Development of the Calculating Method for the Loads of Water Consumption in Restaurant

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Abstract

The purpose of this study is to develop a new calculating method for water supply demands in restaurant.

It is difficult to clarify the characteristic of water supply demands and to estimate its volumes in each faucet and cooking equipment in restaurant because the water usage, in each operation or cooking equipment, is various and complicated. However, it is possible to get the data of water consumption in a whole kitchen easily and to clarify the characteristic of water supply demands there.

The authors have advanced the development of calculating method for the time series loads, such as daily, hourly, and instantaneous loads by using a computer. We have proposed the method that applies the unit model as the water consumption of one flat in an apartment, at the CIB/W62 symposium (S. Murakawa, 2002, 2003). Applying the view of a unit model, it is possible to prospect the loads of water consumption in restaurant.

In this paper, the measurements of water consumption were carried out in 21 restaurants, and the basic data on the store characteristics were offered by the management company. First of all, the method of the numerical analysis for a large data recorded the volumes of water consumption in every one- minute over a year was studied. Secondly, the relationship between store characteristics and number of customers was analyzed. In addition, by analyzing the measurement data of water consumption, the calculating unit model of water usage in the kitchen was set up. The time series loads in the restaurants were calculated by using the method that applied the Monte Carlo Simulation technique, and the precision of results were studied as a comparison with the measurement data. As the results, it was shown that the calculating method was effective in restaurants.

Keywords

Water Consumption, Monte Carlo Simulation, Restaurant

1. Introduction

As the calculating method for water supply demands in the buildings of various types, the authors have developed the method and have suggested a part of them, as a case study of apartment houses, on the 28^{th} and 29^{th} International Symposium of CIB/W62, Iasi (Rumania), Ankara (Turkey) [1, 2]. The method is to estimate the demands in the time series such as daily, hourly, and instantaneous loads. The accurancy of applying the Monte Carlo Simulation technique was proved by the calculation of the demands in the time series. Furthermore, the flat unit model, as one flat water supply demands summed up the each fixture usage in a flat, was suggested.

In this paper, the water consumption in the 21 restaurants is studied. It is difficult to clarify the characteristic of water supply demands and to estimate its volumes in each faucet and cooking equipment in a restaurant. However, applying the view of a unit model, it is possible to estimate the loads of water consumption in the restaurants.

2. Outline of the investigation

2.1 Outline of the building

The measurements of water consumption were carried out in the 21 restaurants which are placed in the complex commercial building (that has department, hotel, hall etc.). The outlines of the complex commercial building and the restaurants are shown in Table 1 and Table 2. These restaurants have various floor areas from 66.5 to 781.9 [m2]. Most of the restaurants, except restaurant B and D, use the city gas for the kitchen's heat sauce. Restaurant B and D use the electric power. Also, the most of the restaurants individually use the instantaneous water heater by gas for the hot water supply system.

2.2 Outline of the measurement

We measured water consumptions in each restaurant by setting up water meters to the main pipelines. Pulses from water meters (10L/pulse) were recorded by one minute interval as water consumptions. The measurements were carried out from April 1, 2002 to May 12, 2003.

Table 1 - Outline of the complex commercial building

Location	Hiroshima city
Building use	Department, Hotel, Hall, Restaurant etc.
Lot area	21800 [m^2]
Total floor area	166000 [m^2]
Scale	Hotel zone : 33 stories, 2 basement Commercial zone : 12 stories, 2 basement
Structure	Steel structure (A Part of structure and besement are steel encased reinforced concrete.)
Cold water supply system	Gravity water supply (A part of water supply system is pressurization system)
Elevated tank	For drinking water : 90 [m^3] ×1, For non-drinking service water : 70 [m^3] ×2

In addition, the data of daily water consumptions from April 1, 2000 to March 31, 2002, the daily number of customers from April 1, 2000 to March 31, 2003, and the the store characteristics, such as floor area, number of employees, number of seats, and so on, were offered by the management company.

Table 2 - Outline of the restaurants

Restaurant (food type)	Floor area [m^2]	Kitchen area [m^2]	Number of seats [Seat]	Number of employees*1 [Person]	Kitchen ratio*2	Opening time	Closing time	Time-zone		
								Preparation	Rest	Cleaning
A (Japanese (kaiseki))	211.5	61	60	19	0.29	11:00	22:00	7:30-11:00	15:00-17:00	19:30-22:00
B (Okonomiyaki)	109.0	8	60	13	0.07	11:00	22:30	10:30-11:00	(no rest)	21:30-23:00
C (Japanese food)	279.3	84	142	10	0.30	11:00	23:00	10:00-11:00	15:00-17:00	22:30-23:30
D (Seafood big bowl)	66.5	13	31	11	0.20	11:00	22:00	10:00-11:00	(no rest)	21:00-22:00
E (Japanese (Bar))	136.5	60	64	7	0.44	11:00	23:00	9:30-10:45	15:30-16:30	22:00-23:00
F (Chinese food)	472.9	100	275	19	0.21	11:00	22:00	7:00-11:00	15:00-17:00	22:00-23:30
G (Teppanyaki)	172.5	43	36	14	0.25	11:00	22:30	10:00-11:00	15:00-17:00	22:00-23:00
H (Pasta)	96.3	28	50	6	0.29	11:00	22:00	10:00-11:00	(no rest)	21:30-23:30
I (Churrasco)	781.9	170	164	19	0.22	11:00	22:30	10:00-11:00	16:00-17:00	22:30-23:00
J (Korean (Dakkarubi)	330.4	79	116	13	0.24	11:00	23:00	10:00-11:00	15:00-17:00	23:00-24:00
K (Grilled meat)	165.7	77	105	6	0.46	11:00	23:00	10:00-11:00	15:00-17:00	22:00-23:00
L (Buckwheat noodles)	82.7	29	47	16	0.35	11:00	22:00	9:00-10:00	(no rest)	22:00-22:30
M (Wheat noodles)	87.9	36	60	12	0.41	11:00	21:30	8:00-11:00	(no rest)	21:00-22:00
N (Sushi)	115.7	73	72	12	0.63	11:00	22:30	9:00-11:00	15:00-16:30	22:30-23:30
O (Japanese food)	99.2	41	51	10	0.41	11:00	22:30	10:00-11:00	14:30-17:00	22:30-23:00
P (Pork cutlet)	131.2	47	72	7	0.36	11:00	22:00	10:00-11:00	(no rest)	22:00-23:00
Q (Pasta)	413.2	95	200	29	0.23	11:00	22:00	10:00-11:00	(no rest)	21:30-22:30
R (Curry)	158.3	54	86	9	0.34	11:00	22:00	9:30-11:00	15:30-17:00	21:30-22:30
S (Sandwich)	99.2	37	63	14	0.37	11:00	22:00	10:00-11:00	(no rest)	22:00-23:00
T (Omelet)	181.8	22	94	10	0.12	11:00	21:00	8:00-11:00	15:00-16:00	21:00-22:00
U (Vietnamese food)	277.7	64	84	19	0.23	11:00	23:00	9:45-11:00	(no rest)	23:00-25:00

Notes *1 Number of employees is including the number of part-timers.
*2 Kitchen ratio is a ratio of kitchen area to floor area of a restaurant.

3. Analysis of daily water consumption

The relationship between the daily number of customers and the daily water consumptions in restaurant M is shown in Figure 1 as an example. In the figure, the marked legends are shown by Weekday, from Monday to Friday, and Saturday and Holiday, non working day. However, regression line and correlation coefficient are calculated by using all data. On Saturday and Holiday, according to the increase of the number of customers, water consumptions increase compared with those of Weekday. Therefore, both of the items have a strong relationship with each other. Table 3 shows the regression coefficients and the correlation coefficients that were calculated in each restaurant. The regression coefficients "a" that mean the water consumption per day and per customer are variously valued from 4.48 to 35.45 [L/person/day]. The correlation coefficients show the values from 0.312 to 0.870. These restaurants have the characteristics, such as the turnovers which divide the number of customers by the number of seats are quick. In addition, the payment of the customer per person is low. Therefore, the relationship between the number of customers and the water consumptions is strong because the water consumptions per customer do not change largely.

Table 3 - Regression coefficients and correlation coefficients in each restaurant

Restaurant	The regression coefficients		The correlation coefficients
	a	b	r
A	0.0355	5.24	0.652
B	0.0115	2.94	0.719
C	0.0095	4.02	0.560
D	0.0045	1.48	0.707
E	0.0203	2.30	0.447
F	0.0197	7.53	0.577
G	0.0207	3.32	0.711
H	0.0081	2.23	0.726
I	0.0237	7.99	0.444
J	0.0244	5.33	0.782
K	0.0127	2.20	0.645
L	0.0162	4.12	0.688
M	0.0104	2.35	0.870
N	0.0283	3.94	0.618
O	0.0161	3.42	0.486
P	0.0062	1.96	0.757
Q	0.0093	10.54	0.433
R	0.0166	4.22	0.712
S	0.0170	3.41	0.464
T	0.0164	4.36	0.551
U	0.0054	5.19	0.312

Note : y [m3/day] = a x [person/day] + b

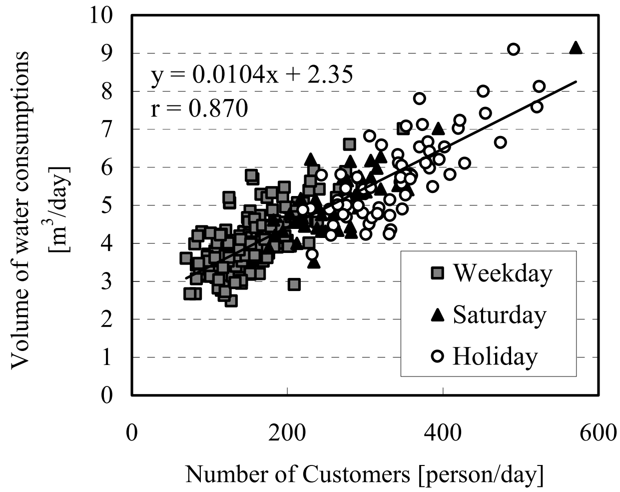


Figure 1 - Relationship between the daily number of customers and the daily water consumptions (Restaurant M)

Based on the number of customers and the floor areas of the restaurants, the water consumption units were calculated in each restaurants. Table 4 shows average value, standard deviation and maximum value of the water consumption units per day. The data of regular holiday in each restaurant were excluded by the calculation.

Table 4 - Water consumption units per day

Restaurant	Water consumption per floor area [L/m^2/day]			Water consumption per customer [L/person/day]		
	Average value	Standard deviation	Maximum value	Average value	Standard deviation	Maximum value
A	33	5.4	51	178	84.8	816
B	42	11.5	96	39	15.0	99
C	20	3.4	34	39	11.3	90
D	38	10.2	82	12	4.3	48
E	32	12.6	94	45	18.8	189
F	26	7.7	79	57	21.5	210
G	34	10.6	80	57	25.0	191
H	37	9.9	81	26	9.6	68
I	18	8.2	52	62	32.6	202
J	25	6.7	62	43	16.4	129
K	21	6.8	48	43	23.5	204
L	95	23.7	174	36	8.9	64
M	51	12.6	104	24	6.5	51
N	53	12.7	95	54	17.7	132
O	58	15.5	101	43	13.1	89
P	24	4.5	39	18	4.6	43
Q	32	7.5	53	62	34.4	258
R	42	9.5	76	52	16.6	147
S	57	30.0	218	51	25.9	234
T	55	25.7	143	32	13.3	77
U	24	6.0	58	29	13.6	104

Focusing on the average values, the water consumptions per floor area are almost in the range of value from 20 to 60 [L/m2/day] excluding restaurant L (95 [L/m2/day]). These values are small in comparison with the value of reference [3] (160 - 200 [L/m2/day]). And the water consumptions per customer are almost in the range of value from 15 to 60 [L/person/day] excluding restaurant A (178 [L/person/day]). Most of the restaurant's values are smaller than the value of reference [3] (50 - 60 [L/person/day]).

4. Analysis of hourly water consumption

4.1 The method of the numerical analysis for water consumption data

First of all, the method of the numerical analysis for a large data which recorded the volumes of water consumption in every one-minute over a year was studied. Figure 2 shows a water consumption data on April 10, 2002 (Wed.) in restaurant I as an example.

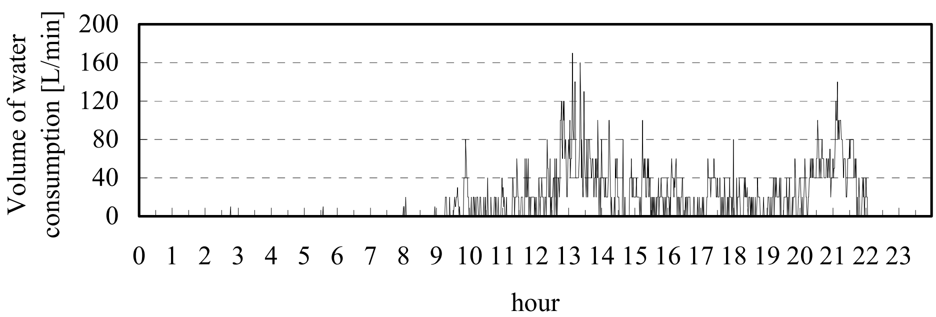


Figure 2 - Measurement results of water consumption (Restaurant I, April 10, 2002 (Wed.))

When the one-minute data are analyzed by a certain interval, the following two cases are considered. As for hourly value, one case is calculating the value by the just interval, for example "7:00 - 8:00". Another case is calculating the value by shifting one minute as the moving average. In this paper, we call the former "the time-zone average", and the latter cases as "the moving average". When the time-zone average value is compared with the moving average value, the maximum of time-zone average value necessarily becomes smaller than that of moving average value. Therefore, the relationship of both average values on the basis of the 5 days water consumption data measured by one-minute interval in the time-zone 7:00 - 24:00 from April 1st (Mon.) to 5th (Fri.) ,2002 was studied. The coefficients of variation were figured up in each restaurant. From the results, 3 restaurants, of which coefficients are the smallest or the biggest or the middle as representative restaurants (restaurant D, F and O), were chosen. Figure 3 shows the ratio of cumulative frequency on the water consumptions in each time-interval; 2, 5, 10, 15, 30, 60 minutes. In the figure, the marked legends show the time-zone average value. The solid lines show the moving value. Table 5 shows the maximum value and failure factor 1 - 50% of the both average values in each time-interval. Compared with the moving average values, the time-zone average values are almost same within the 2 to 15 minute intervals. However, the time-zone average values show the tendency to have a little difference in the 30 and 60 minute intervals. From the Table 5, the difference of the maximum values, such as the time-zone average value and the moving average value, has no tendency by the time-interval. In addition, the values in each failure factor are almost same. Therefore, we decided that the time-zone average value has no problem by using the analysis of the peak value in the certain time interval.

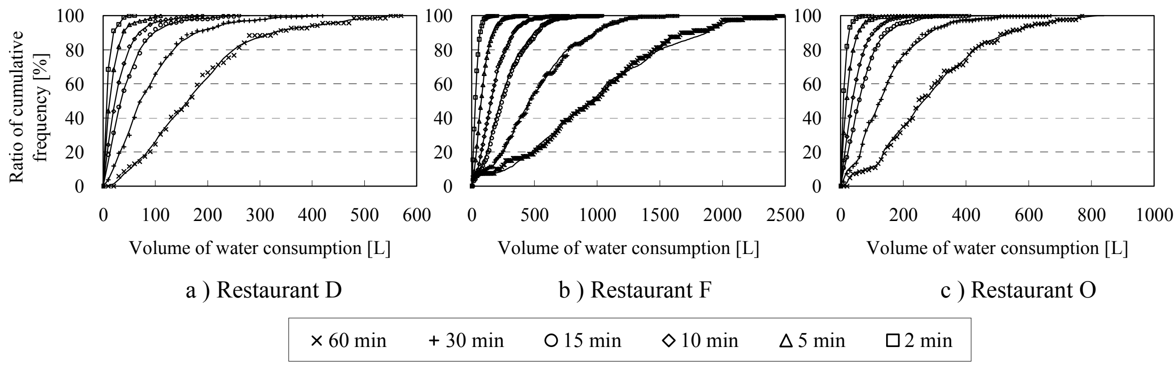


Figure 3 - The ratio of cumulative frequency on the water consumption in each time-interval (Restaurant D, F and O)

Table 5 - The maximum value and failure factor 1 - 50% of the average values in each time-interval

			2 min		5 min		10 min		15 min		30 min		60 min	
			Time-zone avegrege	Moving average	Time-zone avegrege	Moving average	Time-zone avegrege	Moving average	Time-zone avegrege	Moving average	Time-zone avegrege	Moving average	Time-zone avegrege	Moving average
Restaurant D	Maximum [L/min]		30.0	30.0	22.0	24.0	19.0	22.0	17.3	18.7	13.0	14.0	9.2	9.5
	Failure factor [L/min]	1%	25.0	20.0	20.0	20.0	15.0	17.0	15.3	15.3	10.7	11.3	9.2	8.8
		2%	20.0	20.0	18.0	18.0	14.0	14.0	14.0	12.0	10.7	10.7	8.0	8.2
		5%	20.0	20.0	12.0	12.0	10.0	10.0	8.0	8.7	7.7	8.0	7.0	7.2
		10%	10.0	10.0	8.0	8.0	8.0	7.0	6.7	6.7	6.0	6.0	5.7	5.5
		25%	10.0	10.0	6.0	6.0	5.0	5.0	4.7	4.7	4.0	4.3	4.0	4.0
		50%	5.0	5.0	4.0	4.0	3.0	3.0	2.7	2.7	2.7	2.7	2.8	2.8
Restaurant F	Maximum [L/min]		90.0	100.0	88.0	88.0	72.0	77.0	67.3	68.7	51.7	55.0	40.5	41.3
	Failure factor [L/min]	1%	60.0	60.0	58.0	58.0	57.0	57.0	52.7	54.7	44.3	44.7	40.5	38.5
		2%	55.0	55.0	50.0	52.0	50.0	48.0	46.0	46.0	41.7	42.3	36.2	36.7
		5%	45.0	45.0	42.0	44.0	41.0	41.0	38.7	39.3	36.7	38.3	33.2	33.3
		10%	35.0	35.0	36.0	36.0	34.0	34.0	34.0	33.3	33.0	33.0	29.5	31.3
		25%	25.0	25.0	24.0	24.0	25.0	24.0	24.7	24.0	24.3	23.3	23.0	23.5
		50%	15.0	15.0	16.0	16.0	16.0	16.0	16.0	16.0	15.7	15.3	16.3	15.8
Restaurant O	Maximum [L/min]		50.0	50.0	42.0	42.0	34.0	41.0	27.3	34.7	22.3	23.0	12.8	14.0
	Failure factor [L/min]	1%	30.0	30.0	24.0	24.0	20.0	20.0	17.3	18.0	17.0	16.3	12.8	12.8
		2%	25.0	25.0	22.0	20.0	17.0	17.0	16.7	15.3	15.0	14.3	12.7	12.0
		5%	20.0	20.0	16.0	16.0	14.0	14.0	12.7	13.3	11.7	11.3	10.3	10.7
		10%	15.0	15.0	12.0	12.0	11.0	11.0	10.0	10.7	9.3	9.7	8.8	9.0
		25%	10.0	10.0	8.0	8.0	7.0	7.0	6.7	6.7	6.7	6.7	6.8	6.8
		50%	5.0	5.0	4.0	4.0	4.0	4.0	4.0	4.0	4.3	4.3	4.2	4.5

4.2 Hourly water consumption

The investigation on the number of customers was carried out at 3 restaurants on August 14th, 2002 to clarify the relationship between the hourly number of customers and the hourly water consumptions. The ”Going in and out time ” and the number of customers at the representative restaurants were recorded by an investigator and a video camera which was set close to the entrance. Figure 4 shows the hourly fluctuation of the number of customers and the water consumption. In each restaurant, the peak hours of customer occur at the time-zone of 12:00-13:00. However, the peak hours of water consumption are various because the cooking process is different in each restaurant. Table 6 shows the number of customers, the volumes of water consumption and the ratio of water usage in each process time-zone. At the preparation of cooking time-zone, the ratios of water consumption for the daily values are 16 [%] in restaurant E, M, and 24 [%] in restaurant F. At the cleaning time-zone of restaurant F, the volume of water consumption is small comparing with the other restaurants. At the service time-zone, the volumes of water consumption per customer are different between the lunch time and the dinner time in each restaurant. Therefore, the hourly water consumption has little reference to the number of customers in the time-zone. The hourly fluctuation of water consumption receives the influence of cooking process and routine work.

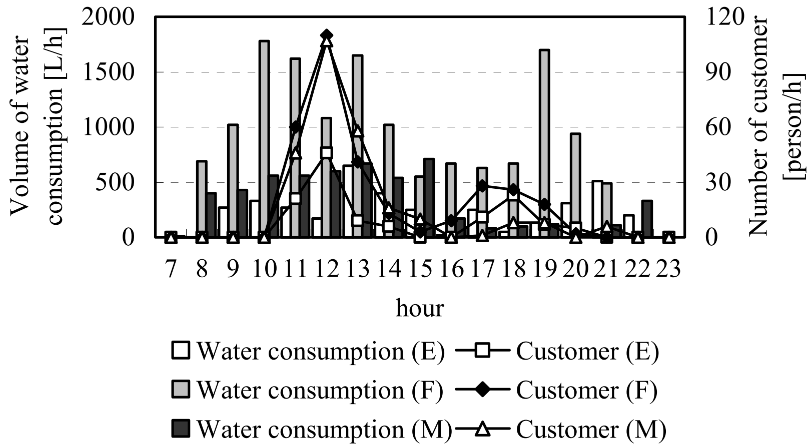


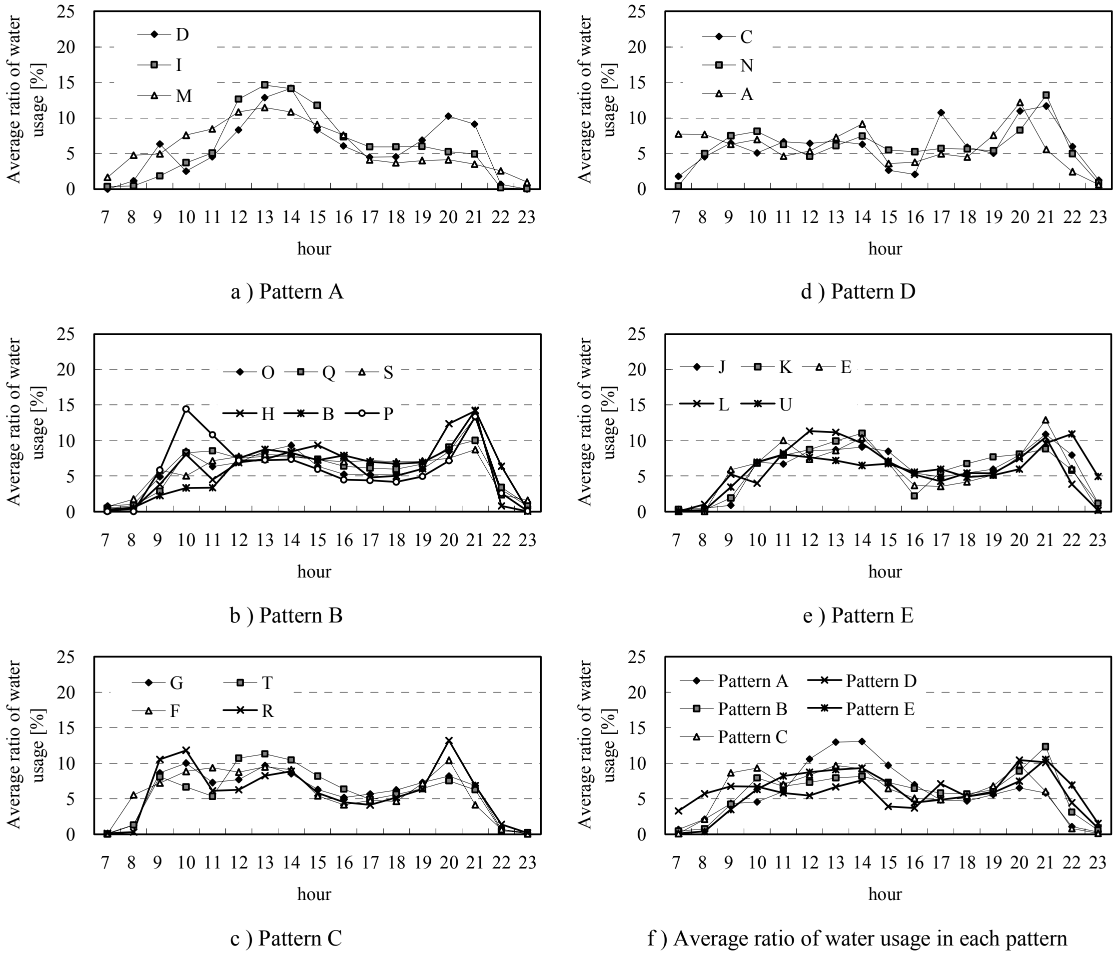
Figure 4 - Hourly number of customers and hourly water consumptions

Table 6 - Number of customers, volume of water consumptions and ratio of water usage in each process time-zone

Time-zone	Number of customer [person]			Volume of water consumption [L]			Ratio of water usage [%]		
	E	F	M	E	F	M	E	F	M
Preparation	0	0	0	600	3500	840	15.7	24.0	15.6
Service (lunch)	82	224	227	1720	5370	2930	45.1	36.9	54.4
Rest	0	0	0	30	0	0	0.8	0.0	0.0
Service (dinner)	46	86	27	750	5650	1180	19.7	38.8	21.9
Cleaning	0	0	6	710	50	440	18.6	0.3	8.2

4.3 Type of the fluctuation pattern for hourly water consumption

As for the calculation of water demands in time series, it is important to typify the fluctuation patterns characterized by the cooking process and routine work in each restaurant. Based on the data of time-zone 7:00-24:00 on “Holiday” in 2002, the fluctuation patterns for hourly water consumptions were studied. The fluctuation patterns of 21 restaurants were shown as the ratio of water usage that divided the hourly volumes of water consumption by the daily volumes of water consumption. The patterns were classified to 5 types by cluster analysis. Figure 5 a)-e) show the restaurants which belonged to the fluctuation patterns of the 5 types in each. Figure 5 f) shows the average ratio of water usage in each pattern. In this paper, we advance to set up the calculating model on the basis of these 5 patterns.



Note : Hourly average ratio of water usage is a percentage to the total water consumption for 17 hours

Figure 5 - The fluctuation patterns of average ratio of water usage

5. The model for calculation

5.1 Behavior of water usage

Calculating the volumes of water consumption in restaurant, it is necessary to set up the condition for water usage model by the worker's behavior in the kitchen . In this paper, the kitchen unit model as the aggregate of some fixtures in the kitchen is set up by using the same idea, such as the flat unit model for cold and hot water consumption in the apartment houses. The Monte Carlo Simulation technique is applied, as in the calculation of apartment houses and office buildings. Therefore, the calculating condition was studied by one-hour time interval, and the average of flow rate, the average of duration time and the frequency of water usage in each time-zone were calculated. Figure 6 and Table 7 show the method of analysis for the behavior of water usage in the kitchen. From the data of water consumption measured by one-minute interval as shown in Figure 6, we decide the change of the behavior of water usage by checking the change of the volumes of water consumption. In other words, when the water flows the constant volume per minute through several minutes, the behavior of water usage continues through the time zone. When the volume of water consumption changes, the behavior finishes or a new behavior startes. We calculated the average of flow rate, the average of duration time and the frequency of water usage in each time-zone as shown in Table 7.

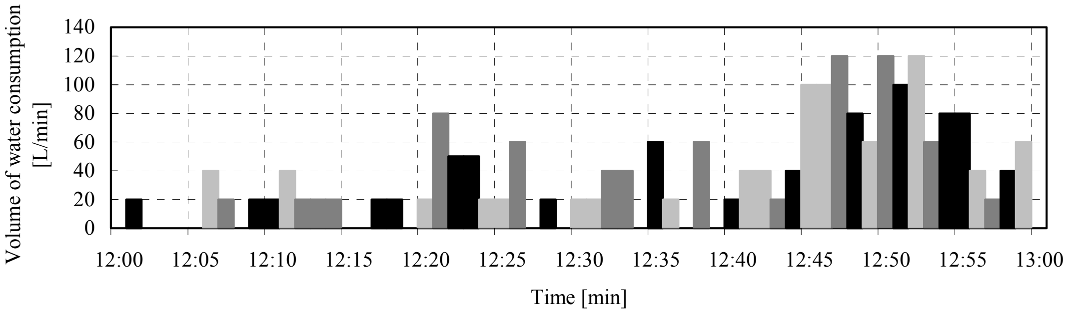


Figure 6 - The method of analysis for the behavior of water usage in the kitchen (Measurement results of water consumption per one minute)

Table 7 - The method of analysis for the behavior of water usage in the kitchen (Calculation for average of flow rate and average of duration time)

Time	[hour]	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12		
	[min]	1	6	7	9	10	11	12	13	14	17	18	20	21	22	23	24	25		
Volume of water consumption [L/min]		20	40	20	20	20	40	20	20	20	20	20	20	80	50	50	20	20		
Cumulative frequency of water usage [time]		1	2	3	4		5	6			7		8	9	10		11		Frequency of water usage [time]	11
Flow rate [L/min]		20	40	20	20		40	20			20		20	80	50		20		Average of flow rate [L/min]	31.8
Duration time per frequency [sec]		60	60	60	120		60	180			120		60	60	120		120		Average of duration time [sec]	92.7

5.2 Analysis of the calculating condition

Figure 7 shows the average of flow rates and the average of duration times in each time-zone as an example of restaurant A. The flow rates are about 15 [L/min] and the duration times are 90-100 [sec] in each time-zone. In the other paper [4], we confirmed that the results which were calculated under two models of 17 conditions in each time-zone and one condition as average of daily time-zone;7:00-24:00, were similar. Therefore, we decided to apply the average value of 17 time-zone as the calculating condition in each restaurant by thinking the simplification model. Figure 8 shows the average flow rates and the average duration times in each restaurant. The average flow rates are various because the floor area and cooking equipment are differed. However, the behavior of water usage on certain fixture did not have big difference. Therefore, we decided the standard values for calculation from the data of some restaurants where the floor scales were small and its water consumptions were small. As the results, the standard models were set up as follows. The average flow rate is 13 [L/min] and the average duration time is 95 [sec], from the data of restaurant D, H, M and S. On the basis of these values, the frequency of water usage was calculated by dividing the daily volume of water consumption by the volume of water consumption per frequency (13 [L/min] x 95 [sec] / 60 [sec]).

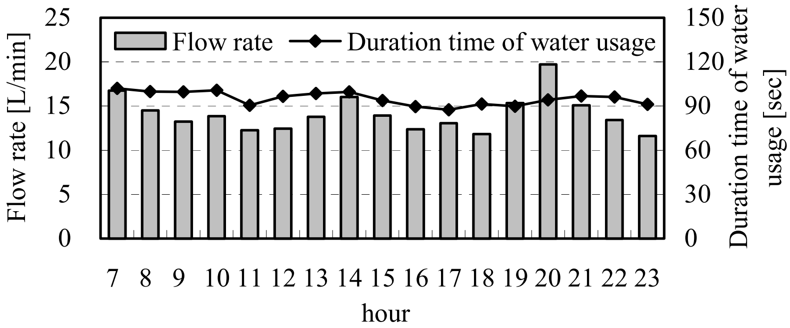


Figure 7 - Average of flow rates and average of duration times in each time-zone (Restaurant A)

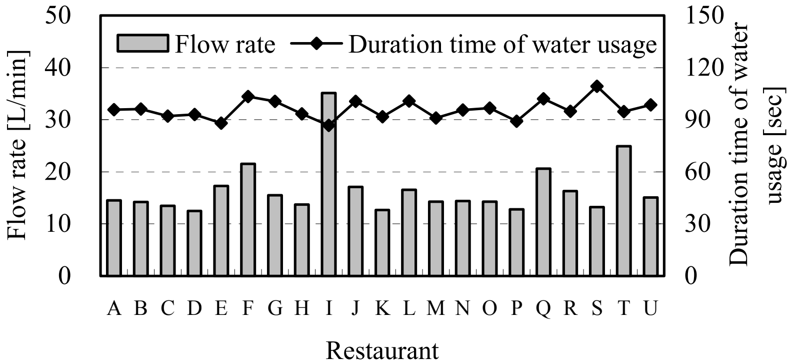


Figure 8 - Average of flow rates and average of duration times in each restaurant

6. Simulation of water consumption in the restaurants

6.1 Calculating model of the restaurants

Table 8 shows the calculating model of the restaurants on holiday. The frequency of water usage per day is divided into the each frequency of hourly time-zone by using the 5 fluctuation patterns of water usage, shown in Figure 5 f), as the model of frequency. The distributions of flow rate and duration time are adapted by the hyper exponential distribution, shown in Figure 9.

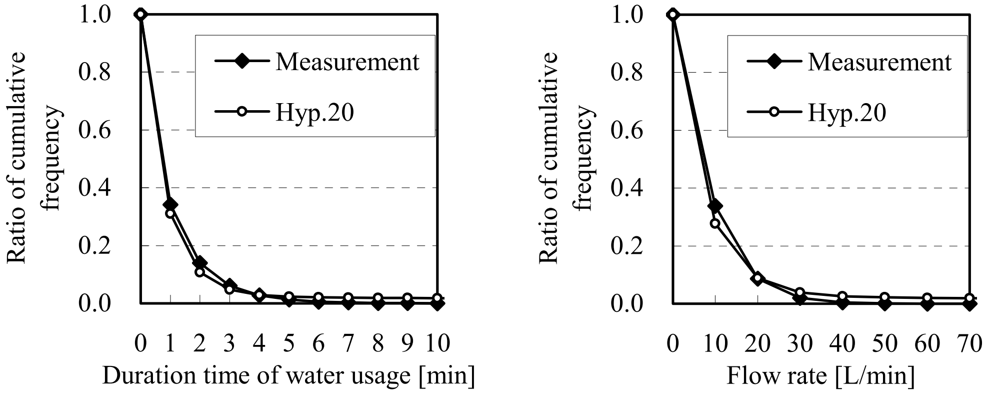


Figure 9 - Ratio of cumulative frequency of the duration time and the flow rate

Table 8 - Calculating model of the restaurants on holiday
; on Sundays including the national holidays

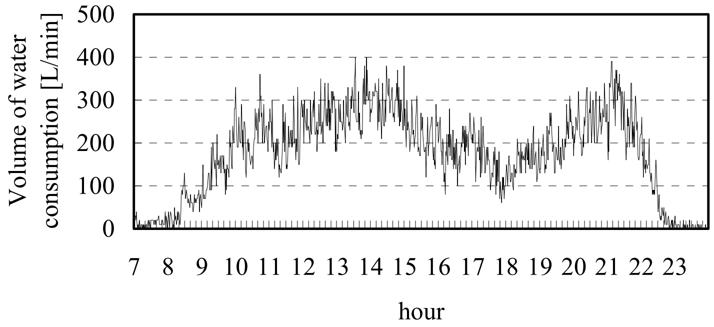
Restaurant	Duration time of water usage [sec]		Flow rate [L/min]		Frequency of water usage [time/day]	Volume of water consumption [L/day]	Frequency model
	Average	Distribution	Average	Distribution			
A	95	Hyp.20	13	Hyp.20	347	7142	D
B	95	Hyp.20	13	Hyp.20	279	5740	B
C	95	Hyp.20	13	Hyp.20	276	5684	D
D	95	Hyp.20	13	Hyp.20	157	3232	A
E	95	Hyp.20	13	Hyp.20	243	4992	E
F	95	Hyp.20	13	Hyp.20	699	14381	C
G	95	Hyp.20	13	Hyp.20	369	7599	C
H	95	Hyp.20	13	Hyp.20	219	4510	B
I	95	Hyp.20	13	Hyp.20	880	18121	A
J	95	Hyp.20	13	Hyp.20	511	10525	E
K	95	Hyp.20	13	Hyp.20	220	4529	E
L	95	Hyp.20	13	Hyp.20	457	9399	E
M	95	Hyp.20	13	Hyp.20	278	5725	A
N	95	Hyp.20	13	Hyp.20	338	6956	D
O	95	Hyp.20	13	Hyp.20	300	6170	B
P	95	Hyp.20	13	Hyp.20	187	3853	B
Q	95	Hyp.20	13	Hyp.20	719	14794	B
R	95	Hyp.20	13	Hyp.20	394	8103	C
S	95	Hyp.20	13	Hyp.20	305	6282	B
T	95	Hyp.20	13	Hyp.20	680	13997	C
U	95	Hyp.20	13	Hyp.20	362	7444	E

6.2 Results of the calculation

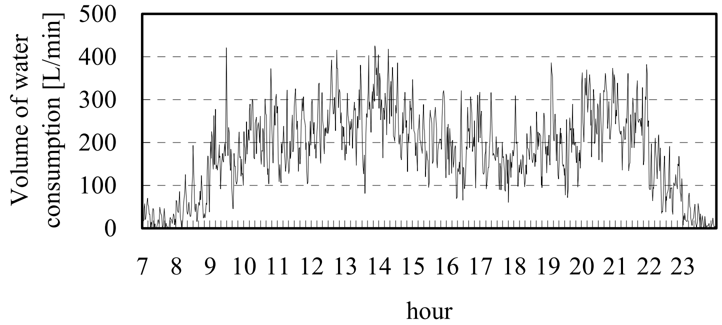
On the basis of calculating model in each restaurant, shown in Table 8, the simulation for water consumption in 21 restaurants was carried out hourly interval through a day; the time-zone of 7:00-24:00. The number of simulation trials for an hour was set up one hundred times.

As for the fluctuation of water consumption per one minute through a day, Figure 10 shows a measurement result on December 15, 2002 and a calculation result as an example. As compared with the measurement values, the calculation values have the wide range of fluctuation and the coefficients of variation are large in the time-zone of 7:00-21:00. However, in the time-zone of after 21:00, the coefficients of variation on the measurement values are large because there are various cases of the closing time on each day.

Figure 11 shows the instantaneous maximum floor rates and the failure factor 0.1%, 0.2%, 1% of measurement results and the failure factor 0.1%, 0.2%, 1% of simulation resuluts in each hourly time-zone. These values were calculated as the total of 21 restaurants. The maximum values of measurement results in each time-zone are changing within the range of the failure factor 0.1-1% of simulation results. When we predict the instantaneous flow rates by the simulation, we should regard the failure factor 0.1-2 % as the maximum value because the maximum value of simulation is too large for the maximum load of water consumption according to the trial numbers of simulation.



a) Measurement result (December 15th, 2002 (Sun.))



b) Simulation result

Figure 10 - Measurement and simulation results

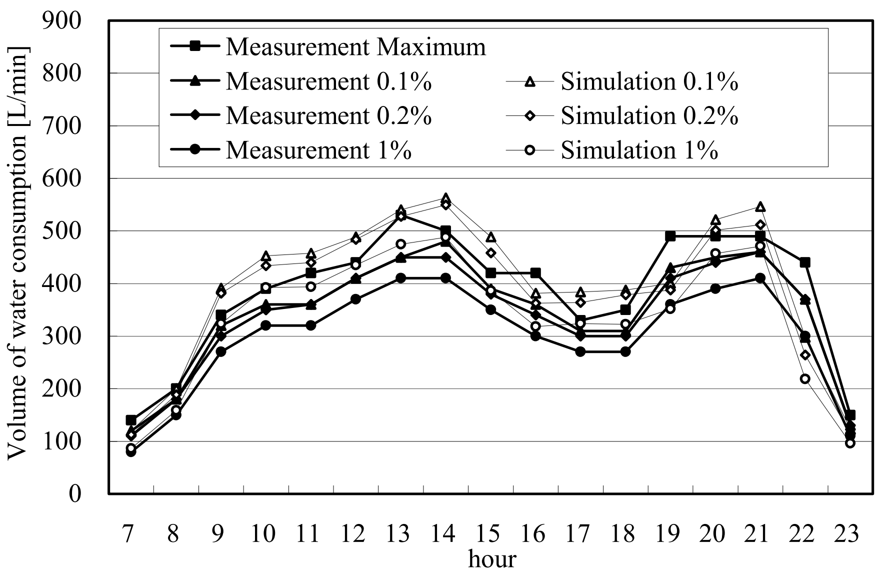


Figure 11 - Instantaneous maximum flow rate

As for the hourly water consumption, calculated as the total of 21 restaurants, Figure 12 shows the average+3 σ (σ: standard deviation), average+2 σ, average value of measurement results and the failure factor 1%, 5%, average value of simulation results. The value of failure factor 1% of simulation results is almost same with average+2 σ of measurement results. As for the average values, the simulation values exceed a little at the time-zone of 20:00-22:00, however the simulation values are almost equal to the measurement values.

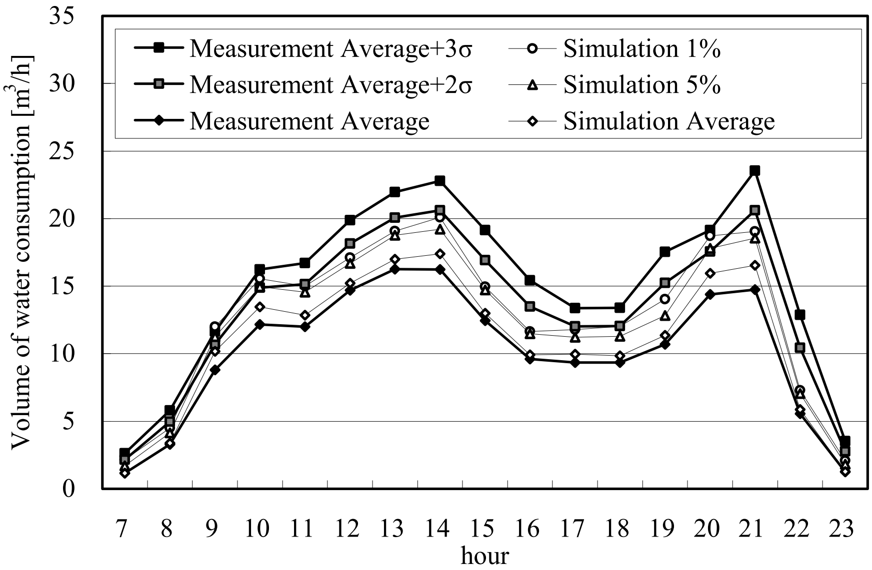


Figure 12 - Hourly water consumption

Table 9 shows the measurement values and the simulation values of the daily water consumption calculated as the total of 21 restaurants. As for the average values, the simulation value has large volume of 7% on the measurement value. As for the maximum values, the average+3 σ value of simulation results is near to the 5th large value of measurement results on 52 days. From the relationship of the average values and the maximum values, the calculating technique is useful in the practical range to estimate of water consumption in the restaurants.

Table 9 - Daily water consumption

	Average [L/day]	Standard deviation [L/day]	Maximum [L/day]	Minimum [L/day]	Average+3σ [L/day]	Number of samples [day]
Measurement	171982	17363	221970	132780	224072	52
Simulation	184366	3733	191578	176422	195567	100

7. Conclusion

In this paper, the authors suggested a calculating method of water consumption loads in restaurant by using the Monte Carlo Simulation technique.

First of all, we carried out the measurement of water consumption in 21 restaurants for one year or more.

Secondly, the hourly number of customers was measured in 3 restaurants. On the basis of these data, the relationship between the water consumption and the number of customers was analyzed. Also, based on the data of holiday in 2002, the fluctuation patterns for hourly water consumption were studied. The fluctuation patterns of 21 restaurants were classified to 5 types by cluster analysis.

In addition, the calculating model in restaurant was set up as the kitchen unit model based on the same idea to apply the flat unit model in apartment houses.

Finally, the results estimated by the simulation model were compared with the measurement values. It was clarified that the kitchen unit model is useful and convenient to deal with the complex water usage in the kitchen. Furthermore, the calculating technique is useful in the practical range to estimate of water consumption in restaurants.

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