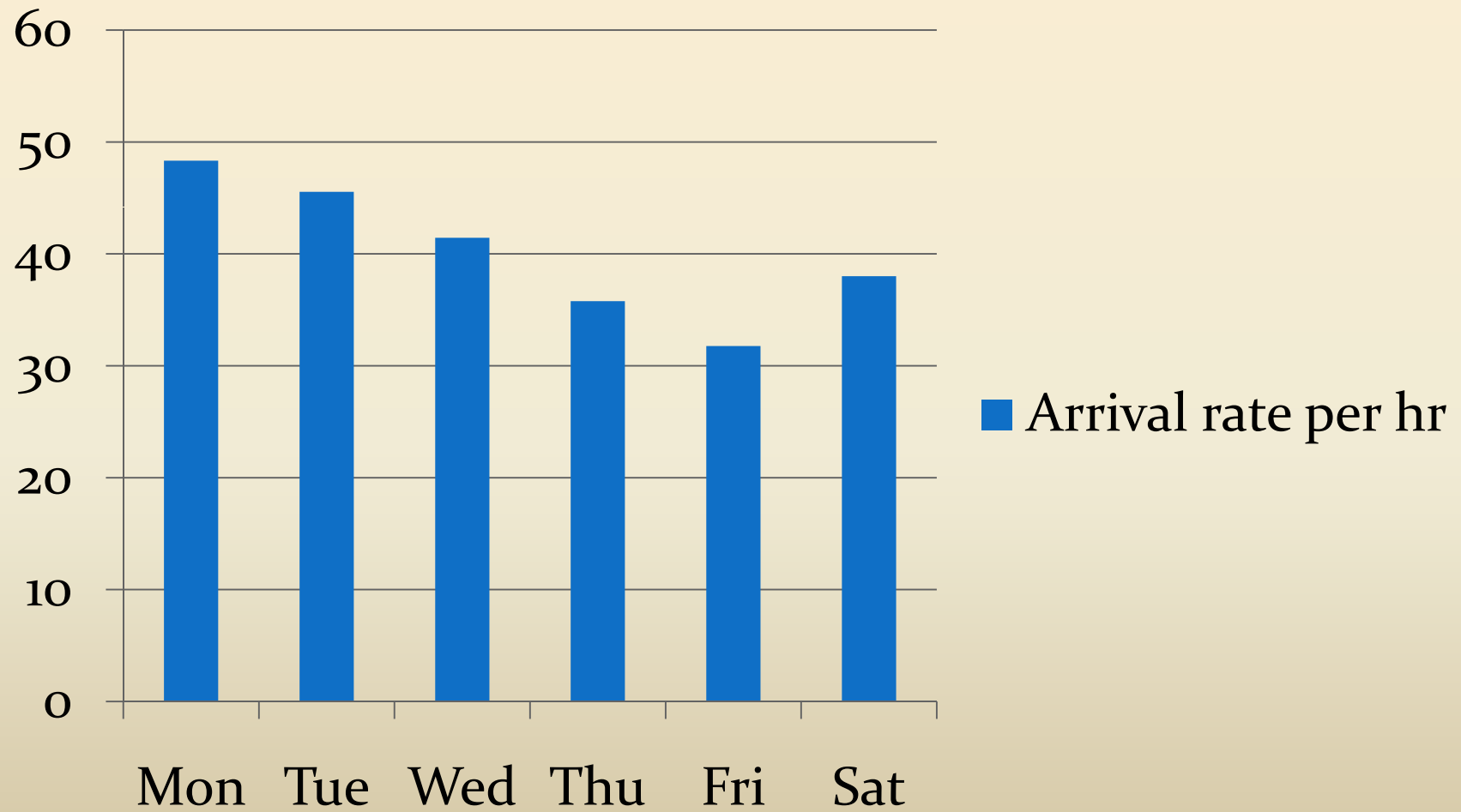
## Service time



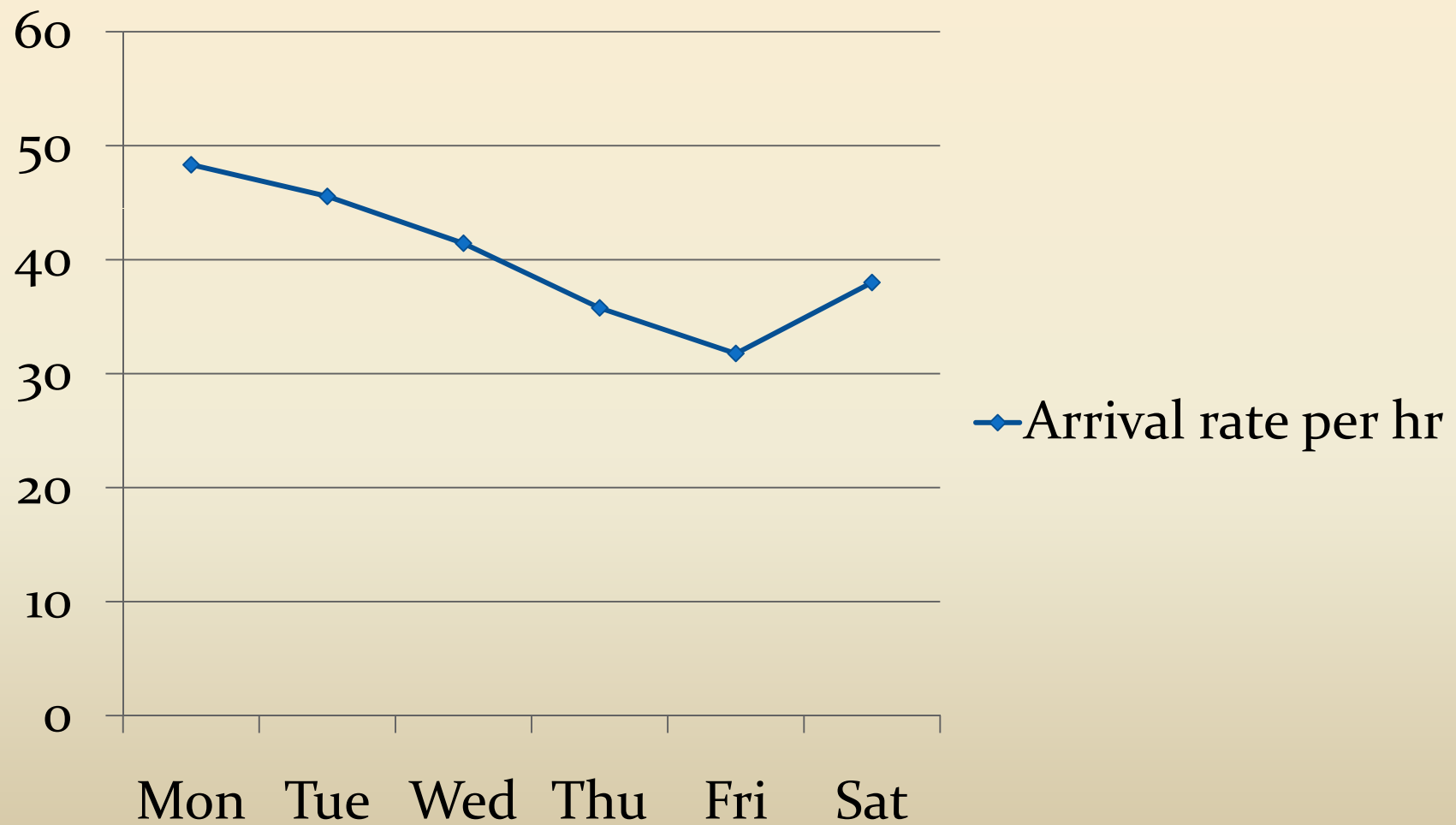


| S. No | Day      | n    | Arrival rate<br>per hr | Service<br>time | service<br>rate / hr |
|-------|----------|------|------------------------|-----------------|----------------------|
| 1     | Mon      | 435  | 48.33                  | 1.57            | 38.2                 |
| 2     | Tue      | 410  | 45.55                  | 1.68            | 35.7                 |
| 3     | Wed      | 373  | 41.44                  | 1.63            | 36.8                 |
| 4     | Thu      | 322  | 35.77                  | 1.35            | 44.4                 |
| 5     | Fri      | 286  | 31.77                  | 1.54            | 38.9                 |
| 6     | Sat      | 342  | 38                     | 1.08            | 55.5                 |
|       | All days | 2168 | 40.14                  | 1.47            | 40.8                 |

## Arrival rate per hr



## Arrival rate per hr



## *Queuing time (QT) Analysis*

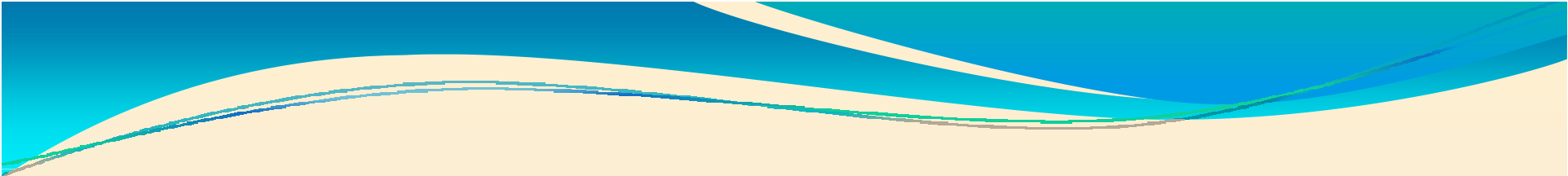
|                 | Mon<br>QT      | Tue<br>QT      | Wed<br>QT      | Thu<br>QT      | Fri<br>QT      | Sat<br>QT      |
|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| <b>Patients</b> | <b>435</b>     | <b>410</b>     | <b>373</b>     | <b>322</b>     | <b>286</b>     | <b>342</b>     |
| <b>Minimum</b>  | <b>0</b>       | <b>0</b>       | <b>0</b>       | <b>0</b>       | <b>0</b>       | <b>0</b>       |
| <b>Median</b>   | <b>1</b>       | <b>0</b>       | <b>1</b>       | <b>1</b>       | <b>0.5</b>     | <b>1</b>       |
| <b>Maximum</b>  | <b>12</b>      | <b>10</b>      | <b>12</b>      | <b>12</b>      | <b>14</b>      | <b>13</b>      |
| <b>Mean</b>     | <b>2.5</b>     | <b>2.0</b>     | <b>2.1</b>     | <b>1.3</b>     | <b>0.9</b>     | <b>1.6</b>     |
| <b>SD</b>       | <b>2.8</b>     | <b>2.2</b>     | <b>2.4</b>     | <b>1.9</b>     | <b>1.5</b>     | <b>2.2</b>     |
| <b>Range</b>    | <b>0-12</b>    | <b>0-10</b>    | <b>0-12</b>    | <b>0-12</b>    | <b>0-14</b>    | <b>0-13</b>    |
| <b>Mean±SD</b>  | <b>2.5±2.8</b> | <b>2.0±2.2</b> | <b>2.1±2.4</b> | <b>1.3±1.9</b> | <b>0.9±1.5</b> | <b>1.6±2.2</b> |

## *Service time (ST) Analysis*

|                 | Mon<br>ST      | Tue<br>ST      | Wed<br>ST      | Thu<br>ST      | Fri<br>ST      | Sat<br>ST      |
|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| <b>Patients</b> | <b>435</b>     | <b>410</b>     | <b>373</b>     | <b>322</b>     | <b>286</b>     | <b>342</b>     |
| <b>Minimum</b>  | <b>1</b>       | <b>1</b>       | <b>1</b>       | <b>1</b>       | <b>1</b>       | <b>0</b>       |
| <b>Median</b>   | <b>1</b>       | <b>1</b>       | <b>1</b>       | <b>1</b>       | <b>1</b>       | <b>1</b>       |
| <b>Maximum</b>  | <b>6</b>       | <b>6</b>       | <b>6</b>       | <b>4</b>       | <b>4</b>       | <b>7</b>       |
| <b>Mean</b>     | <b>1.6</b>     | <b>3.4</b>     | <b>3.3</b>     | <b>1.4</b>     | <b>3.1</b>     | <b>2.6</b>     |
| <b>SD</b>       | <b>0.8</b>     | <b>1.4</b>     | <b>1.4</b>     | <b>0.6</b>     | <b>2.1</b>     | <b>2.0</b>     |
| <b>Range</b>    | <b>1-6</b>     | <b>1-6</b>     | <b>1-6</b>     | <b>1-4</b>     | <b>1-4</b>     | <b>0-7</b>     |
| <b>Mean±SD</b>  | <b>1.6±0.8</b> | <b>3.4±1.4</b> | <b>3.3±1.4</b> | <b>1.4±0.6</b> | <b>3.1±2.1</b> | <b>2.6±2.0</b> |

## *Processing time (PT) Analysis*

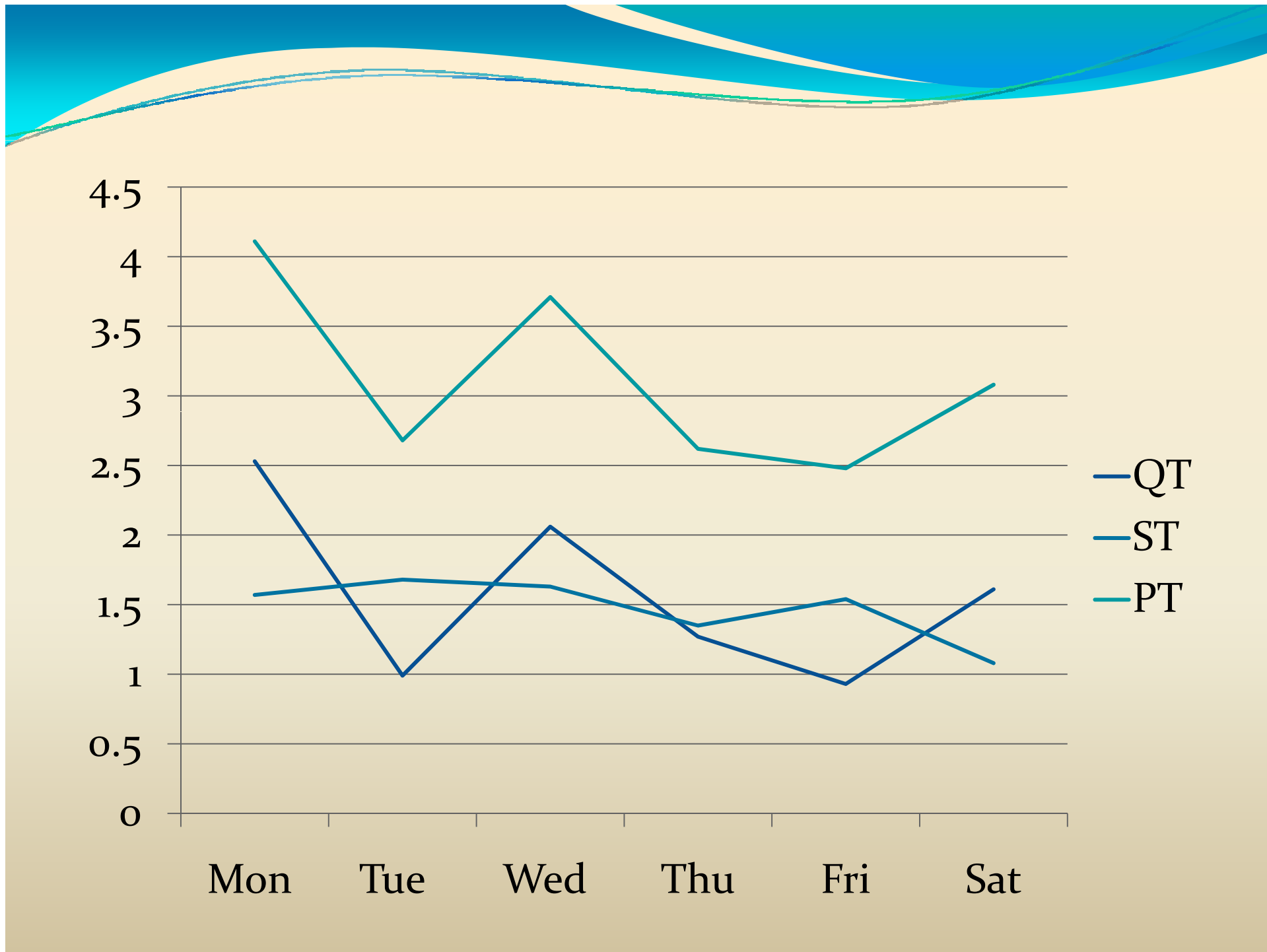
|                 | Mon<br>PT      | Tue<br>PT      | Wed<br>PT      | Thu<br>PT      | Fri<br>PT      | Sat<br>PT      |
|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| <b>Patients</b> | <b>435</b>     | <b>410</b>     | <b>373</b>     | <b>322</b>     | <b>286</b>     | <b>342</b>     |
| <b>Minimum</b>  | <b>1</b>       | <b>1</b>       | <b>1</b>       | <b>1</b>       | <b>1</b>       | <b>1</b>       |
| <b>Median</b>   | <b>3</b>       | <b>2</b>       | <b>3</b>       | <b>2</b>       | <b>2</b>       | <b>2</b>       |
| <b>Maximum</b>  | <b>14</b>      | <b>14</b>      | <b>15</b>      | <b>13</b>      | <b>16</b>      | <b>13</b>      |
| <b>Mean</b>     | <b>4.1</b>     | <b>4.9</b>     | <b>3.7</b>     | <b>2.6</b>     | <b>2.5</b>     | <b>3.6</b>     |
| <b>SD</b>       | <b>3.0</b>     | <b>2.6</b>     | <b>2.6</b>     | <b>1.9</b>     | <b>1.9</b>     | <b>3.1</b>     |
| <b>Range</b>    | <b>1-14</b>    | <b>1-14</b>    | <b>1-15</b>    | <b>1-13</b>    | <b>1-16</b>    | <b>1-13</b>    |
| <b>Mean±SD</b>  | <b>4.1±3.0</b> | <b>4.9±2.6</b> | <b>3.7±2.6</b> | <b>2.6±1.9</b> | <b>2.5±1.9</b> | <b>3.6±3.1</b> |

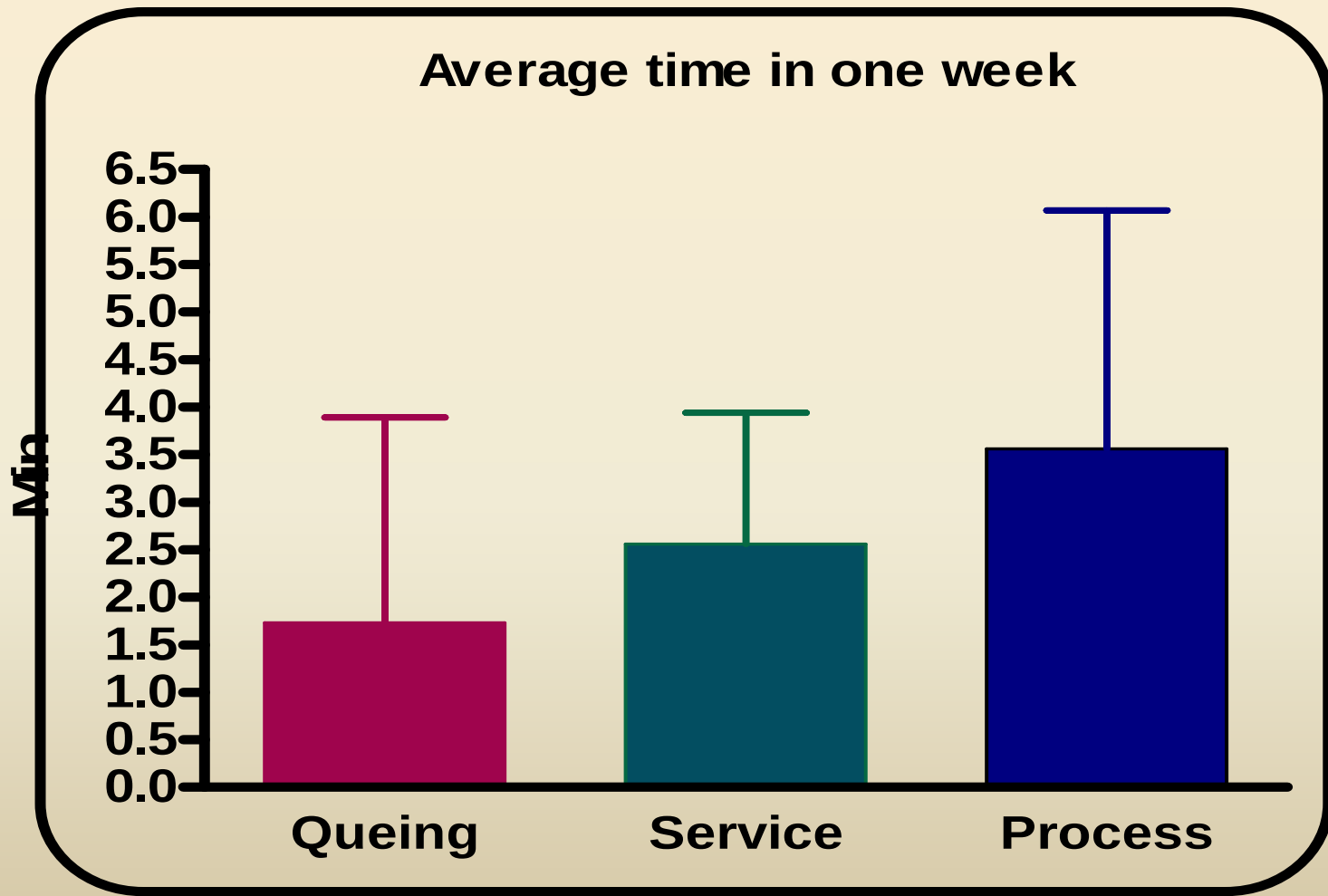


| Day | QT (mts) | ST (mts) | PT (mts) |
|-----|----------|----------|----------|
| Mon | 2.53     | 1.57     | 4.11     |
| Tue | 0.99     | 1.68     | 2.68     |
| Wed | 2.06     | 1.63     | 3.71     |
| Thu | 1.27     | 1.35     | 2.62     |
| Fri | 0.93     | 1.54     | 2.48     |
| Sat | 1.61     | 1.08     | 3.08     |

***Over all QT, ST & PT***

| <b>Over all</b> | <b>Q.T</b>       | <b>S.T</b>       | <b>P.T</b>       |
|-----------------|------------------|------------------|------------------|
| <b>n</b>        | <b>2168</b>      | <b>2168</b>      | <b>2168</b>      |
| <b>Mean</b>     | <b>1.73</b>      | <b>2.56</b>      | <b>3.56</b>      |
| <b>SD</b>       | <b>2.16</b>      | <b>1.38</b>      | <b>2.51</b>      |
| <b>median</b>   | <b>1</b>         | <b>1</b>         | <b>2</b>         |
| <b>min</b>      | <b>0</b>         | <b>1</b>         | <b>1</b>         |
| <b>max</b>      | <b>14</b>        | <b>7</b>         | <b>16</b>        |
| <b>Range</b>    | <b>0-14</b>      | <b>1-7</b>       | <b>1-16</b>      |
| <b>Mean±SD</b>  | <b>1.73±2.16</b> | <b>2.56±1.38</b> | <b>3.56±2.51</b> |







*The total registration time is 9 hours (8 AM to 5 PM) and the same has been applied in the mathematical formulas of queuing theory, in the range from 0 – 4 minutes with mean of 1.73 minutes and  $W_q$  &  $L_q$  are insignificant throughout the week. The arrival pattern per hour shows that 77.25% of registrations are occurring during 9 AM – 1 PM (4hrs) hence the analysis during the peak hours has been presented.*

## *Peak hours in Queuing time*

| PEAK HOURS   |     |     |     |     |      |     |
|--------------|-----|-----|-----|-----|------|-----|
| QUEUING TIME | MON | TUE | WED | THU | FRI  | SAT |
| N            | 335 | 303 | 280 | 262 | 221  | 274 |
| Minimum      | 0   | 0   | 0   | 0   | 0    | 0   |
| Median       | 2   | 1   | 2   | 1   | 1    | 1   |
| Maximum      | 12  | 10  | 12  | 12  | 5    | 13  |
| Mean         | 3.1 | 1.2 | 2.6 | 1.4 | 0.84 | 1.9 |
| SD           | 2.9 | 1.5 | 2.5 | 2   | 0.97 | 2.3 |



***Peak hours in Service time***

| PEAK HOURS       |     |     |     |     |     |     |
|------------------|-----|-----|-----|-----|-----|-----|
| SERVIECE<br>TIME | MO  | TU  | WE  | TH  | FR  | SA  |
| N                | 335 | 303 | 280 | 262 | 221 | 274 |
| Minimum          | 1   | 1   | 1   | 1   | 1   | 1   |
| Maximum          | 6   | 7   | 5   | 4   | 7   | 7   |
| Median           | 1   | 1   | 1   | 1   | 1   | 1   |
| Mean             | 1.5 | 1.6 | 1.6 | 1.4 | 1.5 | 1.5 |
| SD               | 0.8 | 1.0 | 0.8 | 0.6 | 0.7 | 0.9 |

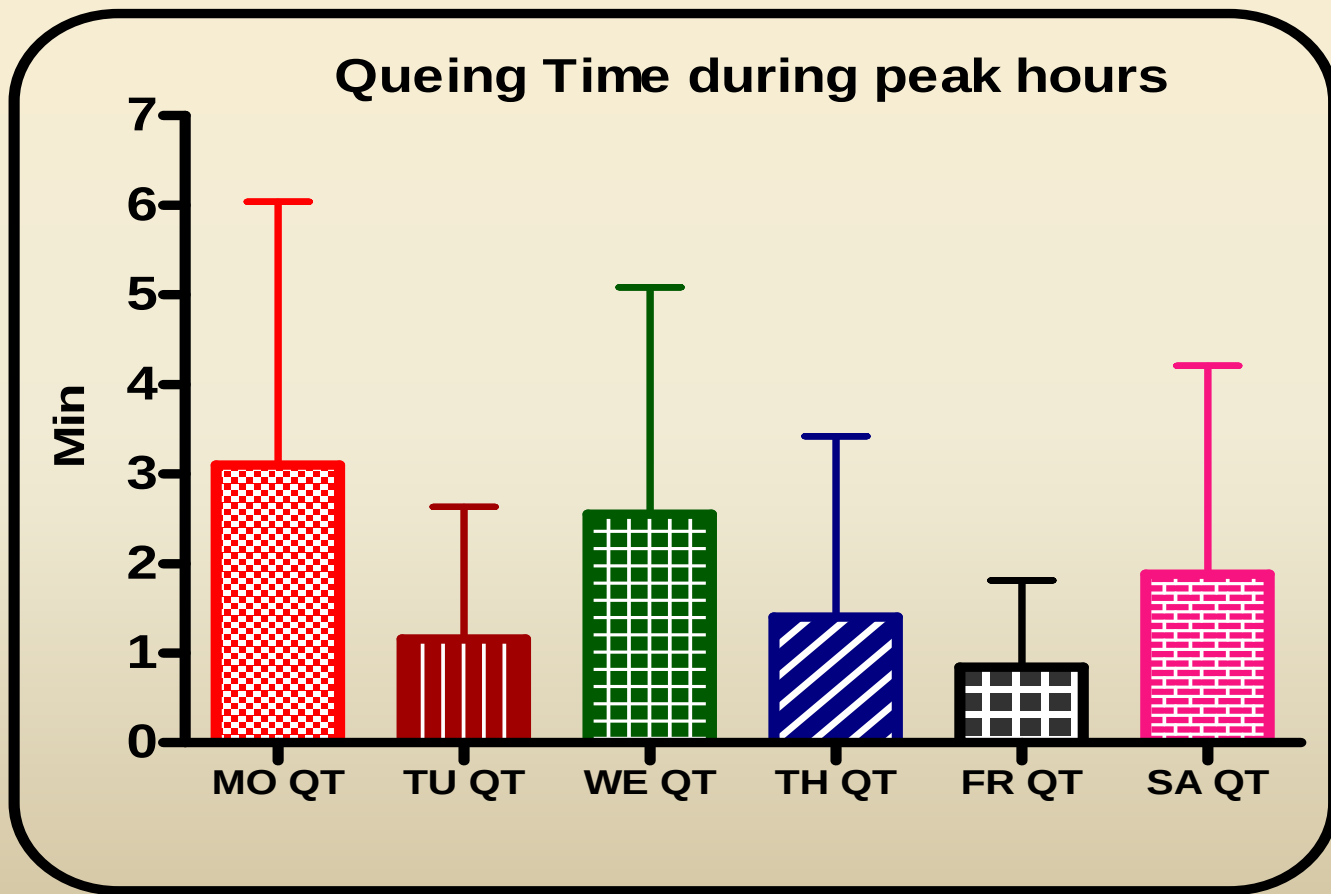
## *Peak hours in Processing time*

| PEAK HOURS      |     |     |     |     |     |     |
|-----------------|-----|-----|-----|-----|-----|-----|
| PROCESSING TIME | MON | TUE | WED | THU | FRI | SAT |
| n               | 335 | 303 | 280 | 262 | 221 | 273 |
| Minimum         | 1   | 1   | 1   | 1   | 1   | 1   |
| Maximum         | 14  | 11  | 15  | 13  | 8   | 16  |
| Median          | 4   | 2   | 3   | 2   | 2   | 3   |
| Mean            | 4.6 | 2.7 | 4.1 | 2.8 | 2.3 | 3.4 |
| SD              | 3.1 | 1.8 | 2.7 | 2   | 1.2 | 2.5 |

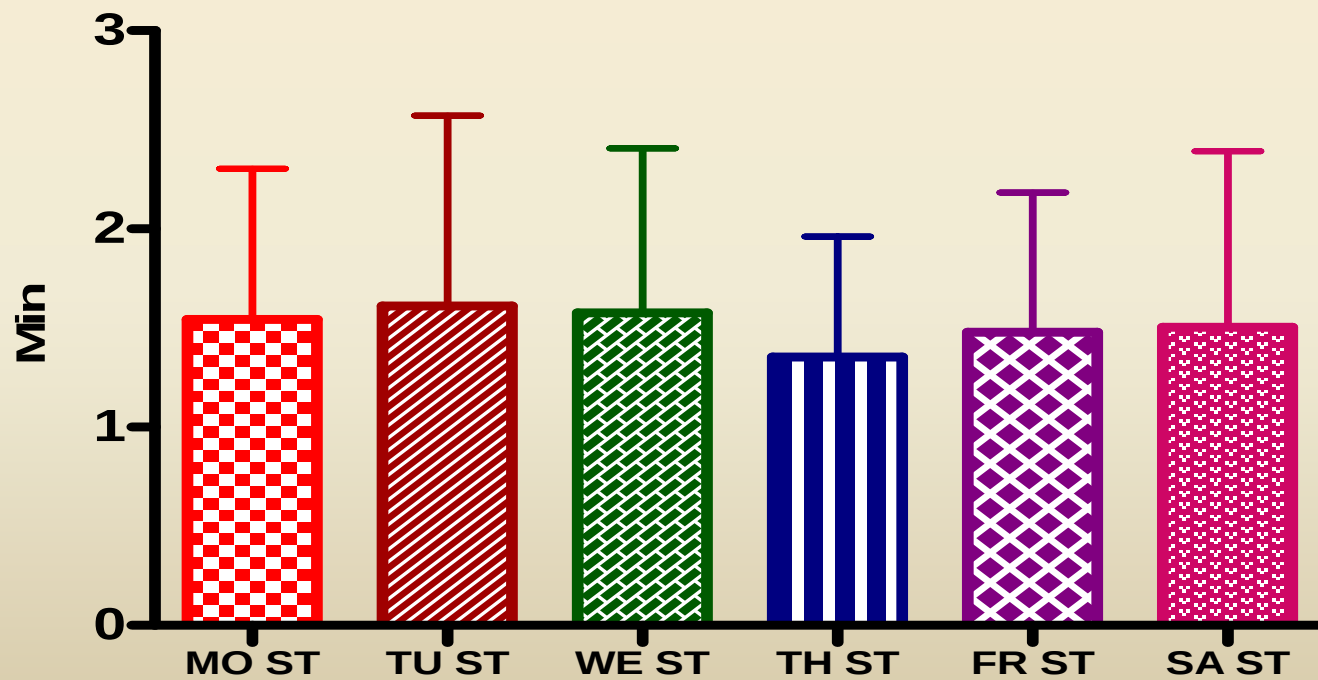


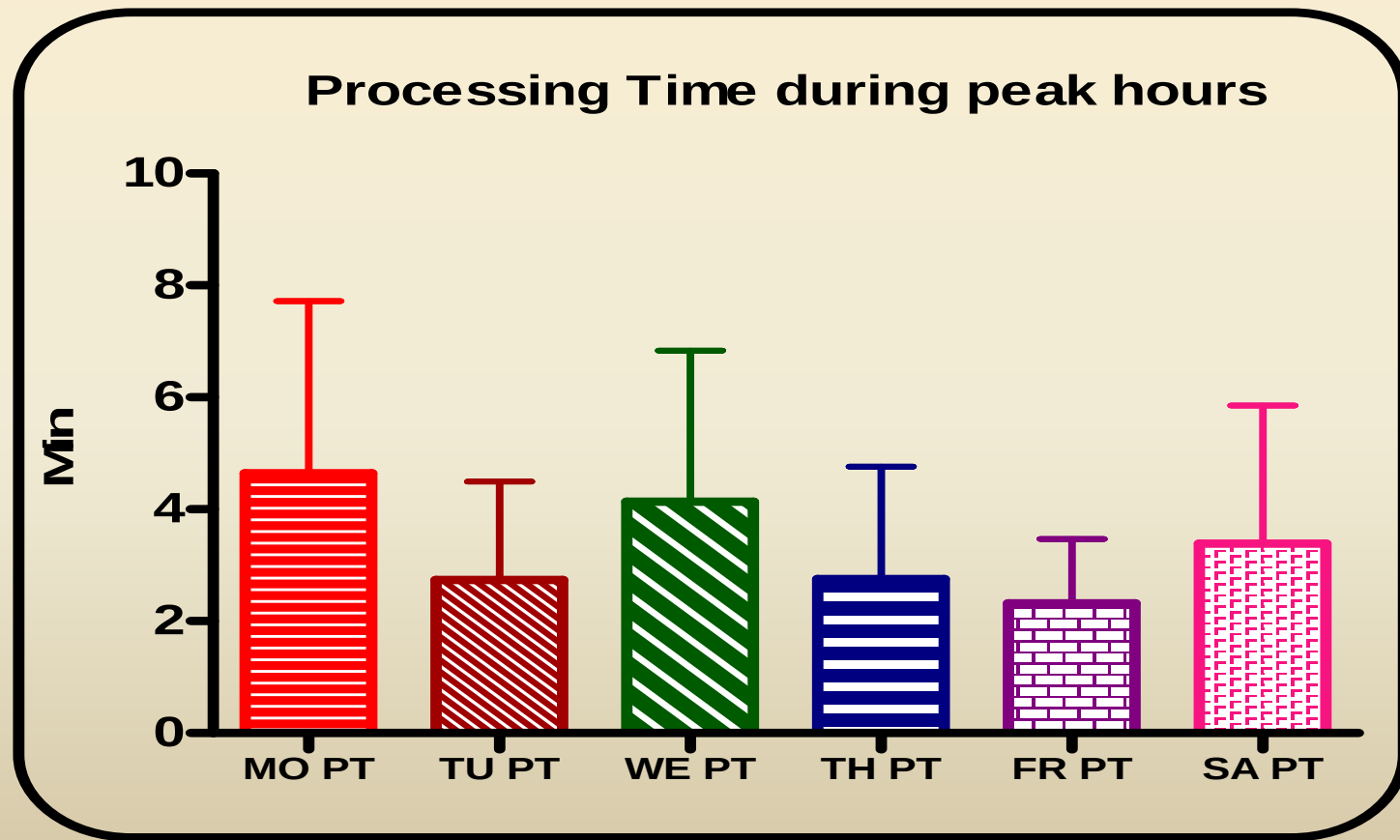
***Overall peak hours QT, ST & PT***

| Over all | QT   | ST   | PT   |
|----------|------|------|------|
| N        | 1675 | 1675 | 1675 |
| MIN      | 0    | 1    | 1    |
| MEDIAN   | 2    | 1    | 2    |
| MAXIMUM  | 13   | 7    | 17   |
| MEAN     | 1.84 | 1.51 | 3.31 |
| SD       | 2.02 | 0.8  | 2.21 |



Service Time during peak hours





## Conclusions and recommendations;

*The findings revealed that the mean of queuing time and service time are 1.73 – 2.56 minutes shows that service is given within in reasonable time as four counters are in operation ( $c=4$ ).*

*Four counters be in place during peak hours from 9 AM to 1 PM and in the after noon 1 or 2 reception is be utilized for other jobs of OPD.*

*There is a need to concentrate at OPD during period for four hours from 9 am to 1 afternoon for guiding the patients to various departments.*



*The availability of doctors in the OP cabins needs to be ensured from 9 am onwards.*

*It is observed that the QT range from 0-14 min's and a standard of ST is 1-7 mts during the a week study period.*

*The individual reasons for specific delays needs to be identified for the day and to be attended for the specific problem like hard ware issues, non availability of the receptionist etc.*



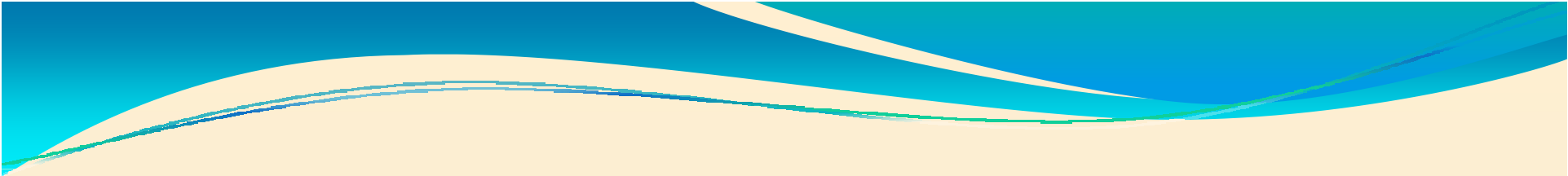
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## References:

- *On the application of queuing theory for analysis of twin date, Twin research, volume 3, No 2 1 June 2000 pp. 92/98 (7) Australian Academic press Kuravsky, levs; malykh, sergey B.2*
- *Encyclopaedia Britannica article*
- *Modeling a health care system as a queuing network the care of a Belgian hospital*  
*Stefan creemen & more R lam treehts*
- *Vikas singh, 2006 use of queuing models in health care the selected works*
- *Queuing theory & computer networking by Ethan Markowitz, eHow*
- *B NET business*
- *Encyclopaedia Britannica eb.com dated 22/7/2010*
- *Operational research by pannersalvam chapter on queueing theory (p-*
- *Scientific proceedings of the workshop on OR at AIIMS in Aug ,2009.*
- *Sampling queuing theory tools you can use in healthcare by jeff Johnson, PD, North Colorado medical centre , Colorado .*



*Thank you all*

MONDAY  
 (Arrival rate  $\lambda = 48$  /hr }  $c=4$  This is in the model of  $(M/M/c):GD/\infty$   
 Service rate  $\mu = 38$  /hr }  
 $\rho = \frac{\lambda}{c\mu} = \frac{48}{4 \times 38} = 1.26$

$$P_n = \frac{\phi^n}{n!} P_0 \quad 0 \leq n \leq c$$

$$= \frac{\phi^n}{c^{n-c} c!} P_0 \quad n > c \Rightarrow \text{Total no patients in the } \phi = \frac{\phi^{c+1}}{(c-1)!(c-\phi)^2} P_0$$

$$P_0 = \left\{ \sum_{n=0}^{c-1} \frac{\phi^n}{n!} + \frac{\phi^c}{c! [1 - \frac{\phi}{c}]} \right\}^{-1} = \left\{ \sum_{n=0}^3 \frac{(1.26)^n}{n!} + \frac{(1.26)^4}{4! [1 - \frac{1.26}{4}]} \right\}^{-1}$$

$$\Rightarrow \left[ \frac{(1.26)^0}{0!} + \frac{(1.26)^1}{1!} + \frac{(1.26)^2}{2!} + \frac{(1.26)^3}{3!} + \frac{2.52}{24 [1 - \frac{1.26}{4}]} \right]^{-1}$$

$$\Rightarrow \left[ 1 + \frac{1.26}{1} + \frac{1.587}{2} + \frac{2}{6} + \frac{2.52}{24 [1 - \frac{1.26}{4}]} \right]^{-1} \Rightarrow \left[ 1 + 1.26 + 0.79 + 0.33 + \frac{2.52}{16.44} \right]^{-1}$$

$$\Rightarrow [1 + 1.26 + 0.79 + 0.33 + 0.153]^{-1} = [3.53]^{-1} = 0.283 \quad \therefore P_0 = 0.283$$

Total no of patients in the queue  $= \frac{(1.26)^c}{2! (1.26)} P_0 = \frac{3.17}{48} P_0 = 0.0704 = 0.07 \times 0.283$   
 " " in the system  $L_s = \frac{\phi}{1-\phi} = \frac{1.26}{1-1.26} = 0.019$   
 $L_s = L_q + \phi = 0.019 + 1.26 = 1.279$

$$\therefore W_q = \frac{L_q}{\lambda} = \frac{0.019}{48} = 0.00039$$

$$W_s = W_q + \frac{1}{\mu} = 0.00039 + \frac{1}{38} = 0.00039 + 0.026 = 0.0267$$

( $\therefore$  Average waiting number of patients in the queue  $L_q = 0.019$   
 " " " " in the system  $L_s = 1.279$ )

Average waiting time per patient in the queue  $W_q = 0.00039$  /hr  
 " " " " in the system  $W_s = 0.0267$  /hr)

$$P_0 = \left\{ \sum_{n=0}^{c-1} \frac{\phi^n}{n!} + \frac{\phi^c}{c! [1 - \frac{\phi}{c}]} \right\}^{-1} \quad L_s = L_q + \phi$$

$$\checkmark L_q = \frac{\phi^{c+1}}{(c-1)!(c-\phi)^2} P_0 \quad W_q = \frac{L_q}{\lambda} \quad W_s = W_q + \frac{1}{\mu}$$