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ON CAPACITY OF PARKING SPACE IN EXPRESSWAY SERVICE AREA

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SYNOPSIS

In this paper, the author presents that the distribution of arrival vehicles for parking is applicable to the Poisson distribution, the distribution of parking durations is most applicable to the Weibull distribution and the relation between the parking demand and the traffic volume is linear, in an expressway service area.

Moreover, the simulation of the parking phenomenon has been carried out by using above results and it has been found that the simulation method affords a more economical and reasonable parking capacity than the turnover-rate method.

Then the auther presented some criteria of parameter for the distribution of parking durations.

1. PREFACE

The parking capacity is generally evaluated by the turnover-rate method (the parking demand is divided by the turnover-rate, one hour/the average parking duration) or by the queuing theory[1),2),3)] (the distribution of arrival vehicles is the Poisson distribution and the distribution of parking durations is the exponential distribution).

The former is assumed that the distribution of parking durations is a regular distribution. This is convenient to evaluate the parking capacity roughly but unreasonable to do preciously, as the parking duration has a frequency distribution in certain range.

The latter is able to evaluate the parking capacity analytically and the Erlang loss formula is very effective in this case, but the distribution of parking durations is not always applicable to the exponential distribution. In fact, the author found that the distribution of parking durations is most applicable to the Weibull distribution as shown in this paper. As the use of the Weibull distribution to the queuing theory make it very difficult to solve the problem analytically, the simulation is carried out in this paper.

The scale of the expressway service area is affected by the parking capacity. In Japan, the evaluation of the precious parking capacity is necessary for the right-of-way cost, the construction cost and the site condition etc..

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2. OBSERVATIONS

Many observation data on the parking phenomena have been obtained in Ootsu Service Area of Meishin Expressway during 1967 8. 5-8. 6 (for Nagoya), in Ashigara Service Area of Toomei Exptessway at 1969 9. 15 (for Nagoya), in Fujigawa Service Area of Toomei Expressway at 1970 10. 10 (for Nagoya) and in Dangoozaka Service Area of Chyuoo Expressway at 1971 10. 24 (for Fujiyoshida).

The observations in Ootsu and Ashigara service areas were carried by manual method recording plate numbers and times, of inflow vehicles at entrance and outflow vehicles at exit of parking place. The others were carried out by using 8 mm cinecameras and 35 mm motor drive cameras, moving at every 2 seconds interval.

At the same time, the through-way traffic volumes were counted. Many data of the Japan Highway Corporation in relation to them were added for next analyses too.

3. ANALYSES

3.1 Desire Ratio of Parking

The relations between the through-way traffic volume and the parking demand are shown at Table 1, Fig. 1 and Fig. 2, and they have the linear relations.

Table 1 Correlation Between Traffic Volume X (vehs/h) and Vehicles Desired Parking Y (vehs/h)

Names of S.A.	For East			For West		
	Regression Equation	Correlation Coefficient	Desire Ratio of Parking	Regression Equation	Correlation Coefficient	Desire Ratio of Parking
Ebina S.A.	Y=0.17X+ 4.14	0.75	17(%)	Y=0.16X− 1.37	0.90	16(%)
Ashigara S.A.	Y=0.23X− 5.14	0.98	23	Y=0.25X− 3.02	0.75	25
Fujigawa S.A.	Y=0.21X− 5.97	0.91	21	Y=0.21X+ 2.92	0.99	21
Makinohara S.A.	Y=0.20X− 7.81	0.98	20	Y=0.20X− 9.32	0.97	20
Hamanako S.A.	Y=0.47X− 5.21	0.95	47	Y=0.51X−20.55	0.91	51
Kamigo S.A.	Y=0.18X+13.56	0.84	18	Y=0.20X+ 8.06	0.96	20
Yooroo S.A.	Y=0.15X− 1.59	0.94	15	Y=0.18X+ 0.32	0.95	18
Taga S.A.	Y=0.21X+ 2.19	0.94	21	Y=0.18X− 3.23	0.94	18
Ootsu S.A.	Y=0.24X+ 8.67	0.89	24	Y=0.29X+17.95	0.91	29
Suita S.A.	Y=0.08X+ 5.79	0.73	8	Y=0.13X− 8.14	0.94	13
Dangoozaka S.A.	Y=0.16X− 6.70	0.90	16	Y=0.20X−14.76	0.87	20

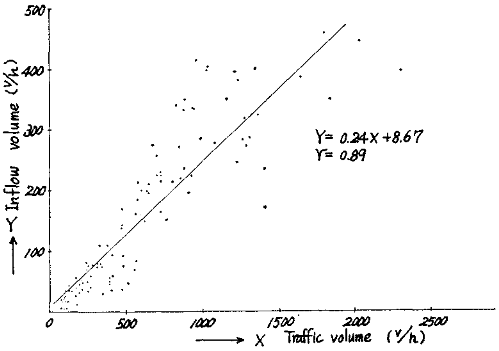

Fig. 1 The Relation between Inflow Volumes into Parking Space and Traffic Volumes on Expressway (at Ootsu Service Area for Nagoya)

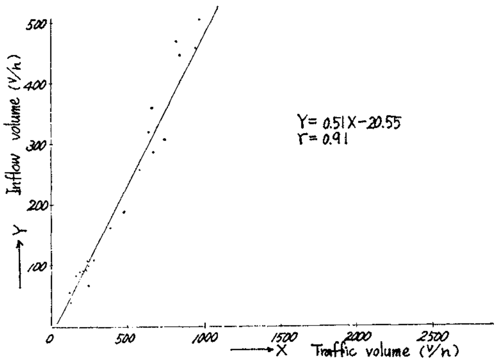

Fig. 2 The Relation between Inflow Volumes into Parking Space and Traffic Volumes on Expressway (at Hamanako Service Area for Nagoya)

The desire ratios of parking in the range of 15% to 25% except the special cases and the average value is about 20%. This fact will enable to presume the parking demand by knowing the through-way traffic volume.

3.2 Arrival Distribution of Parking Demand

If vehicle arrival is random, the arrival distribution is generally presented by the Poisson distribution.[4)5)6)] In this paper, the arrival distribution of parking demand is applicable to the Poisson distribution, too.

They are illustrated in Table 2∼Table 5, Fig. 3 and Fig. 4.

3.3 Distribution of Parking Durations

The data of parking durations were handled by the smoothing method using the mean of three frequencies distincted into five minutes class-width. The frequency distribution of parking durations has a maximum frequency at about 15∼20 minutes. In this case, the exponential distribution is not applicable to such the distribution.

Then, in order to fit to the frequency distribution of parking durations, the Weibull distribution, the gamma distribution and the Erlang distribu-

Table 2 Goodness of Fit of Observed Values to Poisson Distribution
(Ootsu Service Area)

No.	Observed Hour	Arrived Vehicles (v/h)	Average Arrived Vehicles (v/min)	Chi-square Value	Degree of Freedom	Significance Level (%)
1	18:00 ~ 19:00	248	4.13	1.97	5	85
2	19:00 ~ 20:00	329	5.48	5.62	6	15
3	20:00 ~ 21:00	316	5.23	4.42	5	50
4	21:00 ~ 22:00	285	4.75	27.53	5	—
5	22:00 ~ 23:00	227	3.78	6.22	5	30
6	23:00 ~ 24:00	230	3.83	14.67	5	2
7	24:00 ~ 1:00	164	2.73	1.31	3	75
8	1:00 ~ 2:00	170	2.83	5.95	4	20
9	2:00 ~ 3:00	113	1.88	5.13	3	20
10	3:00 ~ 4:00	82	1.37	0.29	2	90
11	4:00 ~ 5:00	74	1.27	2.25	2	35
12	5:00 ~ 6:00	94	1.57	1.48	2	50
13	6:00 ~ 7:00	149	2.48	7.32	4	15
14	7:00 ~ 8:00	277	4.62	11.65	5	4
15	8:00 ~ 9:00	341	5.68	14.53	5	1
16	9:00 ~ 10:00	420	7.00	17.58	5	0.5
17	10:00 ~ 11:00	455	7.58	3.27	6	80
18	11:00 ~ 12:00	386	6.43	3.34	6	75
19	12:00 ~ 13:00	295	4.92	25.44	5	—
20	13:00 ~ 14:00	239	3.98	0.47	5	99.5
21	14:00 ~ 15:00	228	3.80	8.91	5	15
22	15:00 ~ 16:00	216	3.60	3.85	4	45
23	16:00 ~ 17:00	195	3.25	0.91	4	90
24	17:00 ~ 18:00	185	3.10	3.45	4	50

tion were compared by the chi-square test. In this results, it was manifested that the Weibull distribution is most applicable to the frequency distribution of parking durations as shown in Table 6~Table 9.

The two of all applicable situations to the Weibull distribution are illustrated in Fig. 5 and Fig. 6.

4. SOME PROPERTIES OF THE WEIBULL DISTRIBUTION

The probability density function and the cumulative distribution function of the Weibull distribution are presented as follows

$$f(t)=\begin{cases} mt^{m-1}/t_0\cdot\exp(-t^m/t_0) & \text{for } t\geqq 0 \\ 0 & \text{for } t<0 \end{cases} \qquad \cdots\cdots(4.1)$$

$$F(t)=1-\exp(-t^m/t_0) \qquad \cdots\cdots(4.2)$$

here $f(t)$: the probability density function
$F(t)$: the cumulative distribution function
m: the shape parameter
t_0: the scale parameter

The Weibull distribution function has no theoretical basis originally.[8] But this distribution function becomes the exponential distribution at

Table 3 Goodness of Fit of Observed Values to Poisson Distribution

(Ashigara Service Area)

No.	Observed Hour	Arrived Vehicles (v/h)	Average Arrived Vehicles (v/min.)	Chi-square Value	Degree of Freedom	Significance Level (%)
1	24:00 ~ 1:00	56	0.933	1.18	1	30
2	1:00 ~ 2:00	46	0.766	3.57	1	7
3	2:00 ~ 3:00	34	0.566	0.33	1	60
4	6:00 ~ 7:00	44	0.733	1.31	1	22
5	7:00 ~ 8:00	47	0.783	0.04	1	95
6	8:00 ~ 9:00	66	1.100	3.11	2	20
7	9:00 ~ 10:00	109	1.816	1.53	3	70
8	10:00 ~ 11:00	141	2.350	7.77	3	5
9	11:00 ~ 12:00	224	3.733	9.11	5	10
10	12:00 ~ 13:00	317	5.283	8.87	6	20
11	13:00 ~ 14:00	335	5.583	7.21	6	30
12	14:00 ~ 15:00	495	8.250	15.60	7	5
13	15:00 ~ 16:00	452	7.533	3.95	5	60

Table 4 Goodness of Fit of Observed Values to Poisson Distribution

(Fujigawa Service Area)

No.	Observed Hour	Arrived Vehicles (v/h)	Average Arrived Vehicles (v/min.)	Chi-square Value	Degree of Freedom	Significance Level (%)
1	10:00 ~ 11:00	200	3.33	8.87	4	7
2	11:00 ~ 12:00	183	3.05	3.90	5	65
3	12:00 ~ 13:00	248	4.13	0.82	5	97
4	13:00 ~ 14:00	282	4.70	14.31	5	2
5	14:00 ~ 15:00	239	3.98	7.75	6	26
6	15:00 ~ 16:00	190	3.17	3.97	5	60

Table 5 Goodness of Fit of Observed Values to Poisson Distribution

(Dangoozaka Service Area)

No.	Observed Hour	Arrived Vehicles (v/h)	Average Arrived Vehicles (v/min.)	Chi-square Value	Degree of Freedom	Significance Level (%)
1	8:00 ~ 9:00	235	3.92	7.21	5	22
2	9:00 ~ 10:00	281	4.68	13.55	6	4
3	10:00 ~ 11:00	179	2.98	8.49	5	14
4	11:00 ~ 12:00	148	2.47	5.70	4	23

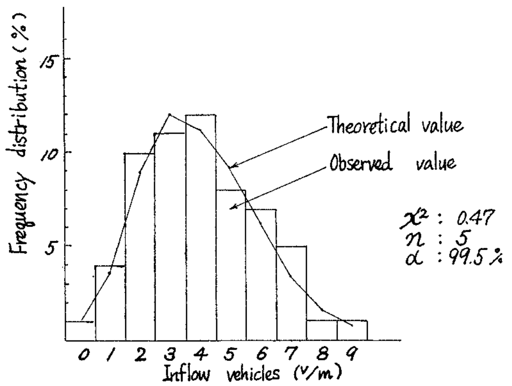

Fig. 3 The Frequency Distribution of Inflow Vehicles at Every one Minute (at Ootsu Service Area for Nagoya) From p.m. 1:00 to p.m. 2:00

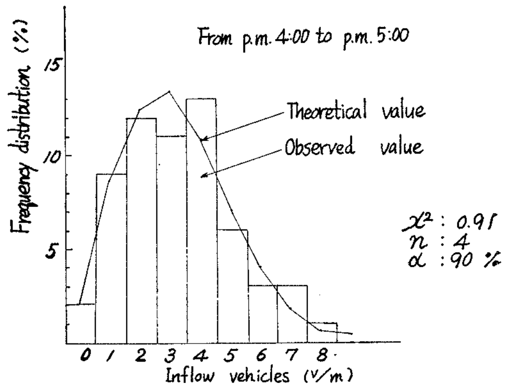

Fig. 4 The Frequency Distribution of Inflow Vehicles at Every one Minute (at Ootsu Service Area for Nagoya)

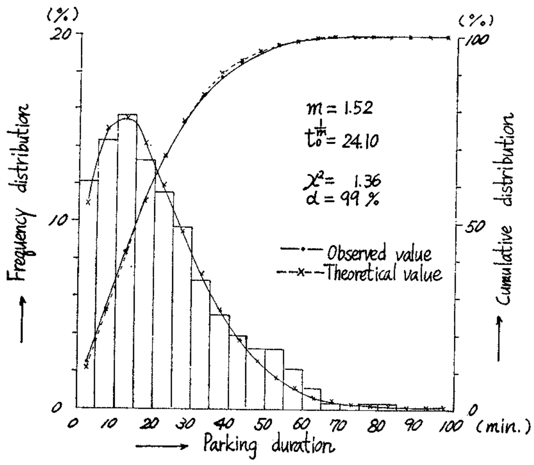

Fig. 5 An Example of Frequency Distribution of Parking Durations (at Ootsu Service Area) From p.m. 6:00 to p.m. 7:00

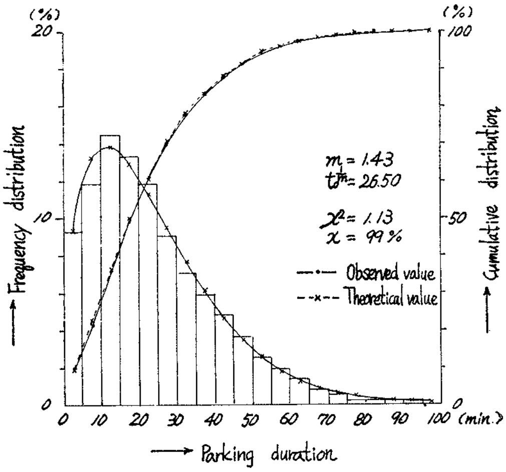

Fig. 6 An Example of Frequency Distribution of Parking Durations (at Ootsu Service Area) From p.m. 8:00 to p.m. 9:00

Table 6 Comparison in Goodness of Fit to Three Distributions (Ootsu Service Area)

No.	Parked Vehicles (v/h)	Recommended Distribution			Gamma Distribution			Erlang Distribution		
		Chi-square Value	Degree of Freedom	Significancc Level	Chi-square Value	Degree of Freedom	Significancc Level	Chi-square Value	Degree of Freedom	Significance Level
1	279	1.64	8	99(%)	7.74	8	50(%)	6.88	8	56(%)
2	347	2.22	10	99	6.83	10	74	17.67	10	7
3	353	1.13	10	99	5.43	10	86	5.14	10	88
4	353	3.38	11	99	4.40	11	95	5.73	11	90
5	278	6.98	10	73	5.35	10	86	11.44	10	33
6	248	9.32	10	50	6.54	10	77	10.15	10	43

7	209	5.05	10	89	10.71	10	39	23.42	10	1
8	203	10.72	9	30	9.73	9	38	10.55	9	30
9	141	2.84	9	97	1.52	9	99	1.52	9	99
10	99	2.82	7	90	11.03	7	15	19.95	7	—
11	89	5.96	7	55	4.40	7	73	3.56	7	90
12	112	6.24	7	51	4.97	7	70	3.15	7	90
13	174	4.30	7	79	5.36	7	62	12.12	7	10
14	306	2.79	8	95	8.79	8	37	15.59	8	5
15	388	4.23	9	89	2.52	9	98	2.81	9	98
16	459	6.87	9	65	3.20	9	95	3.18	9	95
17	485	4.08	9	91	6.33	9	70	7.14	9	63
18	452	3.54	11	98	3.30	11	98	4.74	11	94
19	344	17.33	12	14	40.69	12	—	34.47	12	—
20	305	6.25	12	90	21.95	12	5	13.44	12	35
21	272	4.46	11	95	12.94	11	30	11.41	11	42
22	243	3.25	11	98	8.38	11	68	5.41	11	90
23	247	10.12	10	44	5.93	10	82	8.65	10	70
24	181	10.19	8	26	7.63	8	47	7.30	8	50

Table 7 Comparison in Goodness of Fit to Three Distributions (Ashigara Service Area)

No.	Parked Vehicles (v/h)	Recommended Distribution			Gamma Distribution			Erlang Distribution		
		Chi-square Value	Degree of Freedom	Significance Level	Chi-square Value	Degree of Freedom	Significance Level	Chi-square Value	Degree of Freedom	Significance Level
1	55	0.82	4	93(%)	0.74	4	95(%)	0.71	4	95(%)
2	45	0.15	3	98	0.43	3	93	0.71	3	87
3	38	0.82	2	67	1.56	2	47	2.16	2	35
4	43	0.18	3	98	0.10	3	99	0.18	3	98
5	51	0.71	3	87	1.64	3	65	1.99	3	58
6	67	1.09	4	90	1.44	4	84	2.71	4	61
7	116	1.50	7	98	3.19	7	86	6.85	7	45
8	142	4.72	8	79	6.42	8	60	8.23	8	42
9	236	7.74	10	65	26.10	10	—	18.73	10	5
10	287	15.42	12	22	46.56	12	—	27.02	12	—
11	322	10.79	12	55	34.86	12	—	22.74	12	4
12	342	4.74	11	94	19.44	11	5	13.62	11	26
13	369	3.10	10	98	9.92	10	45	9.00	10	53

Table 8 Comparison in Goodness of Fit to Three Distributions

(Fujigawa Service Area)

No.	Parked Vehicles (v/h)	Recommended Distribution			Gamma Distribution			Erlang Distribution		
		Chi-square Value	Degree of Freedom	Significance Level	Chi-square Value	Degree of Freedom	Significance Level	Chi-square Value	Degree of Freedom	Significance Level
1	193	16.13	9	7(%)	11.14	9	27(%)	9.47	9	40(%)
2	260	7.97	11	72	4.09	11	97	14.32	11	22
3	309	19.32	14	16	52.02	14	—	43.27	14	—
4	362	12.24	14	59	68.96	14	—	63.48	14	—
5	360	6.70	14	94	22.53	14	7	55.59	14	—
6	246	7.72	11	74	6.19	11	86	5.68	11	89

Table 9 Comparison in Goodness of Fit to Three Distributions

(Dangoozaka Service Area)

No.	Parked Vehicles (v/h)	Recommended Distribution			Gamma Distribution			Erlang Dustribution		
		Chi-square Value	Degree of Freedom	Significance Level	Chi-square Value	Degree of Freedom	Significance Level	Chi-square Value	Degree of Freedom	Significance Level
1	240	0.89	7	100(%)	3.31	7	85(%)	7.08	7	43(%)
2	342	6.78	7	46	4.71	7	70	5.78	7	57
3	234	1.54	7	98	2.20	7	95	2.13	7	95
4	171	1.02	5	96	4.11	5	54	3.53	5	62

$m=1$, approximates the normal distribution at $m=3$ or $m=4$ and becomes the regular distribution at $m=\infty$. Namely, this is a probability density function applicable to various frequency distributions.

Assuming that t^m/t_0 in the Eq. (4.1) is $P(t)$, we obtain $p(t)=m/t_0 \cdot t^{m-1}$. Then, replacing m/t_0 to α and $(m-1)$ to β respectively, $p(t)=\alpha t^{\beta}$. Namely, the Weibull distribution is obtained too assuming that a conditional probabitity generating t is proportional to β th powers of t. In this case, the probability density element $f(t)dt$ is illustrated as follows

$$f(t)dt=p(t)\cdot\left\{1-\int_0^t f(t)dt\right\} \quad \cdots\cdots\cdots\cdots\cdots(4.3)$$

i.e. $$f(t)=p(t)\int_t^{\infty} f(t)dt \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(4.4)$$

In the Eq. (4.4), $p(t)$ presents the rate generating an event (duration is t) to remaining events (duration equals and is more than t). This rates are constant in the case of $m=1$, i.e. the exponential distribution, proportional to t in the case of $m=2$ and proportional to t^2 in the case of $m=3$.

In the Weibull distribution, $t_0^{1/m}$ is so important parameter as m and t_0 are. Substituting $t_0^{1/m}$ for t in the Eq. (4.2), we obtain

$$F(t)=1-e^{-1}=0.632 \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(4.5)$$

This means that 63.2% of generating events will have time less than $t_0^{1/m}$ and the Weibull distribution is able to be normalized by dividing t by $t_0^{1/m}$—the time correspond to 63.2% point in the cumulative distribution becomes 1. As the same, substitutiug $t_0^{1/m}$ for t in the Eq. (4.1), the probability density function of the Weibull distribution is standardized.

The mean and the variance of the Weibull distribution function is as follows, respectively

$$\text{the mean} \quad E(t)=t_0^{1/m}\Gamma(1+1/m)$$

$$\text{the variance} \quad V(t)=t_0^{2/m}\{\Gamma(1+2/m) -\Gamma^2(1+1/m)\} \cdots\cdots(4.6)$$

5. DETERMINATION OF PARAMETERS IN THE WEIBULL DISTRIBUTION FROM OBSERVED DATA

Although the determination of the parameters in the Weibull distribution by the observed data is seemed to be troublesome and it is so in fact, we can determine the parameters directly and easily by the Weibull probability graph paper.[7] Both the parameters calculated by electronic computer and obtained by the Weibull probability graph paper approached closely. The parameters determined by the former method are illustrated in Table 10~Table 13.

Parameter m scattered around 1.5 almostly.

In the distribution of parking durations, the parameter $t_0^{1/m}$ is more important than the parameter t_0. As described previously, the parameter $t_0^{1/m}$ is the parking duration of the cumulative distribution 63.2% ($t \leqq t_0^{1/m}$).

The more important objection is that the ratio of the mean value for the parameter $t_0^{1/m}$ is about 0.9. The mean value is decided by m and $t_0^{1/m}$ as shown in the Eq. (4.6), therefore $t_0^{1/m}$ is presumed by estimating the mean value of parking durations.

The distribution of parking durations standardized by $t_0^{1/m}$ is illustrated in Fig. 7. The cases of parameter m=1.4, 1.5, 1.6 are compared. Then $p(t)$ standardized by dividing t by the parameter $t_0^{1/m}$ is illustrated in Fig. 7, too. The fact that the distribution of parking durations is applicable to the Weibull distribution means that the starting rate at a certain instant changes in relation with remaining parking vehicles and it is the function of time as illustrated in Fig. 7.

The author wishes to make the proposal as follows in order to presume the distribution of parking durations in the parking place of an expressway service area.

$$\begin{cases} m=1.5 \\ t_0^{1/m}=1.1\bar{t} \end{cases} \qquad \cdots\cdots(4.7)$$

Here, $\bar{t}$ is the average parking duration.

Table 10 Calculated Results of Observed Values in Ootsu Service Area

No.	Observed Hour	Parked Vehicles (v/h)	Average Parking Duration (min.)	Standard Deviation (min.)	Parameter	
					m	$t_0^{1/m}$ (min.)
1	18:00 ~ 19:00	279	20.7	14.5	1.52	24.10
2	19:00 ~ 20:00	347	22.2	16.8	1.47	26.78
3	20:00 ~ 21:00	353	24.1	17.0	1.43	26.50
4	21:00 ~ 22:00	353	22.6	16.7	1.37	24.75
5	22:00 ~ 23:00	278	22.3	17.2	1.31	24.22
6	23:00 ~ 24:00	248	24.4	18.5	1.39	27.83
7	24:00 ~ 1:00	209	24.4	18.5	1.33	26.58
8	1:00 ~ 2:00	203	25.5	18.2	1.42	27.99
9	2:00 ~ 3:00	141	25.7	18.1	1.44	28.35
10	3:00 ~ 4:00	99	24.6	14.9	1.70	27.60
11	4:00 ~ 5:00	89	27.2	19.7	1.40	29.86
12	5:00 ~ 6:00	112	25.3	18.8	1.37	27.68
13	6:00 ~ 7:00	174	19.1	14.8	1.45	23.28
14	7:00 ~ 8:00	306	18.7	13.8	1.53	23.01
15	8:00 ~ 9:00	388	21.2	14.6	1.47	23.45
16	9:00 ~ 10:00	459	19.6	14.0	1.43	21.61
17	10:00 ~ 11:00	485	19.9	14.4	1.48	23.10
18	11:00 ~ 12:00	452	23.0	16.7	1.46	26.50
19	12:00 ~ 13:00	344	28.1	19.4	1.48	31.12
20	13:00 ~ 14:00	305	29.2	18.5	1.62	32.56
21	14:00 ~ 15:00	272	25.0	17.5	1.45	27.55
22	15:00 ~ 16:00	243	28.0	19.3	1.47	30.98
23	16:00 ~ 17:00	247	26.6	18.9	1.55	31.83
24	17:00 ~ 18:00	181	23.4	17.7	1.46	27.99

Table 11 Calculated Results of Observed Values in Ashigara Service Area

No.	Observed Hour	Parked Vehicles (v/h)	Average Parking Duration (min.)	Standard Deviation (min.)	Parameter	
					m	$t_0^{1/m}$ (min.)
1	24:00 ~ 1:00	55	25.4	15.9	1.45	27.99
2	1:00 ~ 2:00	45	27.8	18.2	1.73	31.18
3	2:00 ~ 3:00	38	28.2	15.6	1.70	31.63
4	6:00 ~ 7:00	43	25.7	18.9	2.19	28.97
5	7:00 ~ 8:00	51	21.2	12.3	1.72	23.73
6	8:00 ~ 9:00	67	21.8	21.5	1.64	26.58
7	9:00 ~ 10:00	116	21.0	11.9	1.51	26.05
8	10:00 ~ 11:00	142	24.2	12.5	1.39	26.51
9	11:00 ~ 12:00	236	27.8	12.0	1.50	30.77
10	12:00 ~ 13:00	287	31.3	15.0	1.56	34.80
11	13:00 ~ 14:00	322	29.6	13.7	1.51	32.82
12	14:00 ~ 15:00	342	26.2	16.9	1.63	31.53
13	15:00 ~ 16:00	369	23.8	19.3	1.52	27.57

Table 12 Calculated Results of Observed Values in Fujigawa Service Area

No.	Observed Hour	Parked Vehicles (v/h)	Average Parking Duration (min.)	Standard Deviation (min.)	Parameter	
					m	$t_0^{1/m}$ (min.)
1	10:00 ~ 11:00	193	22.9	17.7	1.30	24.74
2	11:00 ~ 12:00	260	30.2	19.0	1.63	33.76
3	12:00 ~ 13:00	309	36.5	20.8	1.82	41.10
4	13:00 ~ 14:00	362	36.4	20.9	1.81	40.99
5	14:00 ~ 15:00	360	34.8	21.5	1.66	38.89
6	15:00 ~ 16:00	246	28.8	19.7	1.49	31.84

Table 13 Calculated Results of Observed Values in Dangoozaka Service Area

No.	Observed Hour	Parked Vehicles (v/h)	Average Parking Duration (min.)	Standard Deviation (min.)	Parameter	
					m	$t_0^{1/m}$ (min.)
1	8:00 ~ 9:00	240	16.6	12.4	1.45	19.42
2	9:00 ~ 10:00	342	15.8	11.8	1.35	17.25
3	10:00 ~ 11:00	234	17.2	12.1	1.53	20.19
4	11:00 ~ 12:00	171	17.0	11.8	1.60	20.65

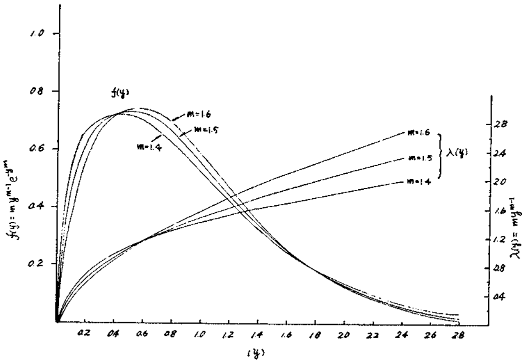

Fig. 7 The Standardized Distribution of Parking Durations $f(y)$ and the Standardized Starting Ratio at a Certain Instant $\lambda(y)$

6. SIMULATION TO EVALUATE PARKING CAPACITY

Some simulations were carried out by the electronic computer FACOM 270/30. The maximum parking demand on two lanes expressway was decided considering the possible capacity, the service level and the desire ratio of parking etc.. The arrival distribution of the parking demand was assumed the Poisson distribution and the distribution of parking durations was assumed the Weibull distribution. The arrival vehicle for parking was assumed that parks in empty parking stall or leaves immediately if there is no empty parking stall at arrival time. The used flow chart is illustrated in Fig. 8.

The relations of the parking demands and the impossible probability for several parking capacities are illustrated in Fig. 9~Fig. 12. The correlation curves are shown all by the smooth curves.

The parking demands which the impossible probability of parking is 0% were calculated for the parking capacities 100 stalls, 150 stalls, 200 stalls and 250 stalls by the simulation method. The results are used to calculate the parking capacities by the turnover-rate method and the comparison are illustrated in Table 14. From the results, it is found that the capacity is less by the simulation method than the turnover-rate method and the capacity is more, the profit is more by the former than the latter.

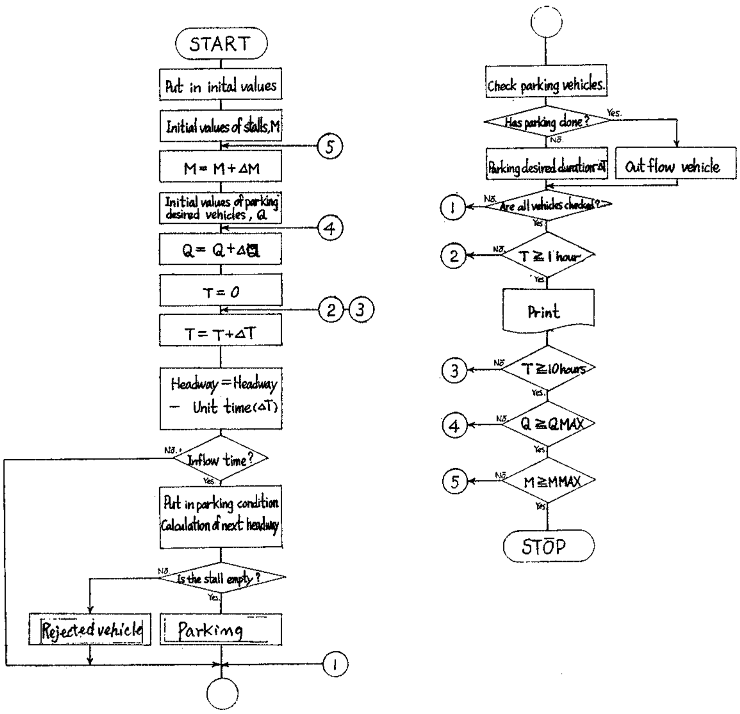

Fig. 8 Simulation Flow Chart

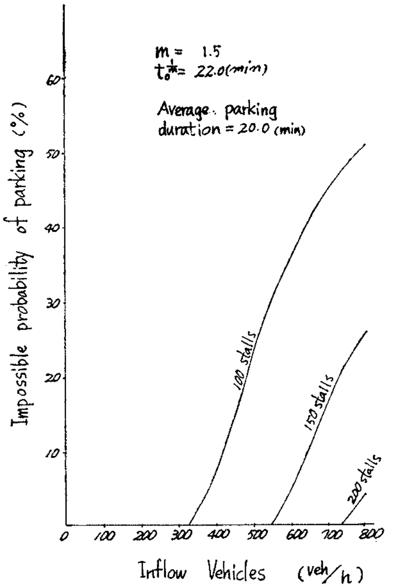

Fig. 9 Impossible Probability of Parking for Capacity

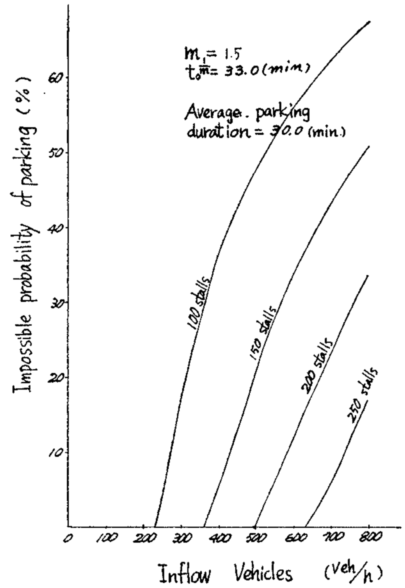

Fig. 10 Impossible Probability of Parking for Capacity

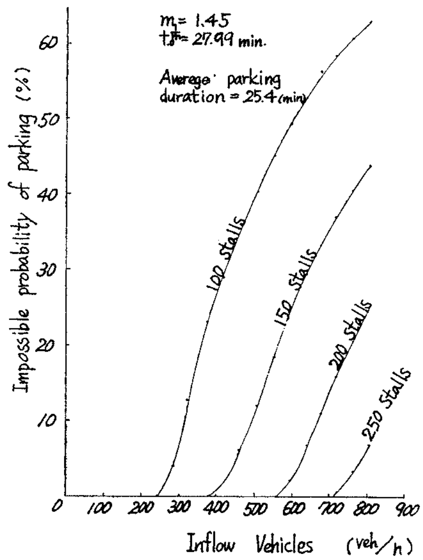

Fig. 11 Impossible Probability of Parking for Capacity

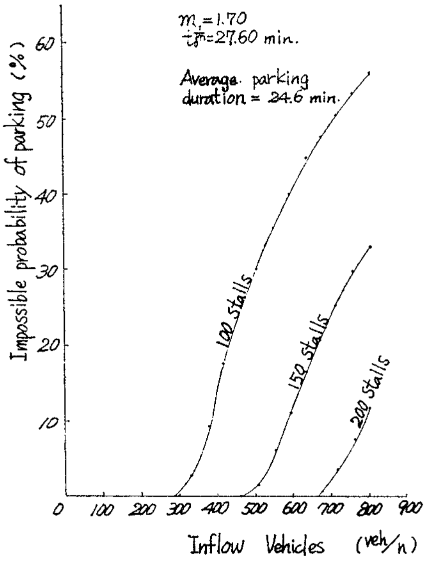

Fig. 12 Impossible Probability of Parking for Capacity

Table 14 Comparison of Parking Capacities in Case which Impossible Probability of Parking is 0%

①	Average Parking duration (min.)	Parameter m	Capacity	①/②	Capacity	①/②	Capacity	①/②	Capacity	①/②
Capacity by turnover-rate method	25.4	1.45	102	1.02	169	1.13	235	1.18	301	1.20
	20.0	1.50	110	1.10	181	1.21	247	1.24	—	—
	30.0	1.50	115	1.15	183	1.22	248	1.24	315	1.26
	24.6	1.70	118	1.18	190	1.27	271	1.36	—	—
② Capacity by simulation method			100		150		200		250	

7. CONCLUSION

From the results of the observations and the analyses in the expressway service areas, the followings were found.

(1) The relation of the parking demand and the traffic volume is linear, and the desire ratio of parking is about 20%.

(2) The distribution of arrival vehicles is applicable to the Poisson distribution.

(3) The distribution of parking durations is most applicable to the Weibull distribution and the representative value of the parameter m is about 1.5 and the parameter $t_0^{1/m}$ is about 1.1 times of the average parking duration.

(4) The parking capacity is evaluated less by the simulation method than by the turnover-rate method and the former is able to presume the impossible probability of parking.

(5) The capacity is more, the profit is more by the simulation method than the turnover-rate method.

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