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SIMULATION EXPERIMENTS FOR INFORMATION NEEDED FOR PROPER ASSIGNMENT OF CALL SERVERS

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Abstract. *As the reduction of CO_2 emission became an established global agenda in 2003, Republic of Korea began imposing the Extended Producer Responsibility (EPR) regulation for manufacturers to properly recycle disposed consumer electronics. In response, electronics manufacturers began implementing the 'Free Visit and Pick-up Service' (FVPS) protocol in 2012 to start-up industries in the Seoul region and FVPS is now being used nationwide in Korea. The expansion of FVPS has caused a sudden increase in electronics disposal collections. However, the capacity of call centers cannot match the rise in demands. This study performed simulation experiments in order to provide the necessary information required for better assignment of limited FVPS call servers as well as the improvement of responses against customer requests.*
Keywords: Free Visit and Pick-up Service, Simulation, Call server assignment

1. **Introduction.** Since 2003, Korean government made the regulation of EPR (Extended Producer Responsibility) which has imposed the responsibility of collection and recycling of disposed end-of-life consumer electronics to manufacturers [1]. According to KERC (Korea Electronics Recycling Cooperative), the increased number of disposed large-size end-of-life consumer electronics has been positively affected by the introduction of EPR regulation [2].

In order to respond to the government's EPR regulation, consumer electronics manufacturers have been introduced a new service of which collecting end-of-life consumer electronics by visiting the location and free pick-up (FVPS: Free Visit and Pick-up Service) from the area of Seoul Metropolitan Government since 2012. The FVPS is positively welcomed by not only consumer electronics manufacturers, consumers, recyclers, but also government because it can solve many existing problems such as consumers' financial burden of disposing fee, moving heavy end-of-life consumer electronics outside, illegal disposing of end-of-life consumer electronics, and illegal exports of E-wastes [3]. However, the improvement of the FVPS is still needed for achieving the stabilized service level by accepting more in-bound calls from consumers without long delay.

The goal of this study is to analyze the necessary number of workers who receives in-bound calls at the FVPS call-center for obtaining desired target service level. The problem considered in this study can be concerned as a typical G/G/k queueing problem with balking and reneging as the customer's behavior of waiting. For this, the model of the FVPS call-center is developed and simulation method is applied properly, and the result of simulation experiments with the real data is proposed and applied to the FVPS call-center to develop a more proper working schedule in advance.

Table 1. Number of disposed large-size end-of-life consumer electronics

Part	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Refrigerator	401	492	521	666	745	767	784	970	960	903	1,093	1,169	1,219
Washing machine	394	395	548	463	492	453	511	520	511	507	572	601	687
TV	334	331	358	469	586	556	553	666	583	1,030	868	1,088	1,187
Total	1,129	1,218	1,427	1,598	1,823	1,776	1,848	2,156	2,054	2,440	2,533	2,858	3,093

2. **Problem Statement and Call-Center Process.**

Currently, a major problem of the FVPS is the incapability to accept all of the requesting in-bound calls due to the limited number of call servers at a certain peak time period. Without the consumers' request, the FVPS cannot identify who wants to dispose the end-of-life consumer electronics at where, when, and how many. The number of in-bound calls from consumers is different depending upon the month, date, and time. Sometimes during the day when many in-bound calls cannot be accepted immediately, there is quite a bit of a wait causing them to quit during the wait. If the FVPS call-center identifies proper number of call servers needed for certain time period in advance, it can very much help to reduce the number of quit in-bound calls before properly accepted.

Currently, consumer who calls at the FVPS call-center first must listen to the recorded welcome and guide message. After then, some in-bound calls are accepted only when call servers are available. When call servers are all busy, there are three choices available for the caller. First, some customers decide not to join the queue and quit the system for not further waiting. Secondly, some are leaving their phone numbers for requesting call-back from the call-center when servers are free, which are called *out-bound calls*. The last is the case that some in-bound calls are still waiting further. Among the in-bound calls that are still waiting, some are accepted when the call servers are finally available.

3. **Call-Center Simulation Model.**

3.1. **Logical model.**

The call-center process in this study is modeled on the basis of Kelton's and Rossetti's logic [4,5]. The key processes shown in Figure 1 are as follows.

1. In-bound calls arrive by the *nonstationary Poisson process* [4]. It is assumed that *Rejection*, the situation where a busy signal is received and the caller is rejected, does not occur. *Entity* represents the call or the corresponding caller in simulation model.
2. Callers receive an initial announcement as if the call engages the system. Callers are automatically handled by the phone system, and there is no limit on the number the system can handle. During the announcement, some callers depart the system voluntarily with an unknown reason, which is called *Balking*. Balking is modeled with a certain probability.
3. Un-balked caller enters into a waiting queue to call a server, which is called the processing queue. It is assumed that there is no concrete capacity limit of the queue.
4. Caller *reneging* occurs when an entity (or caller) joins the processing queue but later decides to depart [5]. To represent reneging, assume that arriving customers who decide not to balk are willing to wait only a limited period of time before they renege from the queue. We will generate this renege tolerance time from a certain reneging distribution inferred from the log data analysis of the call-center. Rossetti [5] can be referred for the logic in detail and the corresponding Arena model.
   - 4-1. Some of reneging callers departing from the queue leave call-back entity with a certain probability, which is called *call-back rate*, while the others depart the system with no action. The call-back entity left in the system is queued in *Out-bound call queue*, until a server picks the call-back number. However, the

entities in the out-bound call queue have a lower priority than the entities in the processing queue.

5. If a call server is available for the next call, the first entity (or caller) in the queues leaves the queue to the requisition process.
6. Entity starts the requisition process by seizing a server (the number of available servers is decreased by 1).
7. It executes the requisition process for a certain time period given by the service time distribution.
8. Hours after, the server is released (the number of available server increased by 1).
9. The entity (or caller) leaves the system.

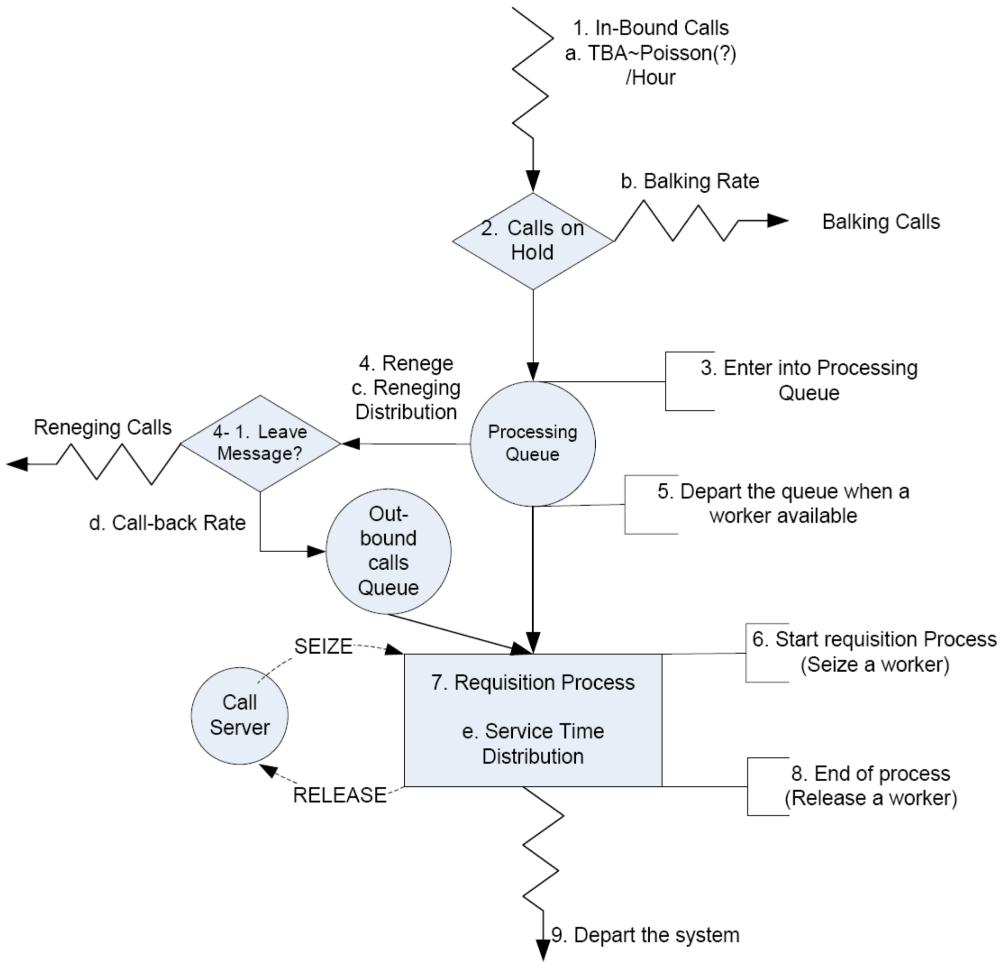

Figure 1. Activity diagram for call-center process

3.2. **Data preparation.** Parameters or statistical distributions (a $\sim$ e in Figure 1) required in the simulation model are inferred from the log data of the call-center in 2015. Each parameter is deducted as follows.

a. In-bound calls arrival rate (Time Between Arrivals): As it is practically hard to establish the nonstationary Poisson process whose arrival rate $\lambda(t)$ varies continuously depending on time t, the piecewise-constant rate function model is applied in this research. With a practical reason, it is assumed that arrivals might be fairly constant over an-hour period but could be quite different in different periods. To generalize the arrival rate for each time period, the in-bound call patterns of the call center were analyzed. Table 2, Table 3, and Table 4 show the number of calls pattern during a day, the number of calls pattern by day of week, and the number of calls by month, in average, respectively.

Therefore, the arrival rate for a certain period can be estimated as follows.

$$\begin{aligned} \textit{Arrival Rate} = & \textit{ average arrival rate of time period}(t) \times \textit{weight factor of day}(d) \\ & \times \textit{weight factor of month}(m) \end{aligned} \tag{1}$$

where t, d, and m represent the time period in day, the day of week, and the month of year, respectively.

b. Balking rate: 16.2% is extracted from the log data in 2015 and applied in this research.
c. Reneging distribution: The call center system records only the number of reneging calls without their time distribution. Therefore, it is assumed that the renege tolerance time is generated from *Exponential* distribution with 65 seconds as μ, since it generates the closest result of the reneging caller's ratio out of all callers [6].
d. Call-back rate: 3.5% like balking rate.
e. Service time distribution: Normal distribution, which has a mean of 172 and a standard deviation of 52, is extracted as service time with post processing time.

TABLE 2. The average number of calls by an-hour period of day

Hour	00~01	01~02	02~03	03~04	04~05	05~06	06~07	07~08	08~09	09~10	10~11	11~12
# of calls	1.3	0.8	0.6	0.5	0.5	0.9	4.3	16.3	109.0	325.3	289.0	252.4
Hour	12~13	13~14	14~15	15~16	16~17	17~18	18~19	19~20	20~21	21~22	22~23	23~24
# of calls	164.6	222.5	209.2	205.7	191.0	145.2	51.3	33.2	17.9	14.5	17.8	2.4

TABLE 3. The average number of calls by day of week

	Monday	Tuesday	Wednesday	Thursday	Friday	Overall average
average # of calls	4143.1	3200.4	3183.9	3092.2	2844.8	3292.9
weight factor	1.26	0.97	0.97	0.94	0.86	1.00

TABLE 4. The number of calls by month

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Overall average
average # of calls	63,894	58,987	77,144	66,035	70,562	83,835	86,994	89,132	74,970	86,429	75,635	76,310	75,827
weight factor	0.84	0.78	1.01	0.87	0.93	1.11	1.15	1.18	0.99	1.14	0.99	1.01	1.00

3.3. **Model verification.** The simulation is modeled and run by using commercial software Arena 14.5. For the verification of the model, we assumed that the number of agents is fixed by date and time period, although the number of workers varies every day in reality. The simulation model was verified by applying the situation of May, July, and November 2015, as the number of inbound calls in May, July and November represent the average level, the highest level, and the lowest level, respectively.

For each test month, 100 replications of simulation were run. With the results, we analyzed the difference between real data and simulation outputs in terms of 3 output measures, shown in Table 5, since these are the only acquirable measures from the call center's log data. Reasoning from the result, it can be argued that the developed simulation model well-reproduces the real call center system, as the gaps between the real data and the simulation result are within an acceptable range.

Table 5. The summary of result on the model verification

	May		July		November	
	Real Data	Simulation Results	Real Data	Simulation Results	Real Data	Simulation results
Balking rate	19.74%	14.37%	17.02%	19.03%	16.56%	17.49%
Reneging rate	7.47%	7.73%	7.47%	9.63%	6.73%	2.96%
Call-back rate	2.80%	2.39%	2.40%	2.77%	2.16%	2.46%

4. **Experimental Results.** In FVPS call-center and also in simulation, the system performance is largely affected by the 2 control variables, the number of in-bound calls and the number of call servers. Then, according to the control variables, the system gives the corresponding performances, which are measured in the utilization of servers and service level. Here, service level is defined as follows,

$$Service\ level = \frac{number\ of\ served\ calls}{total\ number\ of\ inbound\ calls} \times 100(\%) \tag{2}$$

where the served call indicates that the call does not balk nor renege.

To figure out the utilization of call servers and the service level, simulation was conducted 100 times for each combination of the number of in-bound calls and the number of servers. Table 6 and Table 7 show a part of the simulation result in terms of the service level and the utilization of servers, respectively.

Given in-bound call rate, the minimum number of servers for the desired service level can be estimated from Table 6. Also, given in-bound call rate, the minimum number of servers not to exceed the maximum utilization level of servers can be estimated from Table 7. The maximum utilization level of servers is limited to 90% since the percentage allowance in the standard working time is recommended to more than 10% [7]. As a result,

Table 6. The service level according to the in-bound call rate and the number of works (unit: %)

		Number of servers																	
		4	5	6	7	8	9	10	...	26	27	28	29	30	...	37	38	39	40
In-bound call rate per hour	100	78	89	96	98	99	100	100		100	100	100	100	100		100	100	100	100
	150	58	72	82	90	95	98	99		100	100	100	100	100		100	100	100	100
	...																		
	950	11	13	16	19	21	24	27		69	72	74	77	79		92	93	95	96
	1000	10	13	15	18	20	23	25		66	68	71	73	76		89	90	92	93

Table 7. The utilization of servers according to the in-bound call rate and the number of works (unit: %)

		Number of servers																	
		4	5	6	7	8	9	10	...	26	27	28	29	30	...	37	38	39	40
In-bound call rate per hour	100	82	75	65	59	51	46	41		16	15	15	14	14		11	11	11	10
	150	96	92	87	82	74	67	61		24	23	22	21	21		17	16	16	15
	...																		
	950	100	100	100	100	100	100	100		100	100	100	100	100		99	98	97	96
	1000	100	100	100	100	100	100	100		100	100	100	100	100		100	100	99	99

Table 8. Necessary number of call services (utilization level = 0.9)

		In-bound call rate per hour																		
		100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
Service level (%)	80	5	6	8	11	13	16	18	20	23	25	28	30	32	34	37	39	40+	40+	40+
	85	5	7	8	11	13	16	18	20	23	25	28	30	32	34	37	39	40+	40+	40+
	90	6	7	9	11	13	16	18	20	23	25	28	30	32	34	37	39	40+	40+	40+
	95	6	8	10	12	14	16	18	20	23	25	28	30	32	34	37	39	40+	40+	40+

given in-bound call rate, the necessary number of servers for obtaining both desired service level and utilization level simultaneously can be inferred as briefly represented in Table 8. In Table 8, 40+ indicates that more than 40 servers are needed to fulfill the requirement.

5. **Conclusion.** The FVPS, which can help to solve the current problems such as consumers' financial burden of disposal fees and moving heavy end-of-life consumer electronics outside, has been recognized as positive effects by consumers and extensively introduced. However, in order to achieve stabilized level of service, more in-bound calls for requesting the FVPS should be accepted without long delay.

The goal of this study is to analyze the necessary number of call servers who are needed for receiving in-bound calls at the FVPS call-center for obtaining desired service level. For this, the model of the FVPS call-center is developed and simulation method is applied properly. Also, in order to increase the utilization of results from this study, proper number of servers at the call-center is analyzed based upon different situations which are composing with different number of in-bound calls and different targeted service levels (80%, 85%, 90%, and 95%).

This study can provide important information needed to achieve the targeted service level by assigning proper number of servers depended upon the situation. By using the developed information, the FVPS call-center can develop a more proper working and resting plans for each individual server and also can apply it for hiring part-time servers. More advanced FVPS call-center will provide the environment where more requesting of end-of-life consumer electronics' disposal can be accepted.

The results provided by this study are based on the accuracy of simulation model that was developed with limited data only obtained from current process of FVPS call-center, and it is needed to obtain more detailed necessary data for further improvement of simulation model's accuracy.

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