

A Simulation Study on toll gate system in M/M/1 Queueing Models

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Abstract: In this paper, we analyze the application of Simulation in Queueing model in tollgate are discussed. We visualize the activities of each lane is discussed. The main aim of this paper is, the management can easily find which system are busy and which system is ideal and the movement of each type of vehicles in each lane is simulated by the arrival and departure time. The numerical studies for various aspects are discussed.

Keywords: Mathematical model, Quantitative model, M/M/1 Queueing model, Simulation, Probability distribution.

I. Introduction

Queueing theory is originated in telephony with the work of Erlang [8]. His pioneering work stimulated many authors to develop a variety of queueing models incorporating various arrival patterns, various service time distributions. Queueing theory is the mathematical study of waiting lines. In this, a model is constructed means queue lengths and waiting times can be predicted [2]. Queueing is a phenomenon in a number of fields, and it has been extensively analyzed in the study of queueing theory [4].

Queueing theory can be applied the imperfect matching between the customer and service facilities is caused by one's inability to predict accurately the arrival and service time of customers. It tries to answer the questions like, the mean waiting time in the queue, the mean system response time (waiting time in the queue plus service times), mean utilization of the service facility, distribution of the number of customers in the queue, distribution of the number of customers in the system and so forth. These questions are mainly investigated in a stochastic scenario, where e.g. the inter arrival times of the customers or the service times are assumed to be random.

Simulation is the imitation of the operation of a real world process over time [3]. The study of simulation models in tollgate simulation is a significant and the powerful force for the improvement of management operations. Now a day, it has been used to increase the efficiency, quickly obtainable and adaptable and economy of service operations. In this case study, we describe and emphasis the valuable contribution of simulation and how to help the development of operations in a project. The merging of queueing model and simulation technologies has seen a remarkable growth in recent years. The fruitful reason for the importance of simulation in queueing model is that many real world problems in operations research are too complex to be given tractable mathematical formulations. In such situations, resources can be listed in a series in the hope that at least one will give an adaptable solution.

Ultimately the striking goal in simulation and queueing model is to create a way to produce high quality solutions without any mathematical structures. It first requires that a model be developed and the model represents the behaviors of the process. Simulation can be used to predict the performance of an existing or planned system and to compare alternative solutions to a particular design problem [1]. Simulation can be used to show the eventual real effects of alternative conditions and courses of action. It's also used when the real system cannot be engaged, because it may not be accessible, or it may be dangerous or unacceptable to engage, or it is being designed but not yet to build, or it may simply not exist. [5].

Simulation approach is suitable to analyze large and complex real life problems for sensitivity analysis of complex systems. It allows the decision-maker to study the interactive system variable and the effect of changes in these variables on the system performance in order to determine the desired one. Simulation can be used to 'experiment' on a model of a real situation without incurring the costs of operating on the system and its used as a pre-service test to try out new policies and decision rules for operating a system before running the risk of experimentation in the real system.

An approach of simulation-based methods have been applied to various areas related to transportation systems and its feasibilities have been reported [6; 9; 10; 14; 11; 12]. Simulation models are expensive and take a long time to develop in sometimes and it is the trial and error approach that produces different solutions in repeated runs. Each application of simulation is ad hoc to a great extent. As a part of transportation system in Salem toll gate system is expected to provide several great advantages; improvement of usability for vehicles drivers to reduce traffic jams and a solution to environmental issues. The main reason of traffic jams in the

tollgate in each vehicle is required to stop to pay toll fees. Over viewing the tollgate system in Salem, this paper presents the simulation model which has been developed in this study, the result of simulation provides two kinds of observations. One is management can easily find which system is busy and which system is ideal. The other one is to analyze the numerical study of the tollgate to achieve more efficient performance.

We collect the data from the tollgate near Periyar University Salem, situated in Salem Bangalore route (10kms from Salem). Here we have 4 types of vehicles category like F1 (car/jeep), F2 (Light Commercial Vehicles-LCV), F3 (Truck/Bus), F4 (Multi axel vehicles-MAV). Since the goal of the study is to propose a practical solution [7] to traffic jam issues actually occurred in the toll gate, we have designed and developed a Simulation model for toll gate in Salem as a case Study [13]. Physical layout data and measured traffic data are applied in this model and proposes some solutions derived from the simulation of the model. Now we analyses the tollgate simulation in queuing system.

II. Arrival Distribution Tables for F₁, F₂, F₃, F₄

ARRIVAL DISTRIBUTION FOR F ₁					
S. No	Inter Arrival Time(min)	No. of Vehicles	Prob.	Cum. Prob.	Tag Nos.
1	0-1	85	0.425	0.425	000 - 424
2	1-2	46	0.23	0.655	425 - 654
3	2-3	27	0.135	0.79	655 - 789
4	3-4	14	0.07	0.86	790 - 859
5	4-5	10	0.05	0.91	860 - 909
6	5-6	4	0.02	0.93	910 - 929
7	6-7	5	0.025	0.955	930 - 954
8	7-8	1	0.005	0.96	955 - 959
9	8-9	1	0.005	0.965	960 - 964
10	9-10	2	0.01	0.975	965 - 974
11	10-11	0	-	-	-
12	11-12	0	-	-	-
13	12-13	1	0.005	0.98	975 - 979
14	13-14	0	-	-	-
15	14-15	1	0.005	0.985	980 - 984
16	15-16	0	-	-	-
17	16-17	0	-	-	-
18	17-18	1	0.005	0.99	985 - 989
19	18-19	1	0.005	0.995	990 - 994
20	19-20	0	-	-	-
21	20-21	0	-	-	-
22	21-22	0	-	-	-
23	22-23	0	-	-	-
24	23-24	1	0.005	1	995 - 999
25	24-25	0	-	-	-
26	25-26	0	-	-	-
27	26-27	0	-	-	-
28	27-28	0	-	-	-
29	28-29	0	-	-	-
30	29-30	0	-	-	-
TOTAL		200			

ARRIVAL DISTRIBUTION FOR F ₂					
S. No.	Inter Arrival time(min)	No. Of Vehicles	Prob.	Cum. Prob.	Tag Nos.
1	0-1	27	0.216	0.216	000 - 215
2	1-2	27	0.216	0.432	216 - 431
3	2-3	25	0.2	0.632	432 - 631
4	3-4	8	0.064	0.696	632 - 695
5	4-5	12	0.096	0.792	696 - 791
6	5-6	6	0.048	0.84	792 - 839
7	6-7	9	0.072	0.912	840 - 911
8	7-8	2	0.016	0.928	912 - 927
9	8-9	3	0.024	0.952	928 - 951
10	9-10	1	0.008	0.96	952 - 959
11	10-11	0	-	-	-

12	11-12	0	-	-	-
13	12-13	1	0.008	0.968	960 - 967
14	13-14	0	-	-	-
15	14-15	0	-	-	-
16	15-16	0	-	-	-
17	16-17	2	0.016	0.984	968 - 983
18	17-18	0	-	-	-
19	18-19	0	-	-	-
20	19-20	1	0.008	0.992	984 - 991
21	20-21	0	-	-	-
22	21-22	0	-	-	-
23	22-23	0	-	-	-
24	23-24	0	-	-	-
25	24-25	0	-	-	-
26	25-26	0	-	-	-
27	26-27	0	-	-	-
28	27-28	0	-	-	-
29	28-29	0	-	-	-
30	29-30	1	0.008	1	992 - 999
TOTAL		125			

ARRIVAL DISTRIBUTION FOR F ₃					
S. No	Inter Arrival Time(min)	No. of Vehicles	Prob.	Cum. Prob.	Tag Nos.
1	0-1	23	0.211	0.211	000 - 210
2	1-2	25	0.229	0.44	211 - 439
3	2-3	12	0.11	0.55	440 - 549
4	3-4	12	0.11	0.66	550 - 659
5	4-5	11	0.101	0.761	660 - 760
6	5-6	8	0.073	0.834	761 - 833
7	6-7	6	0.056	0.89	834 - 889
8	7-8	2	0.018	0.908	890 - 907
9	8-9	1	0.009	0.917	908 - 916
10	9-10	2	0.018	0.935	917 - 934
11	10-11	0	-	-	-
12	11-12	2	0.018	0.953	935 - 952
13	12-13	0	-	-	-
14	13-14	0	-	-	-
15	14-15	1	0.01	0.963	953 - 962
16	15-16	0	-	-	-
17	16-17	0	-	-	-
18	17-18	0	-	-	-
19	18-19	1	0.009	0.972	963 - 971
20	19-20	1	0.009	0.981	972 - 980
21	20-21	0	-	-	-
22	21-22	0	-	-	-
23	22-23	0	-	-	-
24	23-24	0	-	-	-
25	24-25	0	-	-	-
26	25-26	0	-	-	-
27	26-27	1	0.01	0.991	981 - 990
28	27-28	1	0.009	1	991 - 999
29	28-29	0	-	-	-
30	29-30	0	-	-	-

TOTAL	109
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ARRIVAL DISTRIBUTION FOR F ₄					
S. No.	Inter Arrival Time(min)	No. of Vehicles	Prob.	Cum. Prob.	Tag Nos.
1	0-1	12	0.15	0.15	000 - 149
2	1-2	11	0.138	0.288	150 - 287
3	2-3	9	0.112	0.4	288 - 399
4	3-4	12	0.15	0.55	400 - 549
5	4-5	7	0.088	0.638	550 - 637
6	5-6	7	0.088	0.726	638 - 725
7	6-7	7	0.088	0.814	726 - 813
8	7-8	3	0.037	0.851	814 - 850
9	8-9	1	0.013	0.864	851 - 863
10	9-10	0	-	-	-
11	10-11	0	-	-	-
12	11-12	2	0.025	0.889	864 - 888
13	12-13	2	0.024	0.913	889 - 912

14	13-14	0	-	-	-
15	14-15	0	-	-	-
16	15-16	0	-	-	-
17	16-17	0	-	-	-
18	17-18	3	0.037	0.95	913 - 949
19	18-19	0	-	-	-
20	19-20	1	0.013	0.963	950 - 962
21	20-21	0	-	-	-
22	21-22	1	0.012	0.975	963 - 974
23	22-23	0	-	-	-
24	23-24	1	0.013	0.988	975 - 987
25	24-25	0	-	-	-
26	25-26	0	-	-	-
27	26-27	1	0.012	1	988 - 999
28	27-28	0	-	-	-
29	28-29	0	-	-	-
30	29-30	0	-	-	-
TOTAL		80			

III. Service Distribution Tables for F₁, F₂, F₃, F₄

Service distribution for F₁

S. No.	Service Time (min)	No. of Vehicles	Prob.	Cum. Prob.	Tag Nos.
1	1	92	0.46	0.46	000 - 459
2	1.5	46	0.23	0.69	460 - 689
3	2	26	0.13	0.82	690 - 819
4	2.5	20	0.1	0.92	820 - 919
5	3	16	0.08	1	920 - 999
Total		200			

Service distribution for F₂

S. No.	Service Time (min)	No. of Vehicles	Prob.	Cum. Prob.	Tag nos.
1	1	41	0.328	0.328	000 - 327
2	1.5	32	0.256	0.584	328 - 583
3	2	22	0.176	0.76	584 - 759
4	2.5	14	0.112	0.872	760 - 871
5	3	16	0.128	1	872 - 999
Total		125			

Service distribution for F₃

S. No.	Service Time (min)	No. of Vehicles	Prob.	Cum. Prob.	Tag Nos.
1	1	34	0.312	0.312	000 - 311
2	1.5	26	0.239	0.551	312 - 550
3	2	20	0.183	0.734	551 - 733
4	2.5	11	0.101	0.835	734 - 834
5	3	18	0.165	1	835 - 999
Total		109			

Service distribution for F₄

S. No.	Service Time (min)	No. of Vehicles	Prob.	Cum. Prob.	Tag Nos.
1	1	26	0.325	0.325	000 - 324
2	1.5	14	0.175	0.5	325 - 449
3	2	10	0.125	0.625	500 - 624
4	2.5	22	0.275	0.9	625 - 899
5	3	8	0.1	1	900 - 999
Total		80			

IV. Calculation-Simulation Tables for F₁, F₂, F₃, F₄

SIMULATION TABLE FOR F₁

S. No	Random No.	Inter Arrival Time (min)	Actual Arrival Time (min)	Random No.	Service Begins	Service Time (min)	Service Ends	Waiting time		Queue Length
								Customer	Server	
1	218	1	10:31:00	741	10:31:00	2	10:33:00	-	-	-
2	112	1	10:32:00	766	10:33:00	2	10:35:00	00:01:00	-	1
3	711	3	10:35:00	27	10:35:00	1	10:36:00	-	-	-
4	655	3	10:38:00	70	10:38:00	1	10:39:00	-	00:02:00	-
5	419	1	10:39:00	648	10:39:00	1.5	10:40:30	-	-	-
6	354	1	10:40:00	956	10:40:30	3	10:43:30	00:00:30	-	1
7	174	1	10:41:00	238	10:43:30	1	10:44:30	00:02:30	-	1
8	910	5	10:46:00	912	10:46:00	2.5	10:48:30	-	00:01:30	-
9	76	1	10:47:00	480	10:48:30	1.5	10:50:00	00:01:30	-	1
10	349	1	10:48:00	558	10:50:00	1.5	10:51:30	00:02:00	-	1
11	129	1	10:49:00	917	10:51:30	2.5	10:54:00	00:02:30	-	1
12	439	2	10:51:00	403	10:54:00	1	10:55:00	00:03:00	-	1
13	380	1	10:52:00	932	10:55:00	3	10:58:00	00:03:00	-	1
14	498	2	10:54:00	13	10:58:00	1	10:59:00	00:04:00	-	1
15	134	1	10:55:00	838	10:59:00	2.5	11:01:30	00:04:00	-	1
16	59	1	10:56:00	635	11:01:30	1.5	11:03:00	00:05:30	-	1
17	966	8	11:04:00	476	11:04:00	1.5	11:05:30	-	00:01:00	-
18	761	3	11:07:00	525	11:07:00	1.5	11:08:30	-	00:01:30	-
19	850	4	11:11:00	472	11:11:00	1.5	11:12:30	-	00:02:30	-
20	697	3	11:14:00	364	11:14:00	1	11:15:00	-	00:01:30	-
21	579	2	11:16:00	576	11:16:00	1.5	11:17:30	-	00:01:00	-
22	636	2	11:18:00	44	11:18:00	1	11:19:00	-	00:00:30	-
23	416	1	11:19:00	793	11:19:00	2	11:21:00	-	-	-
24	35	1	11:20:00	553	11:21:00	1.5	11:22:30	00:01:00	-	1
25	913	6	11:26:00	105	11:26:00	1	11:27:00	-	00:03:30	-
26	582	2	11:28:00	133	11:28:00	1	11:29:00	-	00:01:00	-
27	628	2	11:30:00	572	11:30:00	1.5	11:31:30	-	00:01:00	-
28	752	3	11:33:00	90	11:33:00	1	11:34:00	-	00:01:30	-
29	897	5	11:38:00	163	11:38:00	1	11:39:00	-	00:04:00	-
30	232	1	11:39:00	734	11:39:00	2	11:41:00	-	-	-
31	218	1	11:40:00	280	11:41:00	1	11:42:00	00:01:00	-	1
32	365	1	11:41:00	74	11:42:00	1	11:43:00	00:01:00	-	1
33	592	2	11:43:00	304	11:43:00	1	11:44:00	-	-	-
34	394	1	11:44:00	620	11:44:00	1.5	11:45:30	-	-	-
35	195	1	11:45:00	292	11:45:30	1	11:46:30	00:00:30	-	1
36	211	1	11:46:00	669	11:46:30	1.5	11:48:00	00:00:30	-	1
37	747	3	11:49:00	826	11:49:00	2.5	11:51:30	-	00:01:00	-
38	867	5	11:54:00	958	11:54:00	3	11:57:00	-	00:02:30	-
39	906	5	11:59:00	188	11:59:00	1	12:00:00	-	00:02:00	-
40	643	2	12:01:00	967	12:01:00	3	12:04:00	-	00:01:00	-
41	183	1	12:02:00	203	12:04:00	1	12:05:00	00:02:00	-	1
42	188	1	12:03:00	841	12:05:00	2.5	12:07:30	00:02:00	-	1
43	679	3	12:06:00	567	12:07:30	1.5	12:09:00	00:01:30	-	1
44	206	1	12:07:00	119	12:09:00	1	12:10:00	00:02:00	-	1
45	729	3	12:10:00	526	12:10:00	1.5	12:11:30	-	-	-
46	344	1	12:11:00	38	12:11:30	1	12:12:30	00:00:30	-	1
47	543	2	12:13:00	516	12:13:00	1.5	12:14:30	-	00:00:30	-
48	309	1	12:14:00	403	12:14:30	1	12:15:30	00:00:30	-	1
49	227	1	12:15:00	345	12:15:30	1	12:16:30	00:00:30	-	1
50	483	2	12:17:00	385	12:17:00	1	12:18:00	-	00:00:30	-
		107					77	00:42:30	00:30:00	23

1. Average queue length = 23/50 = 0.46.
2. Average waiting time of a customer = 42.5/50 = 0.85 minutes.
3. Average service time = 77/50 = 1.54 minutes.
4. Time A customer spends in the system = 0.85 + 1.54 = 2.39 minutes.
5. Average waiting time of a server = 30/50 = 0.6 minutes.
6. Average arrival time = 107/50 = 2.14 minutes.

SIMULATION TABLE FOR F2

S. No	Random No.	Inter Arrival Time (min)	Actual Arrival Time (min)	Random No.	Service Begins	Service Time (min)	Service Ends	Waiting time		Queue Length
								Customer	Server	
1	722	5	10:48:00	232	10:48:00	1	10:49:00	-	-	-
2	116	1	10:49:00	457	10:49:00	1.5	10:50:30	-	-	-
3	508	3	10:52:00	546	10:52:00	1.5	10:53:30	-	00:01:30	-
4	554	1	10:53:00	248	10:53:30	1	10:54:30	00:00:30	-	1
5	84	1	10:54:00	504	10:54:30	1.5	10:56:00	00:00:30	-	1
6	118	1	10:55:00	292	10:56:00	1	10:57:00	00:01:00	-	1
7	767	5	11:00:00	618	11:00:00	2	11:02:00	-	00:03:00	-
8	189	1	11:01:00	220	11:02:00	1	11:03:00	00:01:00	-	1
9	338	2	11:03:00	471	11:03:00	1.5	11:04:30	-	-	-
10	814	6	11:09:00	627	11:09:00	2	11:11:00	-	00:04:30	-
11	351	2	11:11:00	823	11:11:00	2.5	11:13:30	-	-	-
12	964	13	11:24:00	527	11:24:00	1.5	11:25:30	-	00:10:30	-
13	843	7	11:31:00	182	11:31:00	1	11:32:00	-	00:05:30	-
14	876	7	11:38:00	638	11:38:00	2	11:40:00	-	00:06:00	-
15	874	7	11:45:00	147	11:45:00	1	11:46:00	-	00:05:00	-
16	952	10	11:55:00	320	11:55:00	1	11:56:00	-	00:09:00	-
17	476	3	11:58:00	822	11:58:00	2.5	12:00:30	-	00:02:00	-
18	841	7	12:05:00	633	12:05:00	2	12:07:00	-	00:04:30	-
19	943	9	12:14:00	548	12:14:00	1.5	12:15:30	-	00:07:00	-
20	342	2	12:16:00	344	12:16:00	1.5	12:17:30	-	00:00:30	-
21	682	4	12:20:00	461	12:20:00	1.5	12:21:30	-	00:02:30	-
22	852	7	12:27:00	319	12:27:00	1	12:28:00	-	00:05:30	-
23	112	1	12:28:00	483	12:28:00	1.5	12:29:30	-	-	-
24	580	3	12:31:00	517	12:31:00	1.5	12:32:30	-	00:01:30	-
25	928	9	12:40:00	63	12:40:00	1	12:41:00	-	00:07:30	-
26	695	4	12:44:00	229	12:44:00	1	12:45:00	-	00:03:00	-
27	593	3	12:47:00	797	12:47:00	2.5	12:49:30	-	00:02:00	-
28	804	6	12:53:00	562	12:53:00	1.5	12:54:30	-	00:03:30	-
29	221	2	12:55:00	66	12:55:00	1	12:56:00	-	00:00:30	-
30	837	6	1:01:00	914	01:01:00	3	01:04:00	-	00:05:00	-
31	705	5	1:06:00	511	01:06:00	1.5	01:07:30	-	00:02:00	-
32	68	1	1:07:00	134	01:07:30	1	01:08:30	00:00:30	-	1
33	129	1	1:08:00	657	01:08:30	2	01:10:30	00:00:30	-	1
34	597	3	1:11:00	602	01:11:00	2	01:13:00	-	00:00:30	-
35	467	3	1:14:00	511	01:14:00	1.5	01:15:30	-	00:01:00	-
36	543	3	1:17:00	504	01:17:00	1.5	01:18:30	-	00:01:30	-
37	41	1	1:18:00	132	01:18:30	1	01:19:30	00:00:30	-	1
38	30	3	1:21:00	946	01:21:00	3	01:24:00	-	00:01:30	-
39	999	30	1:51:00	579	01:51:00	1.5	01:52:30	-	00:27:00	-
40	840	7	1:58:00	262	01:58:00	1	01:59:00	-	00:05:30	-
41	812	6	2:04:00	787	02:04:00	2.5	02:06:30	-	00:05:00	-
42	153	1	2:05:00	331	02:06:30	1.5	02:08:00	00:01:30	-	1
43	364	2	2:07:00	600	02:08:00	2	02:10:00	00:01:00	-	1
44	126	1	2:08:00	318	02:10:00	1	02:11:00	00:02:00	-	1
45	540	3	2:11:00	151	02:11:00	1	02:12:00	-	-	-
46	978	17	2:28:00	647	02:28:00	2	02:30:00	-	00:16:00	-
47	1	1	2:29:00	890	02:30:00	3	02:33:00	00:01:00	-	1
48	494	3	2:32:00	746	02:33:00	2	02:35:00	00:01:00	-	1
49	442	3	2:35:00	995	02:35:00	3	02:38:00	-	-	-
50	135	1	2:36:00	636	02:38:00	2	02:40:00	00:02:00	-	1
		235				82		00:13:00	02:29:30	13

1. Average queue length = $13/50 = 0.26$
2. Average waiting time of a customer = $13/50 = 0.26$ minutes.
3. Average service time = $82/50 = 1.64$ minutes.
4. Time a customer spends in the system = $0.26 + 1.64 = 1.9$ minutes.
5. Average waiting time of a server = $149.5/50 = 2.99$ minutes.
6. Average arrival time = $235/50 = 4.7$ minutes.

SIMULATION TABLE FOR F3

S. No	Random No.	Inter Arrival Time (min)	Actual Arrival Time (min)	Random No.	Service Begins	Service Time (min)	Service Ends	Waiting time		Queue Length
								Customer	Server	
1	589	4	10:47:00	759	10:47:00	2.5	10:49:30	-	-	-
2	830	6	10:53:00	156	10:53:00	1	10:54:00	-	00:03:30	-
3	444	3	10:56:00	426	10:56:00	1.5	10:57:30	-	00:02:00	-
4	642	4	11:00:00	112	11:00:00	1	11:01:00	-	00:02:30	-
5	590	4	11:04:00	853	11:04:00	3	11:07:00	-	00:03:00	-
6	31	1	11:05:00	418	11:07:00	1.5	11:08:30	00:02:00	-	1
7	590	4	11:09:00	422	11:09:00	1.5	11:10:30	-	00:00:30	-
8	304	2	11:11:00	185	11:11:00	1	11:12:00	-	00:00:30	-
9	169	1	11:12:00	857	11:12:00	3	11:15:00	-	-	-
10	573	4	11:16:00	508	11:16:00	1.5	11:17:30	-	00:01:00	-
11	876	7	11:23:00	67	11:23:00	1	11:24:00	-	00:05:30	-
12	216	2	11:25:00	581	11:25:00	3	11:28:00	-	00:01:00	-
13	369	2	11:27:00	90	11:28:00	1	11:29:00	00:01:00	-	1
14	607	4	11:31:00	569	11:31:00	2	11:33:00	-	00:02:00	-
15	822	6	11:37:00	263	11:37:00	1	11:38:00	-	00:04:00	-
16	192	1	11:38:00	368	11:38:00	1.5	11:39:30	-	-	-
17	810	6	11:44:00	612	11:44:00	2	11:46:00	-	00:04:30	-
18	207	1	11:45:00	275	11:46:00	1	11:47:00	00:01:00	-	1
19	747	5	11:50:00	1	11:50:00	1	11:51:00	-	00:03:00	-
20	952	12	12:02:00	888	12:02:00	3	12:05:00	-	00:11:00	-
21	517	4	12:06:00	426	12:06:00	1.5	12:07:30	00:01:00	-	1
22	942	12	12:18:00	927	12:18:00	3	12:21:00	-	00:10:30	-
23	316	2	12:20:00	83	12:21:00	1	12:22:00	00:01:00	-	1
24	423	2	12:22:00	8	12:22:00	1	12:23:00	-	-	-
25	396	2	12:24:00	526	12:24:00	1.5	12:25:30	-	00:01:00	-
26	205	1	12:25:00	282	12:25:30	1	12:26:30	00:00:30	-	1
27	742	5	12:30:00	555	12:30:00	2	12:32:00	-	00:03:30	-
28	795	6	12:36:00	473	12:36:00	1.5	12:37:30	-	00:04:00	-
29	476	4	12:40:00	596	12:40:00	2	12:42:00	-	00:02:30	-
30	14	1	12:41:00	323	12:42:00	1.5	12:43:30	00:01:00	-	1
31	45	1	12:42:00	910	12:43:30	3	12:46:30	00:01:30	-	1
32	655	4	12:46:00	510	12:46:30	1.5	12:48:00	00:00:30	-	1
33	511	4	12:50:00	514	12:50:00	1.5	12:51:30	-	00:02:00	-
34	877	7	12:57:00	537	12:57:00	1.5	12:58:30	-	00:05:30	-
35	2	1	12:58:00	612	12:58:30	2	1:00:30	00:00:30	-	1
36	999	28	1:26:00	555	1:26:00	2	1:28:00	-	00:25:30	-
37	437	2	1:28:00	160	1:28:00	1	1:29:00	-	-	-
38	549	4	1:32:00	679	1:32:00	2	1:34:00	-	00:03:00	-
39	468	4	1:36:00	579	1:36:00	2	1:38:00	-	00:02:00	-
40	55	1	1:37:00	798	1:38:00	2.5	1:40:30	00:01:00	-	1
41	698	5	1:42:00	375	1:42:00	1.5	1:43:30	-	00:01:30	-
42	504	4	1:46:00	628	1:46:00	2	1:48:00	-	00:02:30	-
43	779	6	1:52:00	309	1:52:00	1	1:53:00	-	00:04:00	-
44	647	4	1:56:00	410	1:56:00	1.5	1:57:30	-	00:03:00	-
45	799	6	2:02:00	461	2:02:00	1.5	2:03:30	-	00:04:30	-
46	209	1	2:03:00	945	2:03:30	3	2:06:30	00:00:30	-	1
47	939	10	2:13:00	698	2:13:00	2	2:15:00	-	00:06:30	-
48	477	4	2:17:00	906	2:17:00	3	2:20:00	-	00:02:00	-
49	109	1	2:18:00	347	2:20:00	1.5	2:21:30	00:02:00	00:01:00	1
50	510	4	2:22:00	372	2:22:00	1.5	2:23:30	-	00:00:30	-
		219				87.5		00:13:30	02:09:00	13

1. Average Queue Length = $13/50=0.26$
2. Average waiting time of a customer = $13.5/50=0.27$ minutes.
3. Average service time = $87.5/50=1.75$ minutes.
4. Time a customer spends in the system = $0.27+1.75=2.02$ minutes.
5. Average waiting time of a server = $129/50=4$ minutes.
6. Average arrival time = $219/50=4.4$ minutes.

SIMULATION TABLE FOR F4

S. No	Random No.	Inter Arrival Time (min)	Actual Arrival Time (min)	Random No.	Service Begins	Service Time (min)	Service Ends	Waiting Time		Queue Length
								Customer	Server	
1	624	5	10:58:00	211	10:58:00	1	10:59:00	-	-	-
2	213	2	10:58:00	429	10:58:00	1.5	11:01:30	-	00:01:00	-
3	611	5	11:05:00	364	11:05:00	1.5	11:06:30	-	00:03:30	-
4	241	2	11:07:00	908	11:07:00	3	11:10:00	-	00:00:30	-
5	85	1	11:08:00	870	11:10:00	2.5	11:12:30	00:02:00	-	1
6	959	20	11:28:00	354	11:28:00	1.5	11:29:30	-	00:15:30	-
7	657	6	11:34:00	102	11:34:00	1	11:35:00	-	00:04:30	-
8	98	1	11:35:00	376	11:35:00	1.5	11:36:30	-	-	-
9	875	12	11:47:00	717	11:47:00	2.5	11:49:30	-	00:10:30	-
10	309	3	11:50:00	792	11:50:00	2.5	11:52:30	-	00:00:30	-
11	599	5	11:55:00	62	11:55:00	1	11:56:00	-	00:02:30	-
12	943	18	12:13:00	694	12:13:00	2.5	12:15:30	-	00:17:30	-
13	165	2	12:15:00	205	12:15:30	1	12:16:30	00:00:30	-	1
14	741	7	12:22:00	514	12:22:00	2	12:24:00	-	00:05:30	-
15	943	18	12:40:00	103	12:40:00	1	12:41:00	-	00:16:00	-
16	856	9	12:49:00	367	12:49:00	1.5	12:50:30	-	00:08:00	-
17	562	5	12:54:00	942	12:54:00	3	12:57:00	-	00:03:30	-
18	905	13	01:07:00	863	01:07:00	2.5	01:09:30	-	00:10:00	-
19	481	4	01:11:00	167	01:11:00	1	01:12:00	-	00:01:30	-
20	12	1	01:12:00	908	01:12:00	3	01:15:00	-	-	-
21	626	5	01:17:00	879	01:17:00	2.5	01:19:30	-	00:02:00	-
22	893	13	01:30:00	567	01:30:00	2	01:32:00	-	00:10:30	-
23	285	2	01:32:00	227	01:32:00	1	01:33:00	-	-	-
24	256	2	01:34:00	187	01:34:00	1	01:35:00	-	00:01:00	-
25	922	18	01:52:00	924	01:52:00	3	01:55:00	-	00:17:00	-
26	928	18	02:10:00	401	02:10:00	1.5	02:11:30	-	00:15:00	-
27	191	2	02:12:00	369	02:12:00	1.5	02:13:30	-	00:00:30	-
28	607	5	02:17:00	48	02:17:00	1	02:18:00	-	00:03:30	-
29	256	2	02:19:00	387	02:19:00	1.5	02:20:30	-	00:01:00	-
30	947	18	02:37:00	130	02:37:00	1	02:38:00	-	00:16:30	-
31	754	7	02:44:00	846	02:44:00	2.5	02:46:30	-	00:06:00	-
32	443	4	02:48:00	498	02:48:00	1.5	02:49:30	-	00:01:30	-
33	660	6	02:54:00	198	02:54:00	1	02:55:00	-	00:04:30	-
34	407	4	02:58:00	296	02:58:00	1	02:59:00	-	00:03:00	-
35	84	1	02:59:00	528	02:59:00	2	03:01:00	-	-	-
36	782	7	03:06:00	120	03:06:00	1	03:07:00	-	00:05:00	-
37	105	1	03:07:00	388	03:07:00	1.5	03:08:30	-	-	-
38	811	7	03:14:00	765	03:14:00	2.5	03:16:30	-	00:05:30	-
39	655	6	03:20:00	238	03:20:00	1	03:21:00	-	00:03:30	-
40	530	4	03:24:00	314	03:24:00	1	03:25:00	-	00:03:00	-
41	515	4	03:28:00	3	03:28:00	1	03:29:00	-	00:03:00	-
42	780	7	03:35:00	613	03:35:00	2	03:37:00	-	00:06:00	-
43	438	4	03:39:00	936	03:39:00	3	03:42:00	-	00:02:00	-
44	959	20	03:59:00	609	03:59:00	2	04:00:30	-	00:17:00	-
45	485	4	04:03:00	12	04:03:00	1	04:04:00	-	00:20:00	-
46	550	5	04:08:00	196	04:08:00	1	04:09:00	-	00:04:00	-
47	401	4	04:12:00	405	04:12:00	1.5	04:13:30	-	00:03:00	-
48	126	1	04:13:00	437	04:13:30	1.5	04:15:00	00:00:30	-	1
49	347	3	04:16:00	753	04:16:00	2.5	04:18:30	-	00:01:00	-
50	646	6	04:22:00	663	04:22:00	2.5	04:24:30	-	00:03:30	-
		329				86		00:03:00	04:01:00	3

1. Average Queue length = $3/50=0.06$
2. Average waiting time of a customer = $3/50=0.06$ minutes.
3. Average service time = $86/50=1.72$ minutes.
4. Time a customer spends in the system = $0.06+1.72=1.78$ minutes.
5. Average waiting time of a server = $241/50=4.82$ minutes.
6. Average arrival time = $329/50=6.6$ minutes.

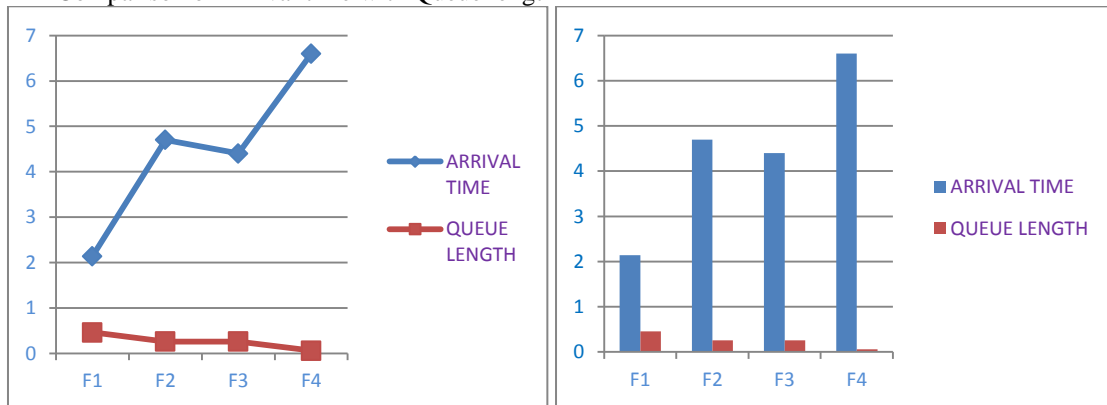
V. Numerical Study

Categories	F1	F2	F3	F4
Arrival Time	2.14	4.7	4.4	6.6
Customer Waiting Time	0.85	0.26	0.27	0.06
Average Service Time	1.54	1.64	1.75	1.72
Queue Length	0.46	0.26	0.26	0.06

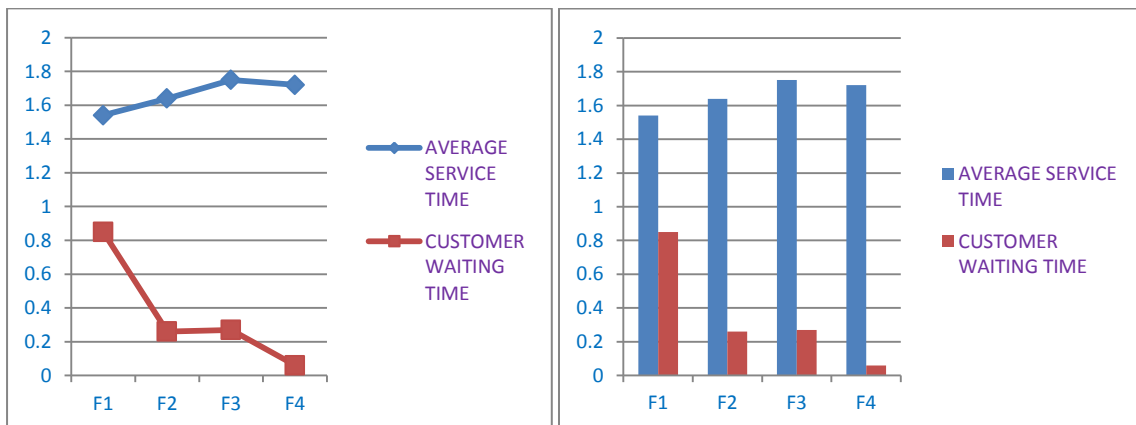
A. Comparison of Arrival time with Customer waiting time



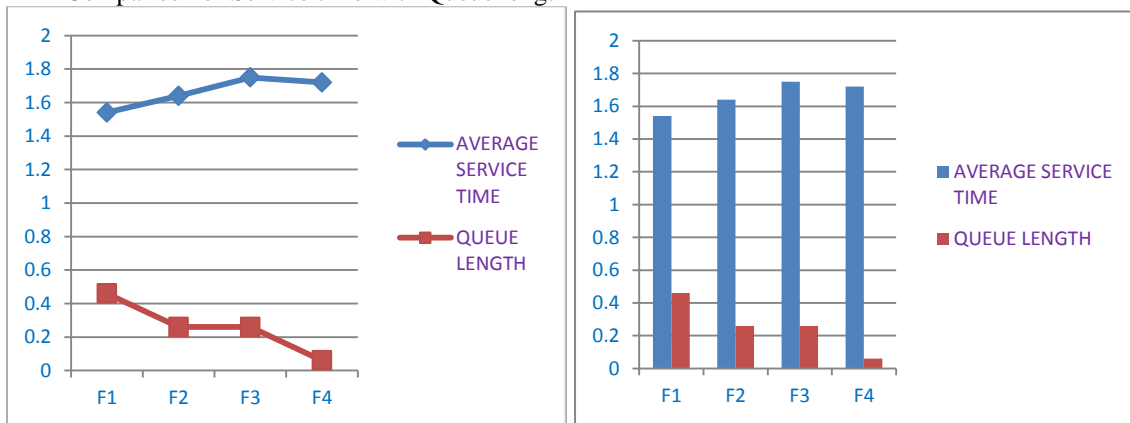
B. Comparison of Arrival time with Queue length



C. Comparison of Service time with Customer waiting time



D. Comparison of Service time with Queue length



VI. Conclusion

In above discussion we calculate the queue length, customer waiting time and average service times in toll gate. It is presented the basic ideas for simulation based approach on mathematical data. The proposed preliminary tollgate simulation table is hoped to be a starting point of my research. The numerical study shows the feasibility of the system. Further simulation studies are required to build a more comprehensive database in toll gate.

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