AN ANALYSIS OF SOFTWARE INDUSTRY IN LAHORE USING QUEUING TECHNIQUE

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1. INTRODUCTION

In the last two decades, IT revolution came into limelight and software industry was the main force of this revolution. Software products and services are moulding the world with every passing day. Rapid inventions and innovations are the corner stone of software industry, which has eliminated the geographical boundaries of knowledge and technology. It is also a source of free flow of information and expertise. Communication technology and liberalization are the foundations of software development.

2. AIMS AND OBJECTIVES

The present study is an effort to analyze conditions prevailing in software industry of Lahore with focus upon the following aspects.

- skills and techniques practiced and required in SWI
- organizational structure, monitoring and appraisal methods
- Problems of retention and absenteeism.
- productivity, efficiency and capacity utilization with the help of operational research tools and aligning it with organizational structure

3. THEORETICAL FRAMEWORK

There are two popular techniques i.e. mathematical programming and Cobb-Douglas production function to analyse the problem of efficiency in utilization of resources or optimization. But these methods had many limitations as in mathematical programming if there are 'n' related quantifiable decisions to be made they are represented as decision variables whose respective values are to be determined The mathematical model might say to choose values of the decision variables so as to maximize the objective function subject to specified constraints. Determining the appropriate values of the decision variables is critical and challenging part of the model building process. Gathering the relevant data is frequently difficult. Therefore, the values assigned to the parameters are the rough estimates. It is important to analyse how the solution may change if the values assigned to the parameters were changed. This is referred to as sensitivity analysis.

The present study uses Queuing Technique for analysis of the Software houses. Queuing Analysis solves and evaluates system performance and costs. It assumes that customers requiring service are generated over time by an input source.

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The queuing system has major elements including a customer population, a queue, and servers. Customer population can be limited or unlimited (infinity) with a specified arrival pattern (distribution); queue can be of limited or unlimited length; and multiple servers are assumed to be identical with a specified service time distribution.

4. QUEUING MODEL

Queuing theory involves the Mathematical study of queues or waiting lines. The formation of waiting lines is a common phenomenon that occurs when the demand for a service exceeds the current capacity to provide that service. Decision regarding the amount of capacity to provide a service is always difficult. It is often difficult to predict accurately when units will arrive to seek the service and how much service is provided at a point of time. The queuing theory does not solve the problem but it provides vital information required for such decisions.

The basic process assumes that customer requiring service are generated over time by input source (population size) and join the queue (maximum permissible number of customers that a system can contain) and at a certain time service is provided to the member of the queue by some queue discipline (FIFO, Random) and required service is provided through a service mechanism (servers).

The model used in this analysis is M/G/S(General) and it assumes that all service times are independent and identically distributed using normal distribution which assumes service requirements of customers are quite similar and inter arrival time distribution is exponential which assumes that arrivals occur randomly.

M/Ms//N(Finite population, λ is the individual arrival rate)

$$P_0 = 1 / \left[{}^{s-1}\Sigma_{n=o} \frac{\gamma N!}{n!(N-n)!} + {}^{N}\Sigma_{n=s} \frac{\gamma^n N!}{s!(N-n)!S^{n-s}} \right]$$

$$P_n = p(n-1)\ \gamma\ (N-n+1)/n \text{ for } n<=s$$

$$Lq = {}^{N}\Sigma_{n=s+1}(n-s)p(n) \qquad L = {}^{N}\Sigma_{n=1}\ nP(n)$$

$$Wq = Lq / \lambda / (N-L) \qquad W = L / \lambda / (N-L)$$

M/Ms/K (Finite Queue)

$$P0 = 1 / \left[{}^{s-1}\Sigma_{n=0} \frac{\gamma n}{n!} + \frac{\gamma s}{s!}\ {}^{k}\Sigma_{n=s}\ \rho n\text{-}s \right]$$

$$Pn = P(n-1)\ \gamma/n \text{ for } n<= s$$

$$Lq = \frac{P0\ \gamma^s\ \rho}{s!(1-p)^2}\ [(1-P^{k-s}(1-k-s)(1-\rho))]$$

$$L = Lq + \gamma\ (1- P(k))$$

$$Wq = Lq / \lambda /(1-P(k))$$

$$W = L / \lambda / (1-P(k))$$

Explanation of Variables

P_0: The probability that all servers are idle

Pn: The probability of n customers in the system

Pw or Pb, the probability an arriving customer waits, i.e., the system is busy (all servers are occupied). Pw = S P(n) for n³s.

Q: Queue capacity (maximum waiting space), which represents the maximum number of customers that can wait for service.

s: Number of servers (or channels)

W: Average time customer spends in the system

Wb: Average time customer spends in the queue for a busy system, Wb = Wq/Pw

Wq: Average time customer spends in the queue

L: Average number of customers in the system

Lb: Average number of customers in the queue for a busy system, Lb = Lq/Pw

Lq: Average number of customers in the queue

N: Customer population, which is the number of customers in the population.

n: Number of customers in the system, including being served and waiting in the queue.

a = Service pressure coefficient. Usually 'a' is a non-negative coefficient for server to speed up the service when the system is busy

b = Arrival discourage coefficient. Usually 'b' is a non-negative coefficient to discourage customer arrival when the system is busy, i.e., all servers are busy

λ = Arrival rate (lambda). Average inter arrival time between customers is 1/l. Usually arrival rate or inter arrival time has a particular pattern or probability distribution.

m = Service rate (mu) per server. Average service time for a customer is 1/m. Usually service rate or service time has a particular pattern or probability distribution.

R= System utilization factor = l/(sm)
g = Traffic intensity = l/m(number of customers)
B = Average number of customers being balked per unit time. B = l
Cb: Cost of customer being balked
Ci: Idle server cost per unit time
Cq: Unit queue capacity cost
Cs: Busy server cost per unit time
Cu: Customer being served cost per unit time
Cw: Customer waiting cost per unit time
K: Number of customers allowed in the system. K = Q + s.

5. DATA COLLECTION

In this research project traditional approach of designing questionnaire, sampling and interview method is used. Information is collected through personally conducted structured and unstructured interviews. The population is all SWHs working in Lahore. Three lists were available for the SWHs.

List of PITB (Pakistan Information Technology Board), List of PSEB (Pakistan Software Export Board), List of PASHA. After comparing all three lists, we were able to form a comprehensive list of almost 170 SWHs

This was an explanatory study. It had two stages. Initially questionnaire to 170 SWHs were sent through e-mail. After sending the questionnaire via e mail personal visits were scheduled to get the filled questionnaire from SWHs. Personal visits revealed that many SWHs have closed or shifted from the listed address or changed the business.

After completion of 1st phase almost 44 software houses were identified excluding all ISPs, call centres, and on paper SWHs, which had registered themselves as software house. The firms were ranked according to number of employees, domestic sales; export earnings, growth rate, revenue, etc. This information is based on the results of first questionnaire and census of Federal Bureau of Statistics. And median group of 12 firms with 21-30 employees was selected for intensive analysis.

Multi stage sampling was opted and in second phase median sampling is used for analysis. In the last stage a sub - sample group of 4 firms was opted for more rigorous analysis.

Median sampling technique reduced the bias as it excluded the extraordinary performers and small SWHs (outliers), which have negligible share in the market. These groups (outliers) do not depict the true conditions in market. After selecting the median group intensive questionnaire is formed for further analysis.

6. RESULTS OF THE QUEUING MODEL

Conditions in firm 1:

The firm was engaged in the areas of financial, inventory and web development operations. It was using windows as the major platform. The total employees in the firm were 25 with 2 project managers. Firm was facing problems in having quality workforce and the main reason for low quality was low standards of education and lack of professional orientation in employees. The reason of low utilization was lack of coordination with HRM and this was due to lack of facilities. The retention was also problem for the firm and attractive pay scales and professionalism were the main factors of retention. Firm used salary structure, and provided professional satisfaction to its employees for rectifying the problem of retention. Firm had no market strategy and it relied on its personal contacts to acquire project. Firm used percent complete method for appraisal and appraisal was based on results and outcomes of the employees. It was a learning organization hierarchy structure with low cost price of the service. The firm always tried to come up to the customers' expectation and wanted to retain better skilled workers. The performance evaluation of the firm showed that its score totaled 71with mean of 3.38.

Analysis of firm 1:

This model for firm 1 (M/G/6/10/40) was developed assuming that queuing system had 6 servers and maximum waiting space was 10 with total population of 40. It assumed exponential inter arrival input source with a fixed mean arrival rate (λ) and it also assumed that the customers had independent service time with the same probability distribution. It assumed that service time was normally distributed where (6/μ) is the mean and σ^2 was the variance of the service time. The queuing system can eventually reach the steady state condition if $\rho = \lambda/\mu < 1$ where ρ is the utilization factor.

Considering the complexity involved in analyzing the model that permits normal service time distribution with more than one server we use approximation method to get the results. The firm had ***(M/G/6/10/40)*** queuing system. The service time distribution was normally distributed with mean (μ) 0.444and s.d (σ). 0.345where 1/μ and 1/λ were expected inter arrival time and expected service time respectively. In this model, 1/μ and 1/λ were 2.52 each which showed that customer arrival rate and service rate were same. ρ was the utilization factor which shows utilization of the system (λ/μ) was 1.29. In this case the system was unstable because $\rho = \lambda/\mu > 1$ which was 1.29. When ρ (λ/μ) >1, it showed unstable transient condition and it suggested that system will tend to grow as time goes on. The over-all utilization was **16.67%**, which was quite low. The average number of expected customers (L) in the system was 1 and the length of the queue (Lq) was 0.0001 which shows lack of demand of the service as there were few customers waiting in the queue and the average number of customers waiting in the queue (L_b) was 16% for a busy system. The low utilization of overall system signified low performance of the servers. The waiting time (W) in the system including service time was almost 5 months. It showed that a project from start to end usually is completed in this time. Lack of demand for the service was obvious from zero waiting time in the queue. In these conditions the probability that all servers were idle (P_0) was 37%. The busy server cost per year was $16,500 and that of idle server was $82,500, which was 5 times more than busy server and showed the inefficiency in utilization of resources. The total costs were high in the local firm, which had to compete in the international market with cost effective techniques depicted that there is great need to increase efficiency and demand for the project. The total cost was $122,000 per year. The idle capacity and low utilization shows that cost can be five times lower than existing cost.

Conditions in firm 2:

The firm was engaged in the areas of financial, inventory, Office automation and MIS operations. It was using windows as the major platform. The total employees in the firm were 30 with 2 project managers. Firm was facing problems in having quality workforce and the main reason for was low standard of education. The reason of low utilization was lack of skills. The lack of resources resulted in delays in project submission. Another reason of delays was flaws in the project planning. The retention was also problem for the firm but the extent of retention was medium. The supervisory structure, attractive pay scales and career development were the methods used for rectifying the problem of retention. The firm had penetration marketing strategy and it relied on its personal contacts and PSEB to acquire project. The firm used percent complete method and current period report for monitoring and appraisal was based on psychometric tests and number of satisfied customers' employees. It had adopted BM (bench marking) and TQM (total quality management) management policy. The organization had network structure with dominant market share. The firm always tried to excel in the exports sector and international market was its first preference and wanted to retain workers with professional attitude. The performance evaluation of the firm showed that its score totals 71 with mean of 3.38.

Analysis of FIRM 3:

This model for firm 2 (M/G/4/8/30) was developed on the existing conditions of a firm assuming that queuing system had 4 servers and maximum waiting space was 8 with total population of 30. It assumed exponential inter arrival input source with a fixed mean arrival rate (λ) and independent service time (μ) with the same probability distribution. It assumed that service time was normally distributed where ($4/\mu$) is the mean and σ^2 was the variance of the service time. The queuing system can eventually reach the steady state condition if $\rho = \lambda/\mu < 1$ where ρ is the utilization factor. The system was unstable when $\rho = \lambda/\mu > 1$.

Considering the complexity involved in analyzing the model that permits normal service time distribution with more than one server we use approximation method to get the results.

The firm had *(M/G/4/8/30)* queuing system. The service time distribution was normally distributed with 0.133 mean (μ) and 0.265 as s.d. (σ). Where expected inter arrival time ($1/\mu$) was 7.52 and the expected service time ($1/\lambda$) was 3.77. In this model, $1/\mu$ and $1/\lambda$ which showed customer arrival rate and service rate respectively were not same. ρ was the utilization factor which showed utilization of the system and it is the ratio of inter arrival rate to service rate.(λ/μ) was 0.5 in this case which showed steady state condition as the (λ/μ)is less than 1.

The over all system utilization was **24.94%** which was quite low. The average number of expected customers (L) in the system was 101.45% and the length of the queue (Lq) were 0.0167 which showed high demand of the service as there was large number of customers waiting in the queues. Due to busy servers, 82% customers were waiting in the queue

The low utilization of overall system signified low performance of the servers due to excessive demand. The waiting time (W) in the system including service time was almost 1.6 months. It showed that a project from start to end was usually completed in this time.

Excessive demand and small service projects were obvious from zero waiting time in the queue. In these conditions the probability that all servers were idle (P_0) was 37%. The probability of an arriving customers waits was 2.03%. The busy server cost was $103,86.52 and that of an idle server was $266,94.21

which was 1.5 times more than busy server and showed inefficiency in utilization of resources due to high pressure of demand. The total costs were high in the local firms which pinpoints the need to increase efficiency for high demand of the project. The total cost was $52,700 per year. The idle capacity and low utilization showed that cost can be lowered 1.5 times than existing cost at full utilization level.

Conditions in firm 3

The firm was engaged in the areas of financial and communication operations. It was using WINDOWS and UNIX as the major platform. The total employees in the firm were 30 with 4 project managers. Firm was facing problems in having quality workforce and the main reason was lack of professional orientation in employees. The reason of low utilization was lack of coordination with HRM and this was due to lack of resources. HRM always tried to save cost. The delays in projects submission was not a major problem but delays occurred due to lack of resources. The extent of retention was medium and firm used salary structure, professional satisfaction, corporate culture and job security to rectify the problem of retention. WBS (work break system) was used for project planning. Activity timing was done on similar to other activities and historical method. The firm had no market strategy and it relied on its personal contacts to acquire project. The firm used current period, cumulative reports and history reports for monitoring and appraisal was based on number of satisfied customers. It was a TQM organization with routine need of R&D. The organization had a team structure with low cost dominant firm. The firm always tried to come up to the customers' expectation and wanted to have career oriented workers. The performance evaluation of the firm showed that it scored total 83 marks with mean of 3.95.

Analysis of FIRM 3

This model for firm 3 (M/G/2/8/30) was developed on the existing conditions of a firm assuming that queuing system had 2 servers and maximum waiting space was 8 with total population of 30. It assumed exponential inter arrival input source with a fixed mean arrival rate (λ) and independent service time (μ) with the same probability distribution. It assumed that service time was normally distributed where ($2/\mu$) is the mean and σ^2 was the variance of the service time. The queuing system can eventually reach the steady state condition if $\rho = \lambda/\mu < 1$ where ρ is the utilization factor. The system was unstable when $\rho = \lambda/\mu > 1$. Considering the complexity involved in analyzing the model that permits normal service time distribution with more than one server we used approximation method to get the results.

The firm had *(M/G/2/8/30)* queuing system. The service time distribution was normally distributed with 2 mean (μ) and 0.083 s.d (σ) where expected inter arrival time $1/\mu$ was 0.5 and expected service time $1/\lambda$ was also 0.5. In this model, $1/\mu$ and $1/\lambda$ which showed customer arrival rate and service rate respectively were same. ρ was the utilization factor which showed utilization of the system (λ/μ) was 1. In this case it showed transient state condition.

The over all system utilization was **50%**, which was quite low. The average number of expected customers (L) in the system was 1.167 and the length of the queue (Lq) was 0.167 which showed high demand of the service as there was large number of customers waiting in the queue and the average number of customers waiting in the queue (L_b) was 50% for a busy system.

The 50% utilization of overall system signified evenly poised level of performance of the servers due to low variability in service rate and it was depicted by the low standard deviation. The waiting time (W) in the system including service time was almost 2.3 per year and it showed that a project from start to end was usually completed in almost 2.3 months. Excessive burden on the system was obvious from average time spent in the queue (Wq) i.e. 0.34 per year. The customers had to wait in the queue for 1.0 year due to busy server. In these conditions the probability that all servers were idle (P_0) was 33%. The probability of an arriving customers waits was 33%. The busy server cost was $6,570 and that of idle server was $5,556. The idle server cost was lower than busy server cost and showed the efficiency in utilization of resources due to high service rate and low variability of the service rate. The total server cost was $12,376 with the average cost of $1,547 per project.

Conditions in firm 4

The firm was engaged in the health care product software. It was using WINDOWS as major platform. The total employees in the firm were 30 with 1 project manager. This firm is a subsidiary software house and developing a product for clinics. The firm was facing problems in having quality workforce and the main reason was lack of professional orientation in employees and low standard of education. The reason of low utilization was lack of coordination with HRM and this was due to the vague roles assigned to HRM. The delays in projects submission was not a major problem. The extent of retention was low and firm used salary structure, professional satisfaction, corporate culture, career development and job security to rectify the problem of retention. WBS (work break system) was used for project planning. Activity timing was done on expert advice and historical method. Firm had development market strategy and it relied on its personal contacts to acquire project. The firm used current period, percent complete method for monitoring and appraisal was based on results and outcomes, production and standard competence. The firm used bench marking and re-engineering management policy. The organization had a hierarchy structure with low cost price structure. The firm always tried to come up to the customers' expectation and wanted to have motivated and skilled workers. The performance evaluation of the firm showed that it scored total 89 marks with mean of 4.2.

This model for firm 4 *(M/G/2/3/1)* was developed on the existing conditions of a firm assuming that queuing system had 2 servers and maximum waiting space was 3 with total population of 1. The firm was engaged in developing software for one institution. It assumed exponential inter arrival input source with a fixed mean arrival rate (λ) and independent service time (μ) with the same probability distribution. It assumed that service time was normally distributed where ($2/\mu$) was the mean and σ^2 was the variance of the service time. The queuing system can eventually reach at the steady state condition if $\rho = \lambda/\mu < 1$ where ρ is the utilization factor, λ is inter arrival rate and μ was the service rate. The system was unstable when $\rho = \lambda/\mu > 1$. Considering the complexity involved in analyzing the model that permits normal service time distribution with more than one server we use approximation method to get the results.

The firm had (M/G/2/3/1) queuing system. The service time distribution was normally distributed with 0.67 mean (μ) service rate and 0.2 s.d (σ).where expected inter arrival time (1/μ) was 1.49 and expected service time (1/λ) was 0.5. In this model, 1/μ and 1/λ which showed customer arrival rate and service rate respectively were different. It showed that service rate was greater than inter arrival rate. ρ was the utilization factor which showed utilization of the system (λ/μ) was 0.33. It showed that ρ was less than 1 and it depicted steady state condition. The performance analysis revealed that effective arrival rate was 2 and effective service rate was 1.4 therefore the ρ was 1.43 and this showed that system was diverging from the equilibrium.

The over-all system utilization was **67%** which was quite better as compared to other SWHs. The average number of expected customers (L) in the system was 1.93 and the length of the queue (Lq) was 0.59 and average number of customers in busy system (Lb) was 1.10 which showed high delays in service. The average waiting time spent in the system (W) was 0.97 per year and the average time spent in the queue (Wq) was 0.30 year and average time customer spent due to busy system (Wb) was 0.55 year.

The 67% utilization of overall system signified high level of performance of the servers due to low variability in service rate and was depicted by the low standard deviation. The waiting time (W) in the system including service time was almost 0.97 per year and showed that a project from start to end was usually completed in almost 11.64 months.

In these conditions the probability that all servers were idle (P_0) was 20%. The probability of an arriving customer waits due to busy server was 54%. The busy server cost was $11,484 and that of an idle server was $2,640. The idle server cost was lower than busy server cost and showed the efficiency in utilization of resources due to high service rate and low variability of the service rate. The total server cost was $25,452.56 with the average cost of $12,726 per project.

7. CONCLUSIONS

The conditions and profiles of industry revealed that our SWI was engaged in cost effective module based SW development. The nature of projects had low tech base. The business structure was based on hierarchy structure with bench marking business strategies and limited inclusion of employees in decision making. Retention, low skills, lack of expertise and brain drain were the anxiety factors in our industry. The lack of managerial abilities and rigid organizational structure with cost saving management policy and labour intensive techniques were the limiting factors of the industry leading to inefficiencies. The low capacity utilization in the median group firms was obvious from the queuing analysis and over- employment in the firms suggested low level of SW projects by aggregate planning. The average utilization level in the industry was analyzed at 39% which was quite low as compared to the 100% theoretical level of capacity utilization. Lack of professional approach, lack of innovation and reluctance to change, hindered its modification and development. Reward and incentives failed to rectify the problem of retention and brain drain. Marketing was the most neglected side in the industry and little attention was paid to it. The businessmen in industry think penny wise and pound foolish. There was dearth of market managers and advertisers. There were difficulties in measuring capacity utilization and efficiency. Firms had been facing problems in quality assurance as there were few firms who had achieved ISO certification and just one firm achieved CMM level 2 and one firm had achieved Tick IT standard. In absence of these quality assurance levels, firms had no effective check of quality which reduced the utilization level of the system and limited the repeatable export business. Lack of interaction amongst the firms hindered growth of knowledge and experience of the industry. The firms had failed to develop long term objective oriented policies and had only short term profit maximization target and therefore not interested in bringing radical changes.

Policy recommendations

The SWHs should take a critical view of their policies by examining where they are and how they can improve the present conditions and what new perspective of learning is available for them.

The SWHs should hire the services of proper marketing managers to introduce their projects in the local as well as in international market.

The SWHs need to be innovative and must go for viable risk taking projects. The employees should participate in design and research activities

Employees' involvement in decision-making will be one of the main sources of performance improvement leading to increase in efficiency and capacity utilization. Autocratic style organizations and short term improvement from cost cutting to cope with the necessary changes should be replaced with employees involvement in decision making.

Reward system was the greater force to increase the efficiency and capacity utilization. Suggestion based reward system can be a good example of participative approach of incentives. Reliable performance measure has to give weightage to quality and quantity of the service provided.

Rewards should have the clear objectives and agreed upon measurement of performance. System should relate rewards to achievement.

The design and climate of the firms should allow opportunities for personal development. Recognition with effective reward system can enhance the performance of the employees.

The improvement in output is a combination of all parts of the organization. The SWHs should acknowledge the interdependency of the organization. Any approach of improving efficiency must include other functions concerned and improvement in one part leads to increase output, as improvement in marketing leads to improvement in quality.

Self-reporting diaries as a means of individuals and group study can provide important information about employees. These self reporting diaries should not be used for exploitation of the employees so that they can freely provide the information about their activities

The engineering assessment is another method to improve capacity utilization. Firms should try to adopt reengineering policies instead of bench marking.

Training and refresher courses can also be used to improve capacity utilization and service. These courses can help to improve the mental capabilities and skills of the professionals.

Increased efficiency should not result in job loss for the better productive employees. Lifetime employment in an organization is an old concept but the fruits of better capacity utilization should reach to employees.

Proper feedback can enhance performance if the employees have regular feedback on how organization as a whole works.

Top management involvement was lukewarm. Their attitude towards work and employees can be a motivational force for the employees

The more efficient use of resources should produce the surplus, which can be invested in an even better utilization of resources

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APPENDICES

Table No.1: Results of the queuing system from approximation (firm 1):

Performance Measure	Result
System: M/G/6/10/40	From Approximation
Customer arrival rate (lambda) per year	2.2523
Service rate per server (mu) per year	2.2523
Overall system effective arrival rate per year	2.2523
Overall system effective service rate per year	2.2523
Overall system utilization	16.67%
Average number of customers in the system (L)	1.0001
Average number of customers in the queue (Lq)	0.0001
Average number of customers in the queue for a busy system (Lb)	0.1604
Average time customer spends in the system (W)	0.4440 years
Average time customer spends in the queue (Wq)	0.0000 years
Average time customer spends in the queue for a busy system (Wb)	0.0712 years
The probability that all servers are idle (Po)	36.79%
The probability an arriving customer waits (Pw or Pb)	0%
Average number of customers being balked per year	0
Total cost of busy server per year	$16,500.00
Total cost of idle server per year	$82,500.00
Total cost of customer waiting per year	$0
Total cost of customer being served per year	$15,000.00
Total cost of customer being balked per year	$0
Total queue space cost per year	$8,000.00
Total system cost per year	$122,000.10

Table No.2: Results of the queuing system from approximation (firm 2)

Performance Measure	Result
System: M/G/4/8/30	From Approximation
Customer arrival rate (lambda) per year	7.5019
Service rate per server (mu) per year	7.5188
Overall system effective arrival rate per year	7.5019
Overall system effective service rate per year	7.5019
Overall system utilization	**24.94%**
Average number of customers in the system (L)	101.45%
Average number of customers in the queue (L_q)	0.0167
Average number of customers in the queue for a busy system (L_b)	0.8258
Average time customer spends in the system (W)	0.1352 years
Average time customer spends in the queue (W_q)	0.0022 years
Average time customer spends in the queue for a busy system (W_b)	0.1101 years
The probability that all servers are idle (Po)	36.82%
The probability an arriving customer waits (Pw or P_b)	2.03%
Average number of customers being balked per year	0.00%
Total cost of busy server per year	$10,386.57
Total cost of idle server per year	$26,694.21
Total cost of customer waiting per year	$25.09
Total cost of customer being served per year	$15,594.82
Total cost of customer being balked per year	$0.00
Total queue space cost per year	$0
Total system cost per year	$52,700.70

Table No. 3: Results of the Queuing system from Approximation (Firm 3)

Performance Measure	Result
System: M/G/2/8/30	From Approximation
Customer arrival rate (lambda) per year	0.5
Service rate per server (mu) per year	0.5
Overall system effective arrival rate per year	0.5
Overall system effective service rate per year	0.5
Overall system utilization	50.00%
Average number of customers in the system (L)	1.167
Average number of customers in the queue (Lq)	0.167
Average number of customers in the queue for a busy system (Lb)	0.5009
Average time customer spends in the system (W)	2.3339 years
Average time customer spends in the queue (Wq)	0.3339 years
Average time customer spends in the queue for a busy system (W_b)	1.0017 years
The probability that all servers are idle (Po)	33.33%
The probability an arriving customer waits (Pw or Pb)	33.33%
Average number of customers being balked per year	0
Total cost of busy server per year	$6,570.00
Total cost of idle server per year	$5,556.00
Total cost of customer waiting per year	$250.43
Total cost of customer being served per year	$0
Total cost of customer being balked per year	$0
Total queue space cost per year	$0
Total system cost per year	$12,376.43

Table No. 4: Results of the Queuing system from Approximation(Firm 3)

Performance Measure	Result
System: M/G/2/3/1	From Approximation
Customer arrival rate (lambda) per year	2
Service rate per server (mu) per year	1.4925
Overall system effective arrival rate per year	2
Overall system effective service rate per year	2
Overall system utilization	67.00%
Average number of customers in the system (L)	1.9344
Average number of customers in the queue (Lq)	0.5944
Average number of customers in the queue for a busy system (Lb)	1.1056
Average time customer spends in the system (W)	0.9672 years
Average time customer spends in the queue (Wq)	0.2972 years
Average time customer spends in the queue for a busy system (Wb)	0.5528 years
The probability that all servers are idle (P_0)	19.76%
The probability an arriving customer waits (Pw or P_b)	53.76%
Average number of customers being balked per year	0
Total cost of busy server per year	$11,483.80
Total cost of idle server per year	$2,640.00
Total cost of customer waiting per year	$1,188.76
Total cost of customer being served per year	$8,040.00
Total cost of customer being balked per year	$0
Total queue space cost per year	$2,100.00
Total system cost per year	$25,452.56