

Modelado y Simulación de Sistemas de Eventos Discretos

Profesores: Xabier Basogain, Ph.D.

Miguel Ángel Olabe, Ph.D.

Departamentos:

Ingeniería de Sistemas y Automática

Electrónica y Telecomunicaciones

ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA

C/ Alameda Urquijo s/n

48013- Bilbao

FIGURAS Y TABLAS (Teoría)

TEMA 1.- INTRODUCCIÓN A LA SIMULACIÓN DE EVENTOS DISCRETOS

SISTEMA	ENTIDADES	ATRIBUTOS	ACTIVIDADES	RECURSO	EVENTOS	VARIABLES DE ESTADO
Banco	Clientes	Tarjeta Oro Preferencial	Realizar Ingreso Consultar Saldo	Oficinista Cajero Automático	Llegada Salida	Nº de Cajeros Ocupados Nº de Clientes Esperando
Fábrica	Máquinas	Velocidad Ratio Averías	Taladrar Soldar	Torno Robot	Avería	Estado de las máquinas (ocupada, averiada, desocupada)
Comunicaciones	Mensajes	Longitud Destino	Transmitir	CPU Buffer	Llegada a destino	Nº de paquetes esperando para ser transmitidos

Figura 1.- Ejemplos de Términos/Conceptos relacionados con Sistemas

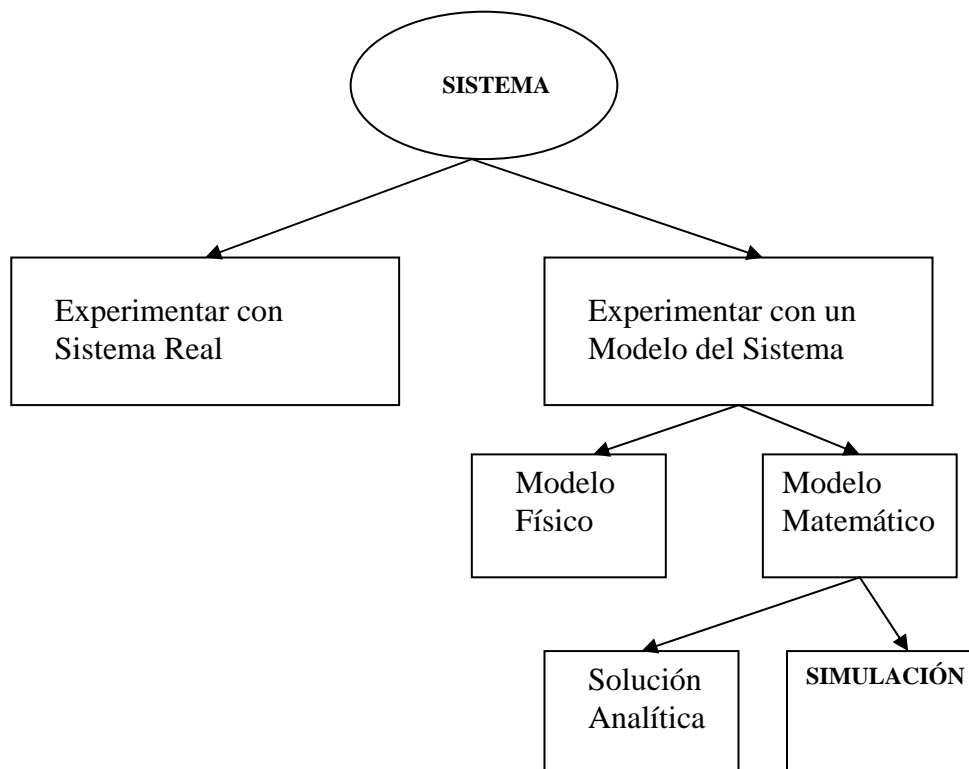


Figura 2.- Formas de realizar el Estudio de un Sistema

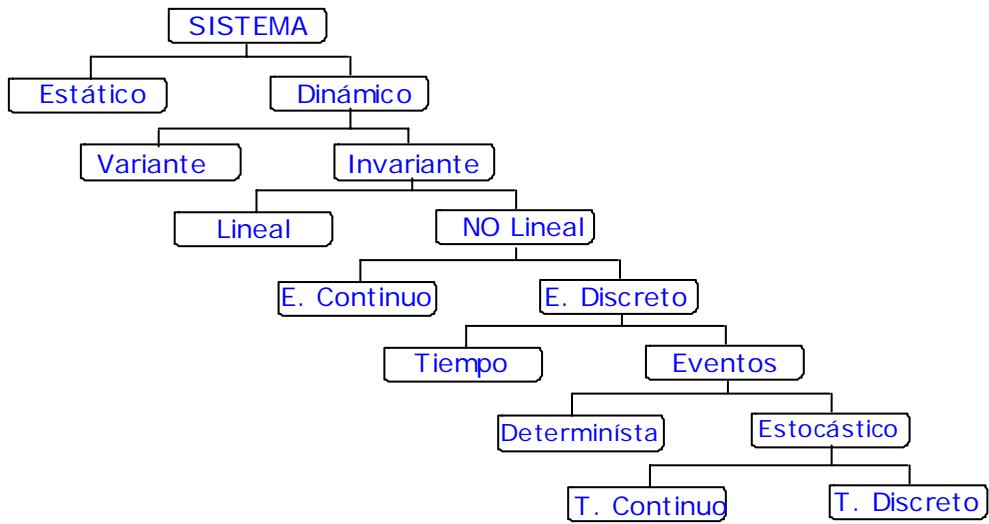


Figura 3.- Clasificación General de Sistemas

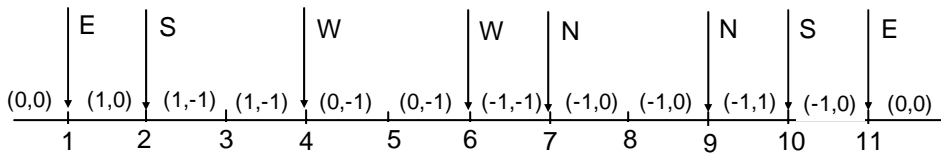


Figura 4.- Ejemplo particular de un Sistema Time-driven: Paseo Random

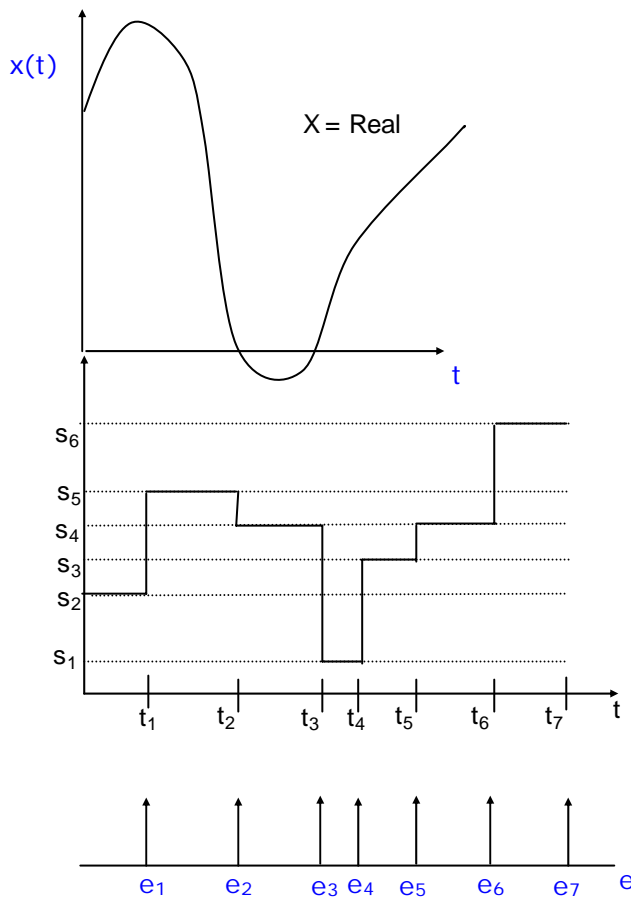


Figura 5.- Comparación gráfica de Sistemas SDVC vs. SED

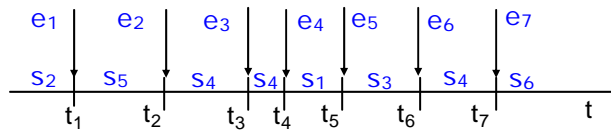


Figura 6.- Representación de Eventos y Estados de un SED

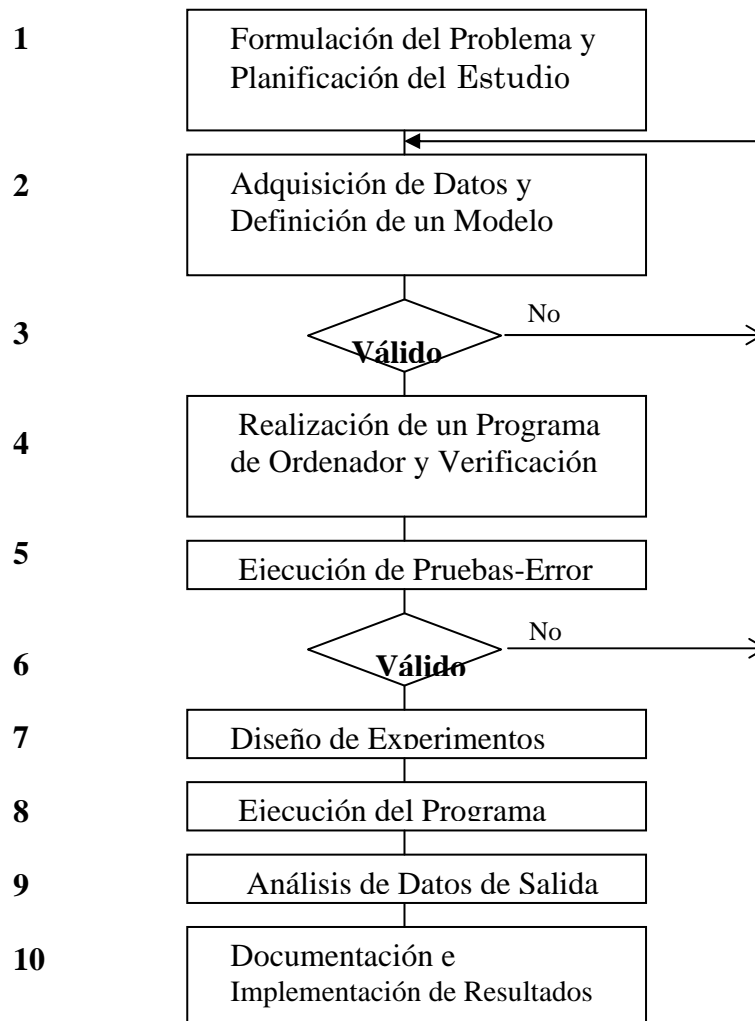


Figura 7.- Pasos en el Estudio de Simulación

TEMA 4 y 5.- MODELOS TEMPORALES Y ESTOCÁSTICOS

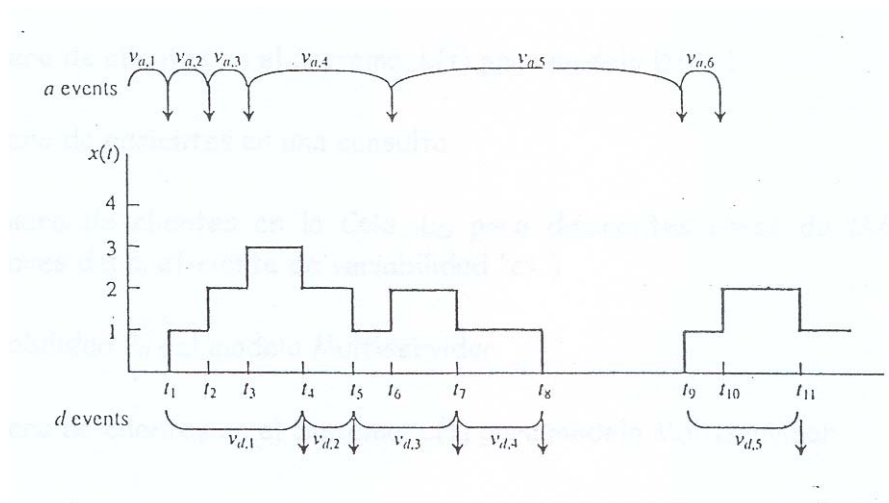


Figura 1.- Sistema de Colas como Autómata Temporal (ejemplo particular)

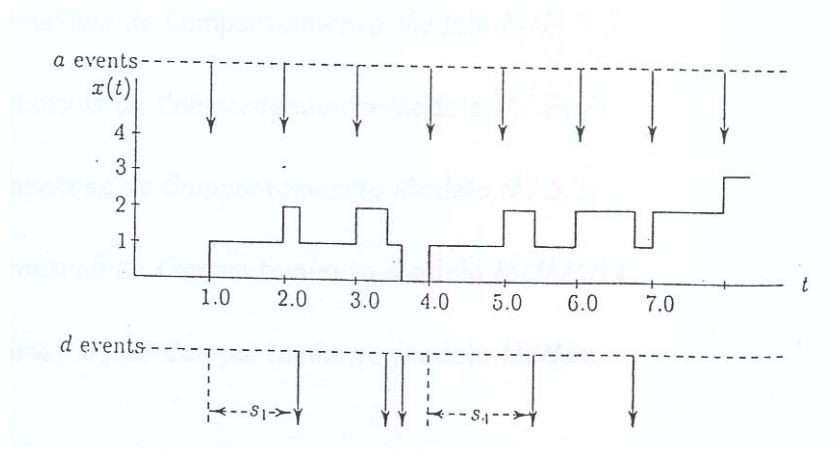


Figura 2.- Sistema de Colas como Autómata Temporal Estocástico (ejemplo particular)

TEMA 6.- MODELO DE COLAS

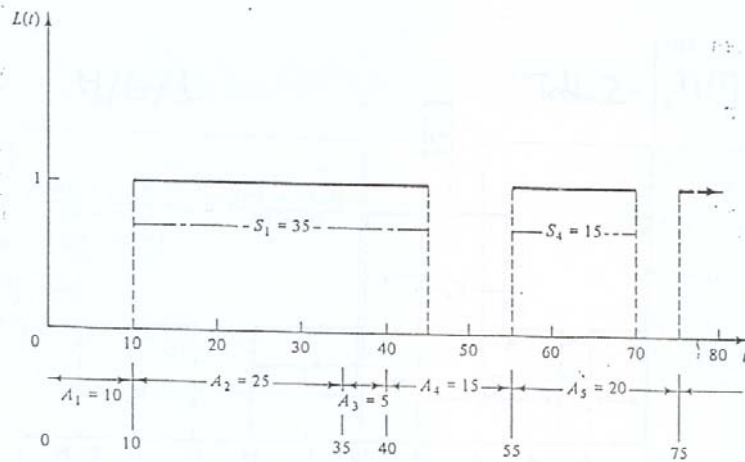


Figura 1.- Ejemplo particular de nº de clientes en un sistema M/M/1/1/infinito

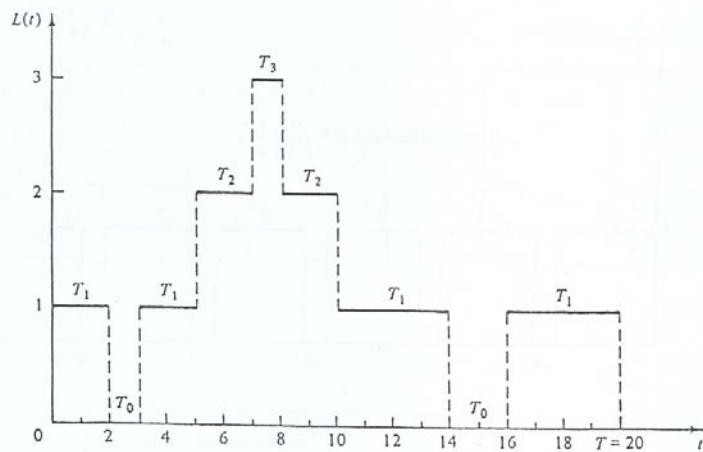


Figura 2.- Representación temporal del Número de clientes en el Sistema, $L(t)$

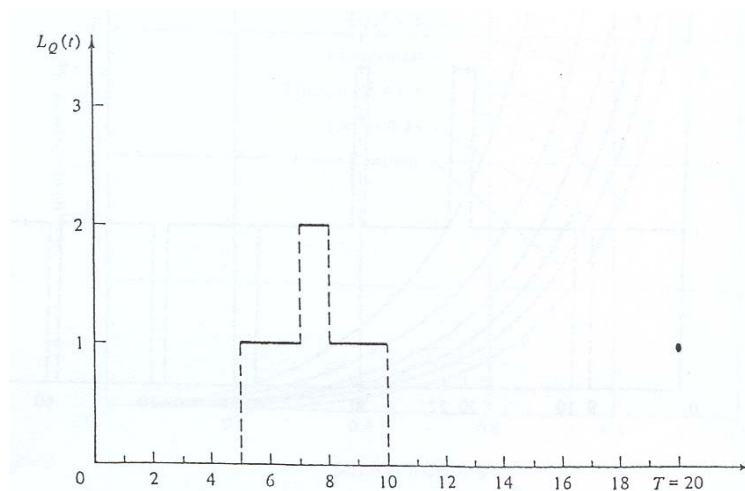


Figura 3.- Representación temporal del Número de clientes en la Cola, $L_Q(t)$

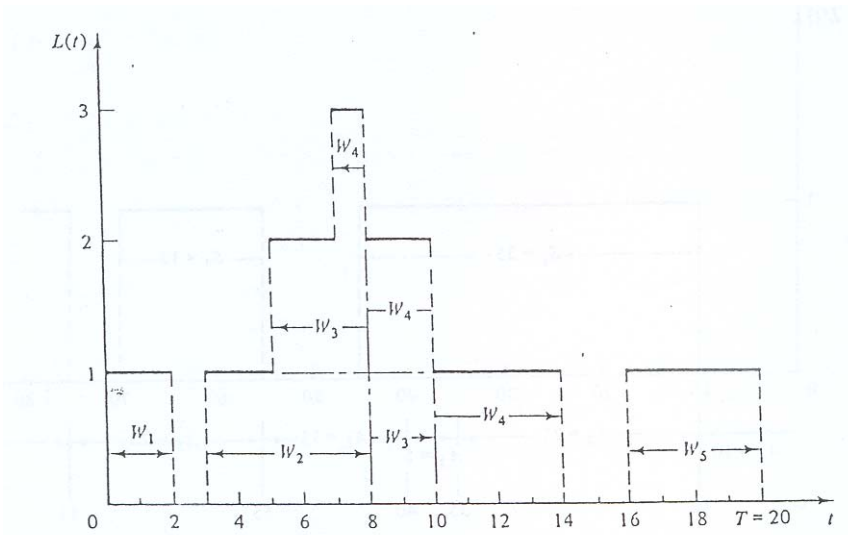


Figura 4.- Tiempos de sistema, W_i

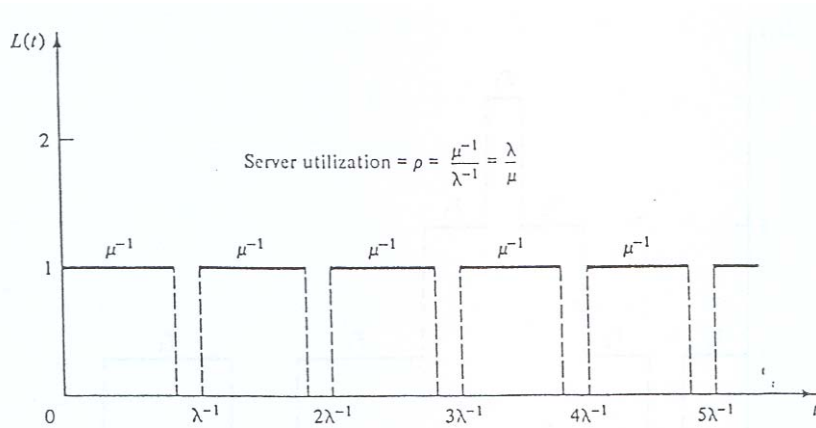


Figura 5.- Número de clientes en el Sistema, $L(t)$ para modelo D/D/1

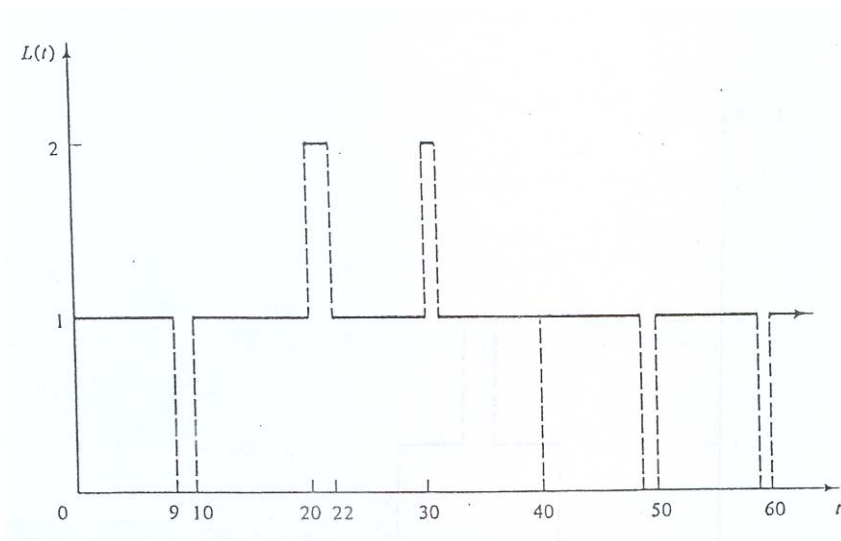


Figura 6.- Número de pacientes en una consulta

ρ	$\frac{\lambda}{\mu}$
L	$\rho + \frac{\lambda^2(\mu^{-2} + \sigma^2)}{2(1-\rho)} = \rho + \frac{\rho^2(1 + \sigma^2\mu^2)}{2(1-\rho)}$
w	$\mu^{-1} + \frac{\lambda(\mu^{-2} + \sigma^2)}{2(1-\rho)}$
w_Q	$\frac{\lambda(\mu^{-2} + \sigma^2)}{2(1-\rho)}$
L_Q	$\frac{\lambda^2(\mu^{-2} + \sigma^2)}{2(1-\rho)} = \frac{\rho^2(1 + \sigma^2\mu^2)}{2(1-\rho)}$
P_0	$1 - \rho$

Tabla 1.- Parámetros de Comportamiento Modelo M/G/1

L	$\frac{\lambda}{\mu - \lambda} = \frac{\rho}{1 - \rho}$
w	$\frac{1}{\mu - \lambda} = \frac{1}{\mu(1 - \rho)}$
w_Q	$\frac{\lambda}{\mu(\mu - \lambda)} = \frac{\rho}{\mu(1 - \rho)}$
L_Q	$\frac{\lambda^2}{\mu(\mu - \lambda)} = \frac{\rho^2}{1 - \rho}$
P_n	$\left(1 - \frac{\lambda}{\mu}\right)\left(\frac{\lambda}{\mu}\right)^n = (1 - \rho)\rho^n$

Tabla 2.- Parámetros de Comportamiento Modelo M/M/1

L	$\frac{\lambda}{\mu} + \frac{1+k}{2k} \frac{\lambda^2}{\mu(\mu - \lambda)} = \rho + \frac{1+k}{2k} \frac{\rho^2}{1-\rho}$
w	$\frac{1}{\mu} + \frac{1+k}{2k} \frac{\lambda}{\mu(\mu - \lambda)} = \mu^{-1} + \frac{1+k}{2k} \frac{\rho\mu^{-1}}{1-\rho}$
w_Q	$\frac{1+k}{2k} \frac{\lambda}{\mu(\mu - \lambda)} = \frac{1+k}{2k} \frac{\rho\mu^{-1}}{1-\rho}$
L_Q	$\frac{1+k}{2k} \frac{\lambda^2}{\mu(\mu - \lambda)} = \frac{1+k}{2k} \frac{\rho^2}{1-\rho}$

Tabla 3.- Parámetros de Comportamiento Modelo M/ E_k /1

L	$\frac{\lambda}{\mu} + \frac{1}{2} \frac{\lambda^2}{\mu(\mu - \lambda)} = \rho + \frac{1}{2} \frac{\rho^2}{1-\rho}$
w	$\frac{1}{\mu} + \frac{1}{2} \frac{\lambda}{\mu(\mu - \lambda)} = \mu^{-1} + \frac{1}{2} \frac{\rho\mu^{-1}}{1-\rho}$
w_Q	$\frac{1}{2} \frac{\lambda}{\mu(\mu - \lambda)} = \frac{1}{2} \frac{\rho\mu^{-1}}{1-\rho}$
L_Q	$\frac{1}{2} \frac{\lambda^2}{\mu(\mu - \lambda)} = \frac{1}{2} \frac{\rho^2}{1-\rho}$

Tabla 4.- Parámetros de Comportamiento Modelo M/D/1

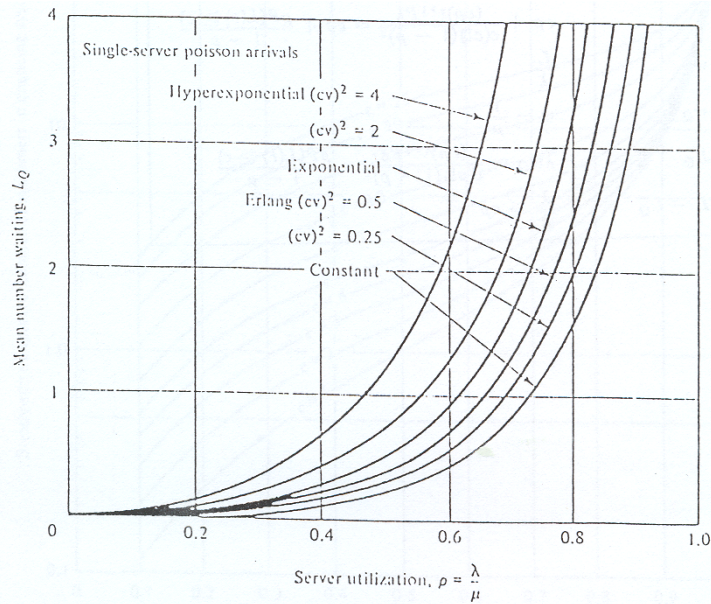


Figura 7.- Número de clientes en la Cola, L_Q para diferentes casos de $M/G/1$ (diferentes valores del coeficiente de variabilidad 'cv')

L	$\begin{cases} \frac{a[1 - (N+1)a^N + Na^{N+1}]}{(1-a^{N+1})(1-a)} & \lambda \neq \mu \\ \frac{N}{2} & \lambda = \mu \end{cases}$	
$1 - P_N$	$\begin{cases} \frac{1 - a^N}{1 - a^{N+1}} & \lambda \neq \mu \\ \frac{N}{N+1} & \lambda = \mu \end{cases}$	
λ_e	$\lambda(1 - P_N) = \mu(1 - P_0) = \mu_e$	
ρ	$\frac{\lambda_e}{\mu} = 1 - P_0$	
w	$\frac{L}{\lambda_e}$	$a = \lambda/\mu$
w_Q	$w - \frac{1}{\mu}$	
L_Q	$\lambda_e w_Q = L - (1 - P_0)$	
P_n	$\begin{cases} \frac{(1-a)a^n}{1-a^{N+1}} & \lambda \neq \mu \\ \frac{1}{N+1} & \lambda = \mu \end{cases}$	$n = 0, 1, 2, \dots, N$

Tabla 5- Parámetros de Comportamiento Modelo $M/M/1/N$

ρ	$\frac{\lambda}{c\mu}$
P_0	$\left\{ \left[\sum_{n=0}^{c-1} \frac{(\lambda/\mu)^n}{n!} \right] + \left[\left(\frac{\lambda}{\mu} \right)^c \left(\frac{1}{c!} \right) \left(\frac{c\mu}{c\mu - \lambda} \right) \right] \right\}^{-1}$ $= \left\{ \left[\sum_{n=0}^{c-1} \frac{(c\rho)^n}{n!} \right] + \left[(c\rho)^c \left(\frac{1}{c!} \right) \frac{1}{1-\rho} \right] \right\}^{-1}$
$P(L(t) \geq c)$	$\frac{(\lambda/\mu)^c P_0}{c!(1-\lambda/c\mu)} = \frac{(c\rho)^c P_0}{c!(1-\rho)}$
L	$c\rho + \frac{(c\rho)^{c+1} P_0}{c(c!)(1-\rho)^2} = c\rho + \frac{\rho P(L(t) \geq c)}{1-\rho}$
w	$\frac{L}{\lambda}$
w_Q	$w - \frac{1}{\mu}$
L_Q	$\lambda w_Q = \frac{(c\rho)^{c+1} P_0}{c(c!)(1-\rho)^2} = \frac{\rho P(L(t) \geq c)}{1-\rho}$
$L - L_Q$	$\frac{\lambda}{\mu} = c\rho$

Tabla 6.- Parámetros de Comportamiento Modelo $M/M/c$

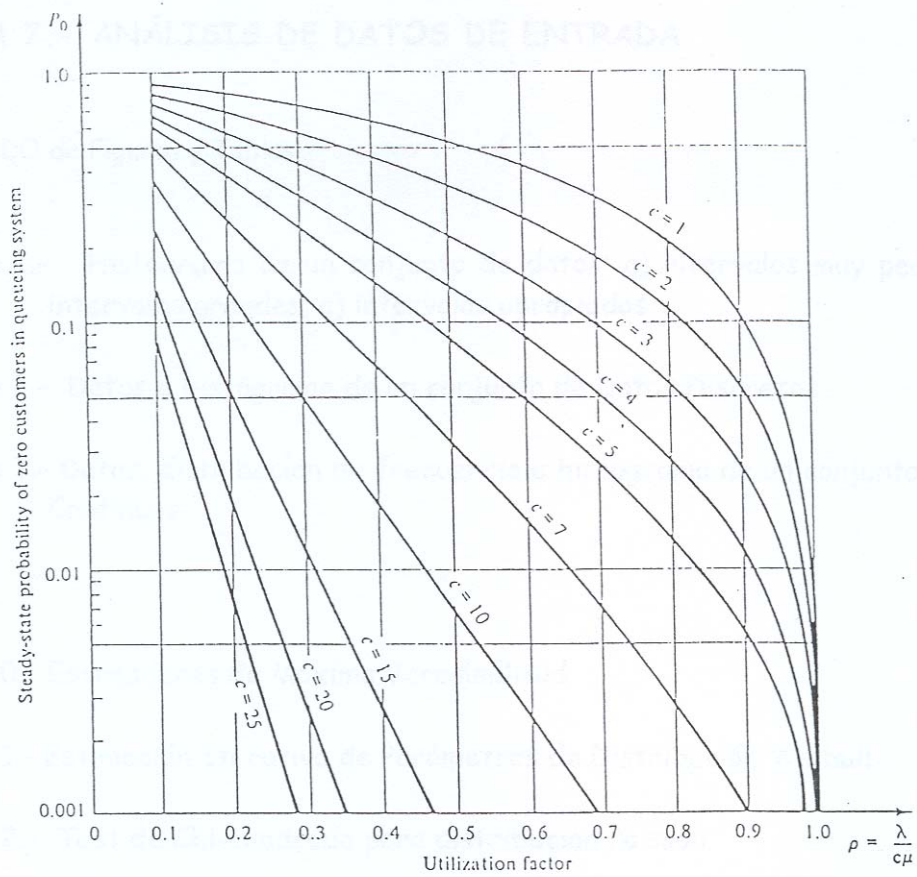


Figura 8.- Probabilidad P_0 del modelo Multiservidor

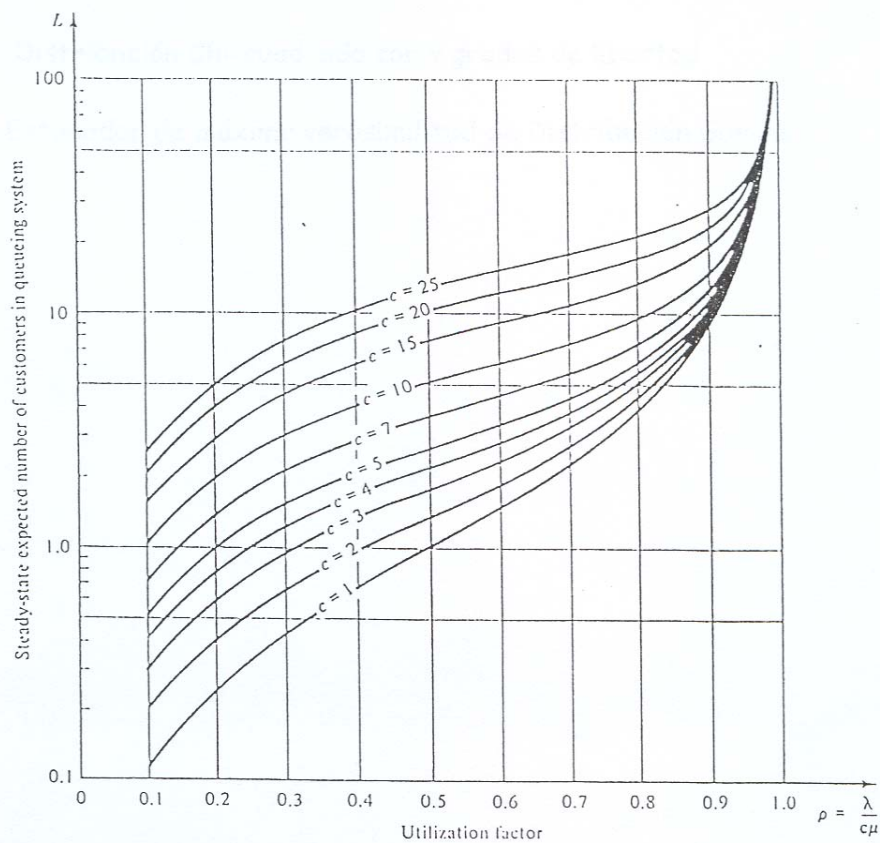


Figura 9.- Número de clientes en el Sistema, $L(t)$ para modelo Multiservidor

TEMA 7.- ANÁLISIS DE DATOS DE ENTRADA

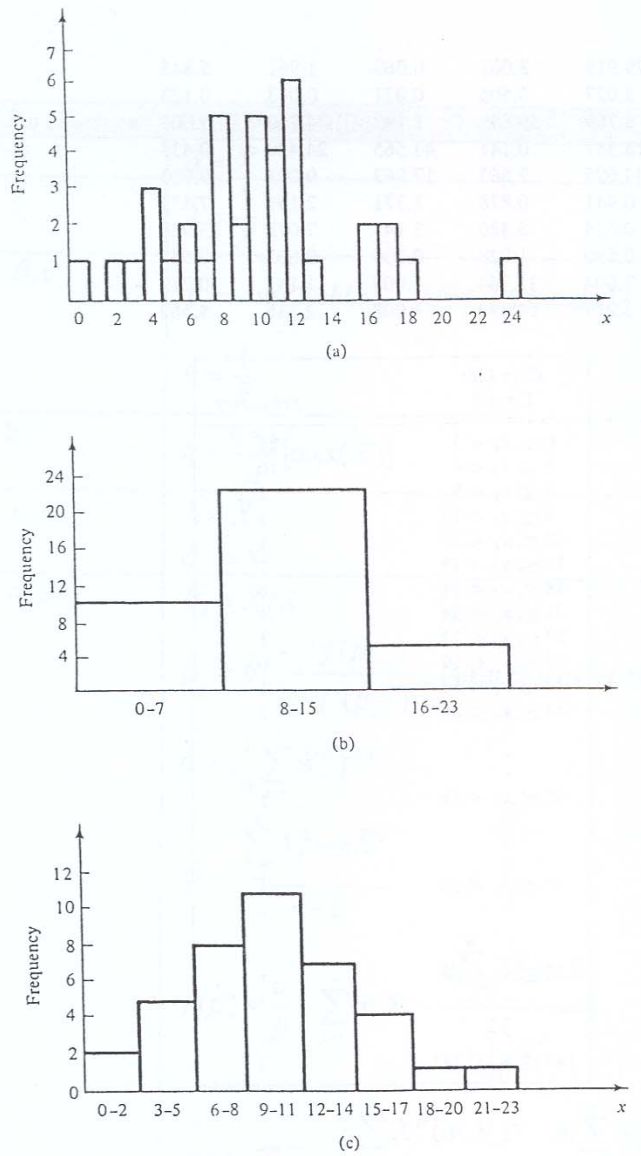


Figura 1.- Histograma de un conjunto de datos: a) intervalos muy pequeños, b) intervalos grandes, c) intervalos apropiados

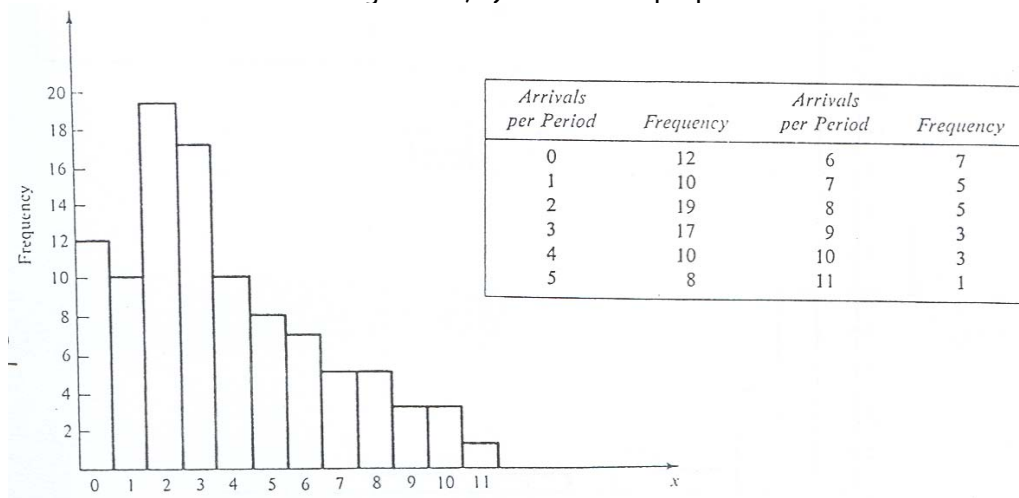


Figura 2.- Datos e histograma de un conjunto de Datos Discretos

79.919	3.081	0.062	1.961	5.845
3.027	6.505	0.021	0.013	0.123
6.769	59.899	1.192	34.760	5.009
18.387	0.141	43.565	24.420	0.433
144.695	2.663	17.967	0.091	9.003
0.941	0.878	3.371	2.157	7.579
0.624	5.380	3.148	7.078	23.960
0.590	1.928	0.300	0.002	0.543
7.004	31.764	1.005	1.147	0.219
3.217	14.382	1.008	2.336	4.562

<i>Chip Life (Days)</i>	<i>Frequency</i>
$0 \leq x_j < 3$	23
$3 \leq x_j < 6$	10
$6 \leq x_j < 9$	5
$9 \leq x_j < 12$	1
$12 \leq x_j < 15$	1
$15 \leq x_j < 18$	2
$18 \leq x_j < 21$	0
$21 \leq x_j < 24$	1
$24 \leq x_j < 27$	1
$27 \leq x_j < 30$	0
$30 \leq x_j < 33$	1
$33 \leq x_j < 36$	1
⋮	⋮
$42 \leq x_j < 45$	1
⋮	⋮
$57 \leq x_j < 60$	1
⋮	⋮
$78 \leq x_j < 81$	1
⋮	⋮
$143 \leq x_j < 147$	1

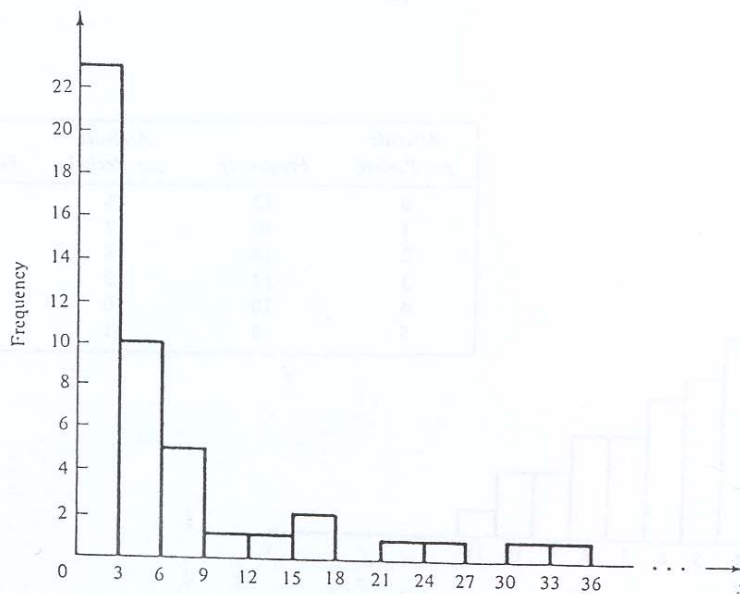


Figura 3.- Datos, distribución de frecuencia e histograma de un conjunto de Datos Continuos

Distribución	Parámetros	ESTIMADOR(ES)
Poisson	α	$\hat{\alpha} = \bar{X}$
Exponencial	λ	$\hat{\lambda} = \frac{1}{\bar{X}}$
Gamma	β, θ	$\hat{\beta} = \text{ver Tabla 5 } (1/M, \beta) \text{ siendo } M = \ln \bar{X} - \frac{1}{n} \sum_1^n \ln X_i$ $\hat{\theta} = \frac{1}{\bar{X}}$
Uniforme entre (0,b)	b	$\hat{b} = \frac{n+1}{n} [\max(X)]$
Normal	μ, σ^2	$\hat{\mu} = \bar{X}$ $\hat{\sigma}^2 = S^2$
Weibull con v=0	α, β	$\hat{\beta}_0 = \bar{X} / S$ $\hat{\beta}_j = \hat{\beta}_{j-1} - \frac{f(\hat{\beta}_{j-1})}{f'(\hat{\beta}_{j-1})}$ iteraciones hasta que $f(\beta) < 0.001$ $\hat{\alpha} = \left(\frac{1}{n} \sum_{i=1}^n X_i^{\hat{\beta}}\right)^{1/\hat{\beta}}$ $S^2 = \frac{\sum_{i=1}^n X_i^2 - n\bar{X}^2}{n-1}$ $f(\beta) = \frac{n}{\beta} + \sum_{i=1}^n \ln X_i - \frac{n \sum_{i=1}^n X_i^\beta \ln X_i}{\sum_{i=1}^n X_i^\beta}$ $f'(\beta) = \frac{-n}{\beta^2} - \frac{n \sum_{i=1}^n X_i^\beta (\ln X_i)^2}{\sum_{i=1}^n X_i^\beta} + \frac{n(\sum_{i=1}^n X_i^\beta \ln X_i)^2}{(\sum_{i=1}^n X_i^\beta)^2}$

Tabla 0.- Estimadores de Máxima Verosimilitud

j	$\hat{\beta}_j$	$\sum_{i=1}^{50} X_i^{\hat{\beta}_j}$	$\sum_{i=1}^{50} X_i^{\hat{\beta}_j} \ln X_i$	$\sum_{i=1}^{50} X_i^{\hat{\beta}_j} (\ln X_i)^2$	$f(\hat{\beta}_j)$	$f'(\hat{\beta}_j)$	$\hat{\beta}_{j+1}$
0	0.477	115.125	292.629	1057.781	16.024	-356.110	0.522
1	0.522	129.489	344.713	1254.111	1.008	-313.540	0.525
2	0.525	130.603	348.769	1269.547	0.004	-310.853	0.525
3	0.525	130.603	348.786	1269.614	0.000	-310.841	0.525

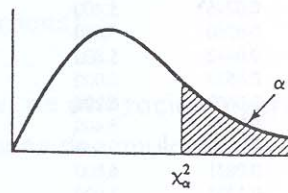
Tabla 1.- Estimación Iterativa de Parámetros de Distribución Weibull

x_i	Observed Frequency, O_i	Expected Frequency, E_i	$\frac{(O_i - E_i)^2}{E_i}$
0	12	2.6	} 7.87
1	10	9.6	
2	19	17.4	} 0.15
3	17	21.1	
4	10	19.2	} 4.41
5	8	14.0	
6	7	8.5	} 0.26
7	5	4.4	
8	5	2.0	} 11.62
9	3	0.8	
10	3	0.3	
11	1	0.1	
	100	100.0	27.68

Tabla 2.- Test de Chi-cuadrado para distribución Poisson

Class Interval	Observed Frequency, O_i	Expected Frequency, E_i	$\frac{(O_i - E_i)^2}{E_i}$
[0, 1.590)	19	6.25	26.01
[1.590, 3.425)	10	6.25	2.25
[3.425, 5.595)	3	6.25	0.81
[5.595, 8.252)	6	6.25	0.01
[8.252, 11.677)	1	6.25	4.41
[11.677, 16.503)	1	6.25	4.41
[16.503, 24.755)	4	6.25	0.81
[24.755, ∞)	6	6.25	0.01
	50	50	39.6

Tabla 3- Test de Chi-cuadrado para distribución Exponencial



ν	$\chi^2_{0.005}$	$\chi^2_{0.01}$	$\chi^2_{0.025}$	$\chi^2_{0.05}$	$\chi^2_{0.10}$
1	7.88	6.63	5.02	3.84	2.71
2	10.60	9.21	7.38	5.99	4.61
3	12.84	11.34	9.35	7.81	6.25
4	14.96	13.28	11.14	9.49	7.78
5	16.7	15.1	12.8	11.1	9.2
6	18.5	16.8	14.4	12.6	10.6
7	20.3	18.5	16.0	14.1	12.0
8	22.0	20.1	17.5	15.5	13.4
9	23.6	21.7	19.0	16.9	14.7
10	25.2	23.2	20.5	18.3	16.0
11	26.8	24.7	21.9	19.7	17.3
12	28.3	26.2	23.3	21.0	18.5
13	29.8	27.7	24.7	22.4	19.8
14	31.3	29.1	26.1	23.7	21.1
15	32.8	30.6	27.5	25.0	22.3
16	34.3	32.0	28.8	26.3	23.5
17	35.7	33.4	30.2	27.6	24.8
18	37.2	34.8	31.5	28.9	26.0
19	38.6	36.2	32.9	30.1	27.2
20	40.0	37.6	34.2	31.4	28.4
21	41.4	38.9	35.5	32.7	29.6
22	42.8	40.3	36.8	33.9	30.8
23	44.2	41.6	38.1	35.2	32.0
24	45.6	43.0	39.4	36.4	33.2
25	49.6	44.3	40.6	37.7	34.4
26	48.3	45.6	41.9	38.9	35.6
27	49.6	47.0	43.2	40.1	36.7
28	51.0	48.3	44.5	41.3	37.9
29	52.3	49.6	45.7	42.6	39.1
30	53.7	50.9	47.0	43.8	40.3
40	66.8	63.7	59.3	55.8	51.8
50	79.5	76.2	71.4	67.5	63.2
60	92.0	88.4	83.3	79.1	74.4
70	104.2	100.4	95.0	90.5	85.5
80	116.3	112.3	106.6	101.9	96.6
90	128.3	124.1	118.1	113.1	107.6
100	140.2	135.8	129.6	124.3	118.5

Tabla 4.- Distribución Chi-cuadrado con ν grados de libertad

$1/M$	β	$1/M$	β
0.020	0.0187	5.200	2.755
0.030	0.0275	5.400	2.855
0.040	0.0360	5.600	2.956
0.050	0.0442	5.800	3.056
0.060	0.0523	6.000	3.156
0.070	0.0602	6.200	3.257
0.080	0.0679	6.400	3.357
0.090	0.0756	6.600	3.457
0.100	0.0831	6.800	3.558
0.200	0.1532	7.000	3.658
0.300	0.2178	7.300	3.808
0.400	0.2790	7.600	3.958
0.500	0.3381	7.900	4.109
0.600	0.3955	8.200	4.259
0.700	0.4517	8.500	4.409
0.800	0.5070	8.800	4.560
0.900	0.5615	9.100	4.710
1.000	0.6155	9.400	4.860
1.100	0.6690	9.700	5.010
1.200	0.7220	10.000	5.160
1.300	0.7748	10.300	5.311
1.400	0.8272	10.600	5.461
1.500	0.8794	10.900	5.611
1.600	0.9314	11.200	5.761
1.700	0.9832	11.500	5.911
1.800	1.034	11.800	6.061
1.900	1.086	12.100	6.211
2.000	1.137	12.400	6.362
2.100	1.188	12.700	6.512
2.200	1.240	13.000	6.662
2.300	1.291	13.300	6.812
2.400	1.342	13.600	6.962
2.500	1.393	13.900	7.112
2.600	1.444	14.200	7.262
2.700	1.494	14.500	7.412
2.800	1.545	14.800	7.562
2.900	1.596	15.100	7.712
3.000	1.646	15.400	7.862
3.200	1.748	15.700	8.013
3.400	1.849	16.000	8.163
3.600	1.950	16.300	8.313
3.800	2.051	16.600	8.463
4.000	2.151	16.900	8.613
4.200	2.252	17.200	8.763
4.400	2.353	17.500	8.913
4.600	2.453	17.800	9.063
4.800	2.554	18.100	9.213
5.000	2.654	18.400	9.363
		18.700	9.513
		19.000	9.663
		19.300	9.813
		19.600	9.963
		20.000	10.16

Tabla 5.- Estimador de máxima verosimilitud de Distribución Gamma

TEMA 8.- ANÁLISIS DE DATOS DE SALIDA

Run, r	Able's Utilization, $\hat{\rho}_r$	Average System Time, \hat{w}_r (Minutes)
1	0.808	3.74
2	0.875	4.53
3	0.708	3.84
4	0.842	3.98

Tabla 1.- Resultados de $\hat{\rho}$ y \hat{w} de 4 simulaciones (replications)

Batching Interval (Minutes)	Batch, j	Replication		
		1, Y_{1j}	2, Y_{2j}	3, Y_{3j}
[0, 1000)	1	3.61	2.91	7.67
[1000, 2000)	2	3.21	9.00	19.53
[2000, 3000)	3	2.18	16.15	20.36
[3000, 4000)	4	6.92	24.53	8.11
[4000, 5000)	5	2.82	25.19	12.62
[0, 5000)		$\bar{Y}_1 = 3.75$	$\bar{Y}_2 = 15.56$	$\bar{Y}_3 = 13.66$

Tabla 2.- Media temporal de Longitud de Cola, L_Q en 5 subintervalos y 3 simulaciones (replications)

Replication, r	Run Length, T_E		
	2 Hours	4 Hours	8 Hours
1	0.808	0.796	0.785
2	0.875	0.825	0.833
3	0.708	0.787	0.806
4	0.842	0.837	0.833
5	0.742	0.825	0.808
6	0.767	0.775	0.800
7	0.792	0.787	0.794
8	0.950	0.867	0.827
9	0.833	0.821	0.815
10	0.717	0.750	0.821
11	0.817	0.808	0.798
12	0.842	0.746	0.817
13	0.850	0.846	0.854
14	0.850	0.846	0.848
15	0.767	0.783	0.796
16	0.817	0.804	0.813

Tabla 3- Datos de Salida: nivel de utilización ρ para 16 simulaciones (replications) y 3 diferentes duraciones de simulación T_E

Number of Replications, R	Run Length, T_E		
	2 Hours	4 Hours	8 Hours
4	0.808 ± 0.036	0.811 ± 0.011	0.814 ± 0.011
8	0.811 ± 0.027	0.812 ± 0.011	0.810 ± 0.006
16	0.811 ± 0.015	0.806 ± 0.009	0.816 ± 0.005

Tabla 4.- Estimación de la utilización $\hat{\rho}$, con desviación estandar

Replication	Batch														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	3.61	3.21	2.18	6.92	2.82	1.59	3.55	5.60	3.04	2.57	1.41	3.07	4.03	2.70	2.71
2	2.91	9.00	16.15	24.53	25.19	21.63	24.47	8.45	8.53	14.84	23.65	27.58	24.19	8.58	4.06
3	7.67	19.53	20.36	8.11	12.62	22.15	14.10	9.87	23.96	24.50	14.56	6.08	4.83	16.04	23.41
4	6.62	1.75	12.87	8.77	1.25	1.16	1.92	6.29	4.74	17.43	18.24	18.59	4.62	2.76	1.57
5	2.18	1.32	2.14	2.18	2.59	1.20	4.11	6.21	7.31	1.58	2.16	3.08	2.32	2.21	3.32
6	0.93	3.54	4.80	0.72	2.95	5.56	1.96	2.07	2.74	3.45	14.24	13.39	7.87	0.94	3.19
7	1.12	2.59	5.05	1.16	2.72	5.12	5.03	4.14	4.98	15.81	9.29	2.14	8.72	29.80	28.94
8	1.54	5.94	5.33	2.91	2.69	1.91	3.27	3.61	10.35	9.66	4.13	6.14	7.90	2.61	7.95
9	8.93	4.78	0.74	2.56	9.43	18.63	8.14	1.49	4.51	1.69	12.62	11.28	3.32	3.42	3.35
10	4.78	2.84	10.39	5.87	1.01	2.59	16.77	27.25	26.81	20.96	7.26	2.32	5.04	8.50	9.11

Tabla 5.- Valores medios de L_Q para sistema $M/G/1$, para 15 subintervalos y 10 simulaciones (replications)

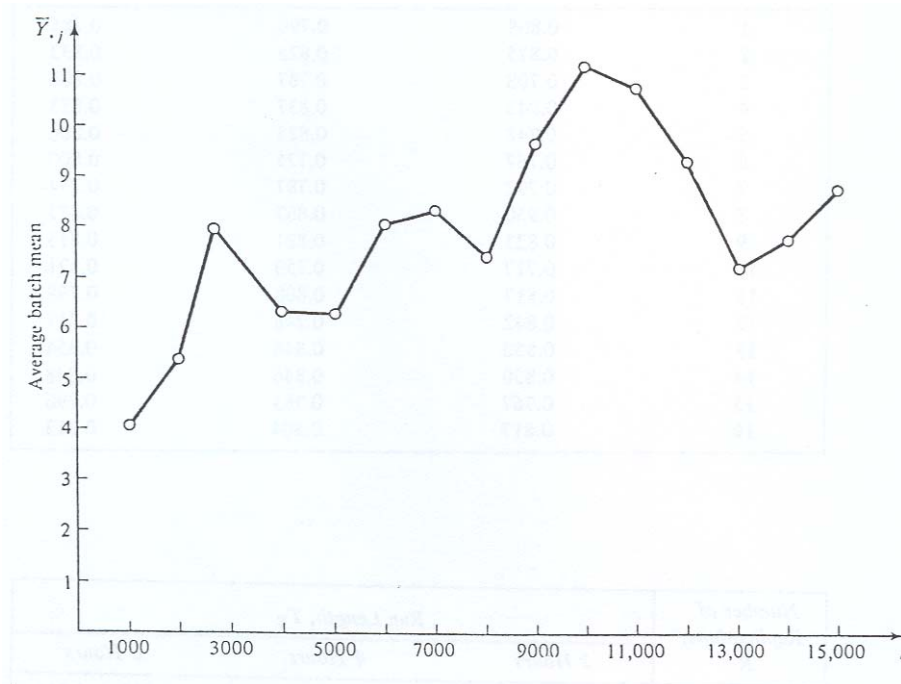


Figura 1.- Representación gráfica de los promedios de cada subintervalo correspondiente a la Tabla 5.

Run Length, T	Batch, j	Averaged Batch Mean, \bar{Y}_j	Cumulative Average (No Deletion), $\bar{Y}_{..}(j, 0)$	Cumulative Average (Delete 1), $\bar{Y}_{..}(j, 1)$	Cumulative Average (Delete 2), $\bar{Y}_{..}(j, 2)$
1,000	1	4.03	4.03	—	—
2,000	2	5.45	4.74	5.45	—
3,000	3	8.00	5.83	6.72	8.00
4,000	4	6.37	5.96	6.61	7.18
5,000	5	6.33	6.04	6.54	6.90
6,000	6	8.15	6.39	6.86	7.21
7,000	7	8.33	6.67	7.11	7.44
8,000	8	7.50	6.77	7.16	7.45
9,000	9	9.70	7.10	7.48	7.77
10,000	10	11.25	7.51	7.90	8.20
11,000	11	10.76	7.81	8.18	8.49
12,000	12	9.37	7.94	8.29	8.58
13,000	13	7.28	7.89	8.21	8.46
14,000	14	7.76	7.88	8.17	8.40
15,000	15	8.76	7.94	8.21	8.43

Tabla 6.- Resumen de datos del sistema M/G/1 : medias de subintervalos, medias acumulativas, sobre 10 simulaciones (replications)

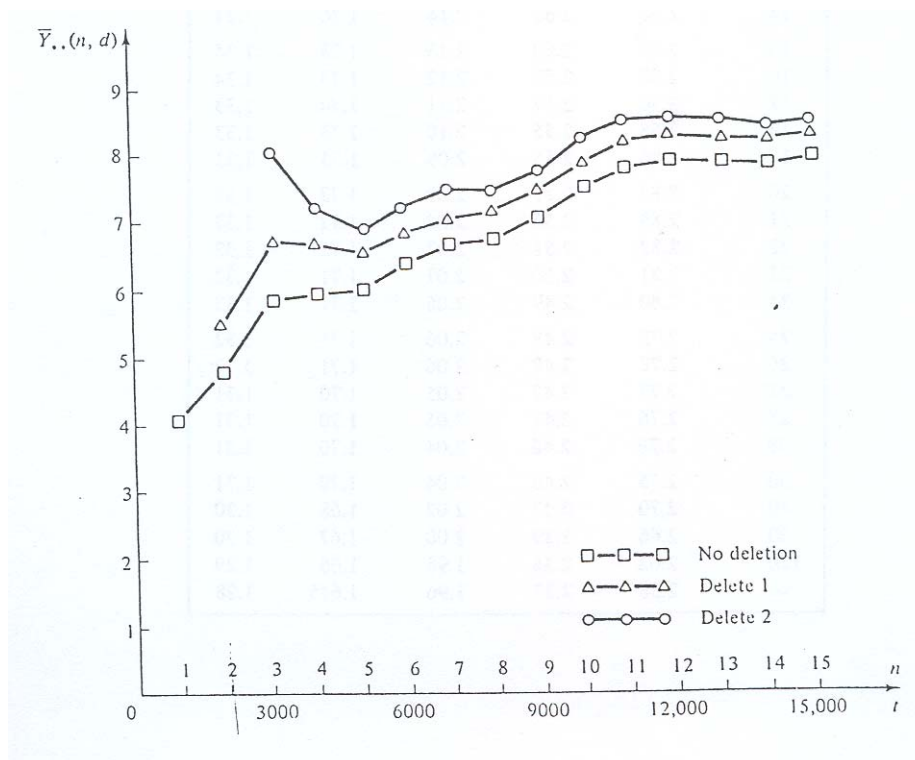


Figura 2.- Representación gráfica de las medias acumulativas correspondientes a la Tabla 6.

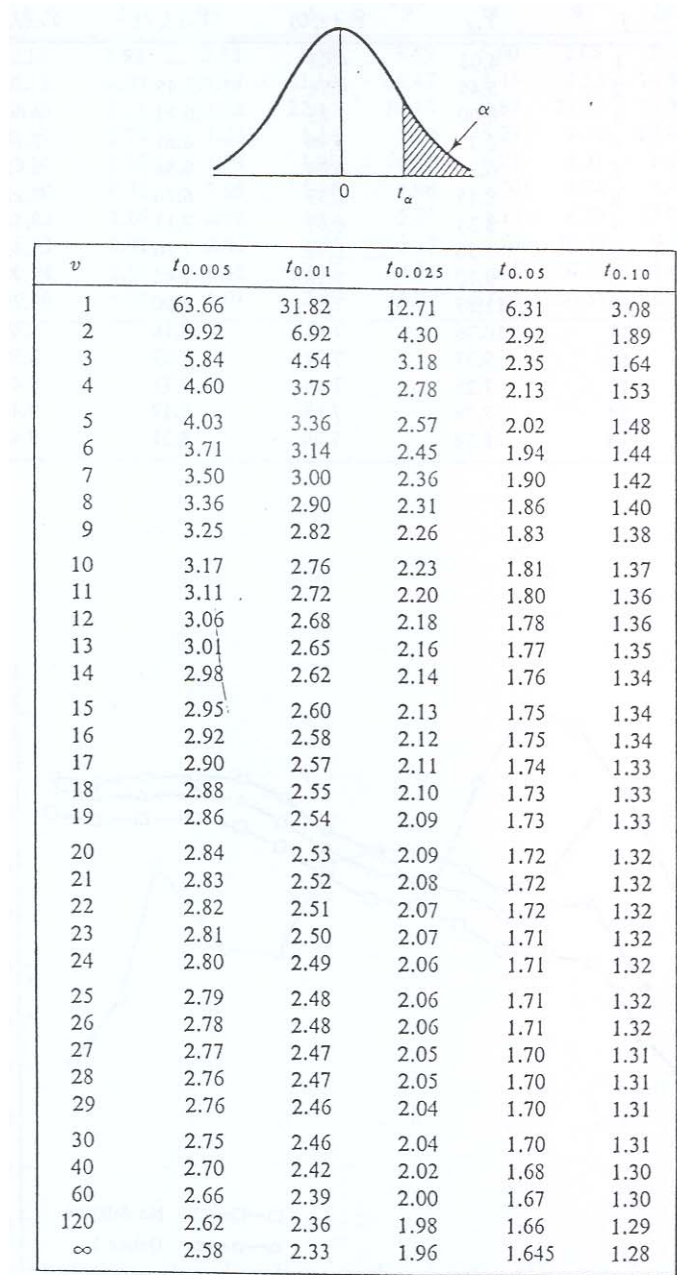


Tabla 7.- Distribución t-students con v grados de libertad.